# INHERITANCE OF SKIN FOLDS OF SHEEP

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ONE of the distinguishing characteristics of the finewool breeds of sheep is the presence of skin folds or wrinkles. These range in size and number from a very slight looseness on the lower line of the neck to skin folds so large and so numerous as to almost completely cover the body. The inherent tendency to have skin folds was evidently present in the early Spanish Merinos from which all the fine wool breeds have descended (Randall, 1863). It was found early by practical breeders that these skin folds could be increased rather easily by selection.

There have been differences in view point in regard to the desirability of skin folds (Austin, 1943). Some of the early breeders of Merinos in America held to the view that the more wrinkles, the greater the skin area and so as a matter of course there would be more wool-producing area, resulting in a heavier fleece. Others maintained that the skin folds were directly associated with density, resulting in more wool on the same area, as well as more area to grow wool. These views led to the production, especially in Vermont and some of the other eastern states, of sheep with the apparent maximum number of skin folds that could be present on an animal. On the other hand, breeders of the strictly Delaine Merino type tended to select for smoothness, limiting the wrinkles to the neck folds, with a considerable degree of success. Breeders of Rambouillets have tended to favor an intermediate type. However, to maintain this intermediate type recourse has been made both to rather wrinkly and smooth types of rams. Practical observations led many breeders to believe that breeding for smoothness leads to a marked reduction in wool production. All or practically all of the above is based on unscoured wool production. The relationship to clean wool production will be discussed later.

The more wrinkly types of finewool sheep have had heavier shrinking fleeces probably due in most instances to the abundance of oil or wool fat

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secreted by the sebaceous glands. This excessive oil or grease, together with the wrinkles, has led to more difficulty in management of the sheep in areas where screw worm flies and wool worm flies are prevalent. Also, buyers of feeder lambs have tended to discriminate against wrinkly lambs, whether justly or not. One of the reasons given for discriminating against the wrinkly lambs was that the pelts were less valuable for leather than were those from smooth lambs (Arnold, 1925). Furthermore the dressed yield of the wrinkly type lambs is lowered due to their heavier pelt.

Many ranchmen, especially in Texas, have concluded that it is more profitable to breed the smoother type even though the grease wool production is in many instances markedly lower than with the more wrinkled type. Studies by Jones et al. (1944) have shown that in the Texas Station's flock of Rambouillets the B type (wrinkly) ewes produced approximately one pound more unscoured wool than was produced by the smooth or C type ewes. However, this difference was caused by the heavier shrinkage of the fleeces produced by the wrinkly or B type ewes together with the scarcity of long stapled fleeces among the B type ewes. There was no significant difference in clean wool produced by the B type and C type ewes. There was a small but significant difference in staple length in favor of the smooth or C type. Also the C type wool was more uniform in both length of staple and in diameter of fiber. Further study of these data showed that clean wool from fleeces of the same staple length classification was greater for the B type. However, only 9 percent of the B type fleeces were 2.5 inches or more compared to 37 percent in the C types. Presumably the extra clean wool of the B type fleeces of the same length as the C type is caused by the greater skin area. If wool is sold on the basis of its shrinkage or net yield as well as grade, there is no advantage in favor of the wrinkly type, the differences being in favor of the smooth or C type sheep. However, until the economics of wool marketing has been developed to the point where the individual producer is paid directly on the basis of clean wool, considerable attention should continue to be given by the producer to unscoured fleece weights even though it may be necessary to tolerate some skin folds to maintain unscoured fleece weights.

While it is true that breeders had early found by practical experience that skin folds could be increased or decreased rather easily by selection, little was known about the actual inheritance of this character. Many isolated experiences needed a logical explanation. Frequently rather smooth rams (C type) would sire what seemed to be too many wrinkly lambs. Sometimes the opposite ensued, i.e., a wrinkly ram (B type) might sire more smooth lambs than it seemed logical to expect.

Realizing the scarcity of definite information on the entire subject relating to comparative weights, lengths and fineness of wool produced by relatively smooth bodies Rambouillet sheep as compared with those carrying various degrees of skin folds, a study was initiated in 1918. The comparative production of B and C types has been reported by Jones et al. (1944). A further objective was the possibility of the development of a relatively smooth bodied Rambouillet possessing the desired fleece characteristics which could be maintained without having to resort to the use of sires or dams of heavy skin-fold development for the purpose of maintaining unscoured fleece weight.

For the purpose of studying the inheritance of skin folds it was necessary first to record in detail the number, size and location of the skin folds on a fairly large number of finewool sheep. This was to learn whether a record of the entire skin surface would be necessary, if the different body regions were definitely associated with each other and with the whole skin surface, and whether the character was expressed differently in the two sexes. After this was done, a study of parent offspring relationship was made for the purpose of determining how much of the variability observed in this particular group of animals was due to heredity and how much to other causes. In addition, it was the hope that some light would be thrown on the mode of inheritance. Finally, a few crosses were made between Corriedale ewes (smooth) and Rambouillet rams for further study of the inheritance of skin folds.

## Materials and Methods

Numerical values based on the number and size of skin folds were given to each sheep studied. These records were taken soon after shearing so as to avoid the obscuring influence of the fleece. Record sheets were used showing both front and side view outline sketches of a sheep, and a printed tabular outline on which to record the number and the relative size of the skin folds by regions (figure 1). The approximate location and relative size differences were shown by drawings on the sketches, and immediately following this the numbers were recorded in tabular form. For this purpose seven regions of the body were designated as follows: face, top neck, under neck, shoulder, side, tail head, and thigh. The relative skin fold sizes were designated as trace, small, medium, and large. Arbitrary values assigned to these sizes were 1, 2, 4, and 8, respectively, these being the apparent approximate differences. The values recorded were totaled first by body regions and then combined to give a total skin-fold value for the animal. An example of the method of recording, based on the animal sketched in figure 1, is shown in the table on the next page.

Since the data of this study were collected and much of the analysis completed, photographic standards for classifying skin folds have been pub-

| Location | Number of folds | | | | Skin-fold value |
|---|---|---|---|---|---|
| | Trace | Small | Medium | Large | |
| Face | 0 | 0 | 0 | 0 | 0 |
| Neck (top) | 5 | 0 | 1 | 0 | 9 |
| Neck (under) | 0 | 0 | 1 | 2 | 20 |
| Shoulders | 1 | 0 | 0 | 0 | 1 |
| Side | 0 | 0 | 0 | 0 | 0 |
| Tail head | 0 | 1 | 0 | 0 | 2 |
| Thigh | 0 | 0 | 0 | 0 | 0 |
| Total skin-fold value | | | | | 32 |

lished by Madsen, Esplin and Phillips (1943); and Carter (1943) included a detailed set of drawings and photographs, to illustrate the different types and amounts of skin folds, in the report of his study of the biology of the skin and fleece of the sheep.

Purebred Rambouillets were used for much of the study. The records of the Rambouillets analyzed in this study were all from animals of approximately one year of age, i.e. just after the first-year fleece was shorn. Results secured from these data should be similar to those from data collected at other ages as it has been shown by Madsen, Esplin and Phillips (1943) that the correlations between skin fold scores at different ages are highly significant. In addition to the Rambouillets, crossbred animals, resulting from the mating of purebred Corriedale ewes to Rambouillet rams, $F_2$ and backcross progenies were included. The records from part of these crossbreds

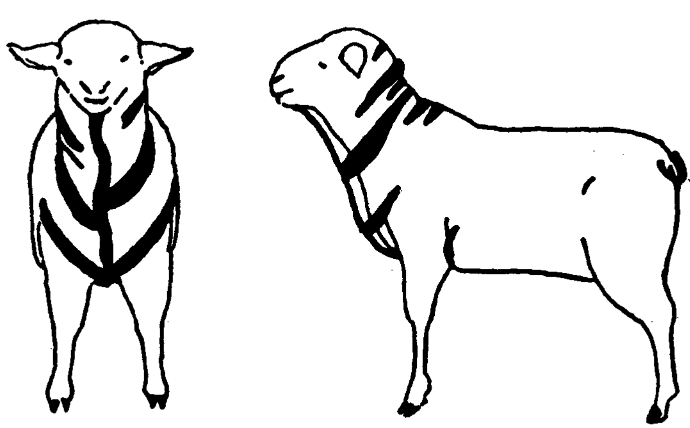

**Figure 1. Example of the method of sketching skin folds on the record form for each animal. Numbers and relative sizes of folds on each body area were also recorded, as is shown in the text.**

were taken when the animals were between 5 and 7 months of age, as they were shorn in the fall. Rambouillets studied include 760 males and 915 females. Crossbreds represent 67 males and 72 females. The sheep studied were in the flock at Substation Number 14, Sonora, Texas. Data from the Rambouillets, collected during the years 1923 to 1941 inclusive, were used. Standard statistical methods were used in the analysis of the data.

## Results

### *Comparison of skin-fold values by body regions and sex*

In Rambouillets the average skin-fold value for each body region is given by sexes in table 1. This shows that the neck regions have higher values than any of the others. Combined values for top and under neck represent over half of the total. The differences between regions are highly significant in every case. The males averaged significantly higher than the females for each region and for the total. The total skin-fold values for the males are approximately 25 percent higher than those of the females. These differences suggest that skin folds are affected by sex or that they represent a sex-influenced character.

TABLE 1. COMPARISON OF SKIN-FOLD VALUES BY SEX AND BODY REGIONS ON RAMBOUILLET SHEEP

| Sex | Face | Top neck | Under neck | Shoulder | Side | Tail head | Thigh | Total |
|---|---|---|---|---|---|---|---|---|
| Male | 2.8 | 13.4 | 16.8 | 3.8 | 6.3 | 4.1 | 9.0 | 56.1 |
| Female | 1.3 | 9.9 | 13.5 | 3.0 | 4.6 | 3.2 | 6.7 | 42.3 |
| Difference[1] | 1.5 | 3.5 | 3.3 | 0.8 | 1.7 | 0.9 | 2.3 | 13.8 |

[1] Each difference highly significant.

The skin-fold values are classed by size and percent frequency for each sex. In table 7 under Rambouillet, and also in figure 2, it will be seen that the two classes with the lowest values have more females represented than males. On the other hand, some females were included in the more wrinkly classes, even though the maximum is represented by the male. We feel that while it would be entirely feasible to "correct" or "convert" all of the records to the equivalent of one sex, the records within the respective sex groups will usually be found more useful than when combined.

### *Correlations of skin folds by regions*

In order to determine whether the skin folds of the different body regions are due to common causes, correlations between parts were computed for all possible combinations and each part with the total, and also with the remainder. These coefficients, as shown in table 2, are all highly significant. As the expression of skin folds in the different regions is not independent, the skin folds of all regions must be due to general skin fold genes rather than being regionally specific. Skin-fold total may be safely used in comparisons of different groups of animals as each region is highly and significantly correlated with total.

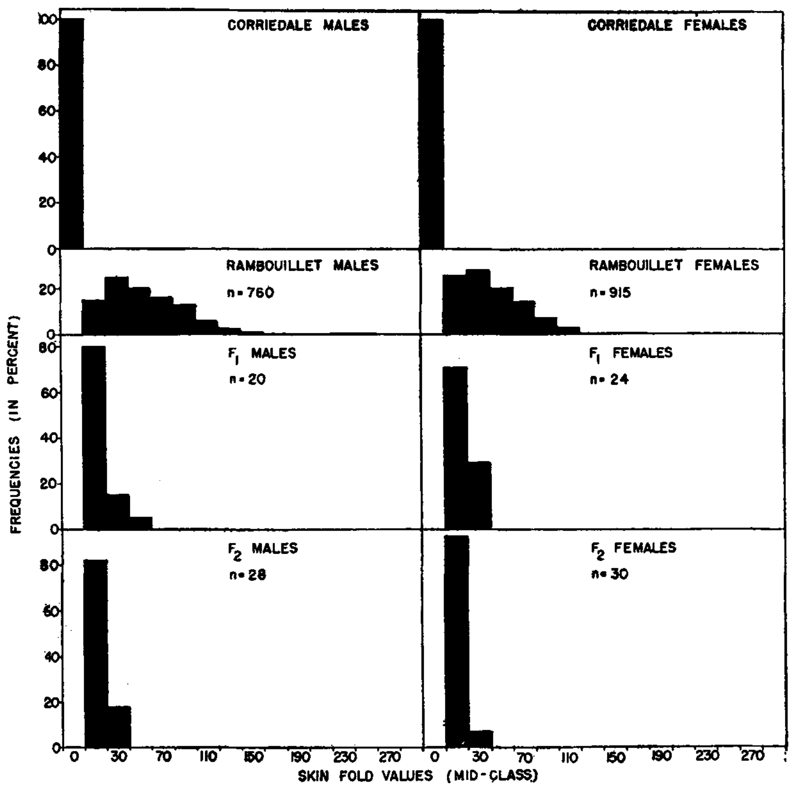


**Figure 2. Distributions of total skin-fold values of Corriedales Rambouillets and of crosses between Corriedales and Rambouillets.**

It is often assumed that the part to total coefficients are spurious and cannot be tested against an assumed zero. However, it has been shown by Baker (1942) that such correlations are valid and may be useful. The relationship of total to separate part is of more direct interest in this study than that of part to the remainder. This is because the only real purpose of the correlation of part to the remainder is for use in estimating the total skin fold value of the animal from the record of one part only. Accordingly, if the estimate of the animal is made by using the regression coefficient for part to remainder the coefficient is found to differ from that of part to total by 1, (see table 3). The standard error of estimate for total and the corresponding standard error of estimate for the remainder are identical. It will be seen

TABLE 2. CORRELATION COEFFICIENTS OF SKIN FOLD VALUES BETWEEN REGIONS, BETWEEN REGION AND TOTAL, AND BETWEEN REGION AND TOTAL MINUS THE REGION CORRELATED

| Body area and sex | Top neck | Under neck | Shoulder | Side | Tail head | Thigh | Total | Total minus region correlated |
|---|---|---|---|---|---|---|---|---|
| Face, rams | .356 | .402 | .388 | .266 | .286 | .384 | .512 | .440 |
| Face, ewes | .226 | .290 | .307 | .244 | .267 | .312 | .404 | .334 |
| Top neck, rams | | .555 | .681 | .640 | .578 | .539 | .858 | .740 |
| Top neck, ewes | | .639 | .602 | .545 | .502 | .492 | .816 | .684 |
| Under neck, rams | | | .468 | .407 | .523 | .576 | .770 | .630 |
| Under neck, ewes | | | .622 | .508 | .533 | .642 | .864 | .737 |
| Shoulder, rams | | | | .705 | .544 | .573 | .801 | .753 |
| Shoulder, ewes | | | | .677 | .497 | .592 | .799 | .753 |
| Side, rams | | | | | .500 | .555 | .790 | .675 |
| Side, ewes | | | | | .460 | .614 | .772 | .668 |
| Tail head, rams | | | | | | .548 | .712 | .664 |
| Tail head, ewes | | | | | | .592 | .687 | .634 |
| Thigh, rams | | | | | | | .796 | .691 |
| Thigh, ewes | | | | | | | .809 | .718 |

that the relative sizes of the standard errors of estimate from lowest to highest parallel the order of sizes of $r$ for part to total, but in reverse order, i.e., the correlations from highest to lowest. The standard errors of estimate with their corresponding correlation coefficients for part to total minus part do not follow the same relative order as the corresponding correlation coefficients for part and total. So far as their use in estimating total skin-fold values is concerned the results will be identical. The only difference is that one additional step is involved where the total minus part is obtained first, as it is still necessarv to add the value of the part to get the final estimated total value. Accordingly, in these data the coefficients of correlation of part to the remainder are largely of academic interest.

It will be seen from table 3 that the different parts do not stand in the same order for males and females. However, the correlations of all parts with total are quite high except those for face and tail head. This is reflected in relatively low errors of estimate, which indicates that we might have a wide choice of regions of the body to use for estimating the total skin-fold value. It seems logical to assume that neck, both top and under, either separately or together might be used to advantage. Using the data from males, a correlation of plus .928 was found between the neck regions (top of neck plus under neck) and total skin folds. The corresponding $r$ for data from females was plus .929. These two regions, top of neck and under neck, are the most prominent skin-fold regions of the body and represent increasing proportions of the total skin-fold value as the average skin-fold value of a flock decreases. These considerations indicate that the skin-fold values of the

TABLE 3. ANALYSIS OF VARIANCE BY REGRESSION, OF SKIN-FOLD VALUES OF SHEEP

| Parts correlated | | Total skin-fold values=$x$ | Total skin fold values minus part correlated=$x$ − part | Standard error of estimate[1] | Regression equation for estimating total skin folds minus part | Regression equation for estimating total skin folds |
|---|---|---|---|---|---|---|
| *Males* | | | | | | |
| | | $r$ | $r$ | | | |
| Top neck | (B) | .8575 | .7400 | 18.09 | 1.94B+16.86 | 2.94B+16.86 |
| Shoulder | (D) | .8001 | .7530 | 21.09 | 6.05D+29.07 | 7.05D+29.07 |
| Thigh | (G) | .7959 | .6914 | 21.25 | 2.68G+23.09 | 3.68G+23.09 |
| Side | (E) | .7897 | .6752 | 21.57 | 2.46E+34.31 | 3.46E+34.31 |
| Under neck | (C) | .7705 | .6304 | 22.41 | 2.05C+ 4.94 | 3.05C+ 4.94 |
| Tail head | (F) | .7129 | .6639 | 24.65 | 6.89F+24.15 | 7.89F+24.15 |
| Face | (A) | .5135 | .4403 | 30.17 | 4.54A+40.71 | 5.54A+40.71 |
| *Females* | | | | | | |
| Under neck | (C) | .8645 | .7370 | 14.40 | 1.73C+ 5.31 | 2.73C+ 5.31 |
| Top neck | (B) | .8159 | .6844 | 16.57 | 1.99B+12.69 | 2.99B+12.69 |
| Thigh | (G) | .8088 | .7178 | 16.85 | 2.99G+15.59 | 3.99G+15.59 |
| Shoulder | (D) | .7986 | .7530 | 17.24 | 6.27D+20.12 | 7.27D+20.12 |
| Side | (E) | .7725 | .6679 | 18.20 | 2.81E+24.71 | 3.81E+24.71 |
| Tail head | (F) | .6874 | .6336 | 20.81 | 6.42F+18.63 | 7.42F+18.63 |
| Face | (A) | .4035 | .3345 | 26.22 | 4.13A+35.56 | 5.13A+35.56 |

[1] Standard error of estimate is for either total skin folds or total minus the part correlated.

neck regions give sufficient information to serve as a guide in selection and may replace total skin-fold value in practical work. Of course, no partial record can be as good as a complete record. However, taking and recording of detailed records on large numbers of animals may easily become so time-consuming as to be impractical for general use.

*Variance and covariance of parent offspring groups*

To estimate the genetic variation in total skin folds an analysis of variance and covariance was made for male and female progeny groups from 29 sires.

TABLE 4. ANALYSIS OF VARIANCE AND COVARIANCE FOR SKIN FOLD VALUES OF DAM AND DAUGHTERS

| Source of variance | Degrees of freedom | Mean squares | | | Errors of estimate | |
|---|---|---|---|---|---|---|
| | | $x$(=Dams) | $y$(=daughters) | $xy$ | Degrees of freedom | Mean squares |
| Intra-year | 523 | 630.6 | 613.3 | 133.9 | 522 | |
| Between sires | 53 | 995.6** | 935.6** | 132.2 | 53 | 925.610** |
| Within sires | 470 | 589.4 | 590.4 | 134.1 | 469 | 561.037 |

** Statistically significant. $P<.01$.

TABLE 5. ANALYSIS OF VARIANCE AND COVARIANCE FOR SKIN FOLD VALUES OF DAMS AND SONS

| Source of variance | Degrees of freedom | Mean squares | | | Errors of estimate | |
|---|---|---|---|---|---|---|
| | | $x$(=dam) | $y$(=sons) | $xy$ | Degrees of freedom | Mean squares |
| Intra-year | 430 | 736.9 | 696.1 | 195.6 | 429 | |
| Between sires | 53 | 1079.3** | 1079.0** | −8.6 | 53 | 1196.058** |
| Within sires | 377 | 664.8 | 642.3 | 224.3 | 376 | 568.127 |

** Statistically significant. $P<.01$.

Only sires which produced 5 or more sons and 5 or more daughters were used in this analysis. The results of this analysis are summarized in tables 4 and 5. Inspection of these tables shows that the amount of variation between sires was statistically significant in both the male and female progeny groups. This difference between sires indicates the superiority of some sires over others in producing progeny with greater or lesser skin-fold values and therefore indicates that selection for or against this character should be successful. It may also be observed from these tables that there is a significant difference in the skin-fold values of the group of dams according to the sires to which they were mated. After adjusting by covariance for the influence of dams there is still a significant difference between the progeny of different sires. The significant influence of season has been held in statistical control in this analysis. The genetic composition of the flock varied somewhat from season to season, because of changes in sires and dams. In addition to this the nutritional level varied with season. Carter (1941) has reported the direct influence of nutrition on number and size of skin folds, animals on the higher plane of nutrition having the greater values. This is supported by the findings of Hazel and Terrill (1944), who found that single lambs and offspring from older ewes had better scores on condition and also more neck folds. Glembockii and Nahimson (1940) observed that the greater the body weight of lambs the more skin folds they possessed. These data were also analyzed without removing the variation due to season with very similar results.

Correlations of dam to daughter, dam to son, half brothers to half brothers, and half sisters to half sisters are shown in table 6. Any one of these correlations may be used in estimating the proportion of the variability in these data that is due to heredity. The four correlations for dam to offspring do not differ significantly from each other and so are estimates of the same parameter. The half-sib correlations are not homogeneous as shown by the intra-year correlation of half-sisters being significantly lower than that found from the data where the year to year variation was not statistically controlled. There were no statistically significant differences between any of the correlations when the seasonal variation was not removed. These correlations were averaged, each component being weighted according to the reciprocal of its respective variance, and from this the heritable portion of the variation was found to be 45.6 percent. Using the correlations where the variation due to season was removed there is a significant difference between the correlation for dam to son and half sister to half sister. However, the average of the four correlations was used to estimate the heritable

TABLE 6. CORRELATION COEFFICIENTS FOR TOTAL SKIN FOLDS OF RELATIVES

| Relative correlated | Variation due to season removed | Variation due to season not removed |
|---|---|---|
| Dam to daughter | .2275 | .2172 |
| Dam to son | .3432 | .2412 |
| ½ brother to ½ brother | .0980 | .1373 |
| ½ sister to ½ sister | .0712 | .2085 |

portion of the variation and was found to be 51.2 percent. Definite progress can be made in selecting either for or against a character with estimates of the heritability of these magnitudes. This progress may be expected without special study of relatives and without progeny testing the sires.

*Inheritance of Skin folds*

The wild species of true sheep are all free from skin folds. Evidence from several sources (Ewart, 1913; Benchley, 1937; Warwick and Berry, 1941) points strongly toward the wild mouflon type as the principal progenitor

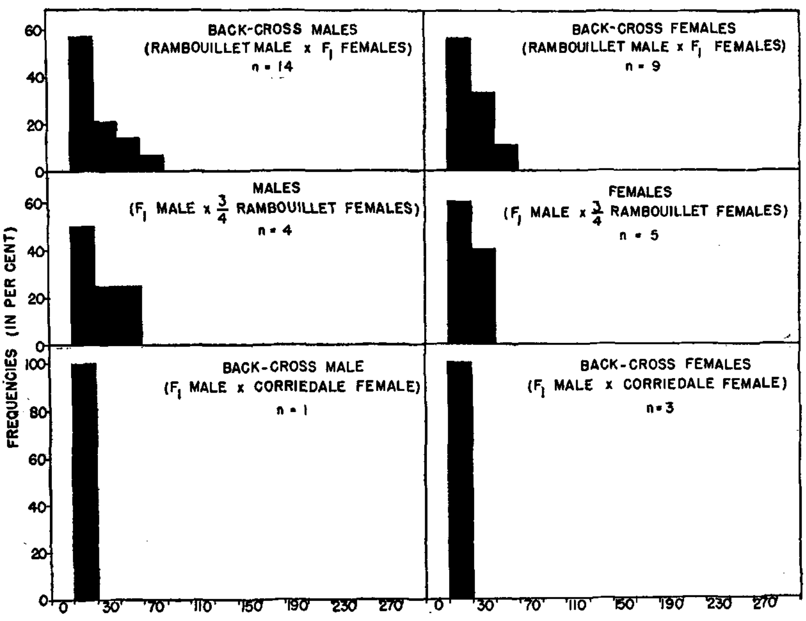


**Figure 3. Distributions of total skin-fold values of backcross populations ($F_1$ to both parent breeds), and of $F_1 \times \frac{3}{4}$ Rambouillet animals.**

of Merinos and Rambouillets. The skin folds typical of the finewool breeds must be the result of the occurrence of and preservation of mutations since domestication. A few crosses of a Mouflon (*Ovis musimon*) male with grade Rambouillet females made at the Texas Station resulted in $F_1$ progeny completely devoid of skin folds. Many crosses of finewool ewes with males lacking skin folds have been made in this country for commercial purposes. The great majority of the $F_1$ lambs were practically smooth, while a few had a small number of skin folds, and very rarely a wrinkly lamb would result. One of the smooth breeds, the Corriedale, was produced by selecting $F_1$, $F_2$ and succeeding progeny from a large number of long-wool × fine-wool (smooth × wrinkly) sheep. The resulting Corriedale breed is almost free from wrinkles.

A few crosses of Corriedale ewes with Rambouillet rams, and some back-crosses to both parent breeds, are included in this study. They are shown in table 7 and figures 2 and 3. The $F_1$ progeny all had some skin folds but the values were low. Two of the smoothest $F_1$ rams were used to sire the $F_2$ progeny and the values obtained from these $F_2$ were even slightly lower than those of the $F_1$ population. $F_1$ ewes bred to two different Rambouillet rams produced progeny with greater skin-fold values than $F_1$ or $F_2$, but not as great as those of the parental group of Rambouillets. Four progeny sired by one of the low value $F_1$ males and out of Corriedale ewes were almost completely smooth.

None of the above progenies should be considered true $F_1$ or $F_2$ because of the hybrid origin of the Corriedale and the high variability of the Rambouillet. However, the results are suggestive of dominance of multiple genes. This is based on the following: (a) crosses involving smooth × finewool breeds give $F_1$ progeny either smooth or predominantly approaching the phenotype free from skin folds; (b) with small numbers $F_2$ progeny are similar to $F_1$; (c) back crosses to the wrinkly parental breed increased the variability in the direction of the wrinkly parent; (d) the frequency distribution of the Rambouillet flock for the period of years studied is suggestive of a modified $F_2$ population. The bulking of numbers at the smooth end of the Rambouillet distribution and the tailing out at the other end with a few relatively high values point in this direction. On the other hand, if this were a true $F_2$ population we would expect some completely smooth individuals. It has long been known that when breeding from an $F_2$ population the succeeding populations will continue to give distributions approximately like $F_2$ so long as the matings are random. When matings are not random, and there is a tendency to mate unlikes together, it tends to reduce the extremes. In this population there is a small negative correlation between the total skin-fold values of the sires and of the dams, indicating that there was a tendency to mate unlikes. No matings between extremely smooth individual Rambouillets were made during the course of this investigation. (e) It seems highly improbable that the highest skin-fold value represented in this study is as high as theoretically possible. This would make it necessary to postulate a type of inheritance in which the recessive end of the curve would have very low probability, so that even in large populations these ex-

TABLE 7. DISTRIBUTIONS OF VALUES OF SKIN FOLDS OF RAMBOUILLETS AND CROSSES WITH CORRIEDALES

| Mid-class value | Rambouillet | | | | $F_1$ | | | | $F_2$ | | | | Rambouillet × $F_1$ | | | | $F_1$ × ¾ Rambouillet | | | | $F_1$ × Corriedale | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Males | | Females | | Males | | Females | | Males | | Females | | Males | | Females | | Males | | Females | | Males | | Females | |
| | N[1] | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| 10 | 116 | 15.26 | 242 | 26.45 | 16 | 80.00 | 17 | 70.89 | 23 | 82.14 | 28 | 93.33 | 8 | 57.14 | 5 | 55.56 | 2 | 50.00 | 3 | 60.00 | 1 | 100.00 | 3 | 100.00 |
| 30 | 191 | 25.13 | 256 | 27.98 | 3 | 15.00 | 7 | 29.19 | 5 | 17.86 | 2 | 6.67 | 3 | 21.43 | 3 | 33.33 | 1 | 25.00 | 2 | 40.00 | | | | |
| 50 | 151 | 19.87 | 184 | 20.11 | 1 | 5.00 | | | | | | | 2 | 14.29 | 1 | 11.11 | 1 | 25.00 | | | | | | |
| 70 | 121 | 15.92 | 129 | 14.10 | | | | | | | | | 1 | 7.14 | | | | | | | | | | |
| 90 | 97 | 12.77 | 68 | 7.43 | | | | | | | | | | | | | | | | | | | | |
| 110 | 48 | 6.31 | 30 | 3.27 | | | | | | | | | | | | | | | | | | | | |
| 130 | 23 | 3.03 | 2 | .22 | | | | | | | | | | | | | | | | | | | | |
| 150 | 9 | 1.18 | 3 | .33 | | | | | | | | | | | | | | | | | | | | |
| 170 | 2 | .26 | 1 | .11 | | | | | | | | | | | | | | | | | | | | |
| 190 | 0 | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | |
| 210 | 0 | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | |
| 230 | 1 | .13 | 0 | 0 | | | | | | | | | | | | | | | | | | | | |
| 250 | 1 | .13 | 0 | 0 | | | | | | | | | | | | | | | | | | | | |
| Totals | 760 | | 915 | | 20 | | 24 | | 28 | | 30 | | 14 | | 9 | | 4 | | 5 | | 1 | | 3 | |

[1] N = number.

treme classes would be absent. (f) It may easily be possible that the phenotype for smooth may include more than one theoretical smooth group. If so, it would be possible to reconcile the very rare occurrence of a fairly wrinkly lamb from matings involving a breed in which wrinkles are absent. The theoretical distributions in $F_2$ with several pairs of dominant genes are shown in figure 4. Also for comparison a typical distribution without dominance is shown. Several alternate theories may be used to explain the above facts. One of the more attractive of these is the postulating of one major pair of dominant genes with several pairs of minor genes. If it is necessary to assume that there are several pairs of genes, it would seem logical to use the simpler approach, unless definite evidence becomes available to make this untenable. However, the number of genes is probably not extreme.

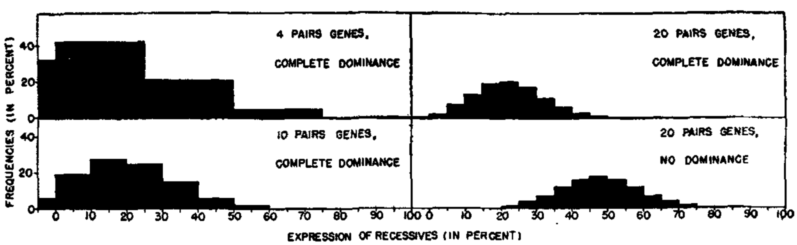


**Figure 4. Theoretical distributions in $F_2$ populations with varying numbers of pairs of genes.**

It should be of interest to consider what may be expected in practical breeding on the basis of the above facts and tentative interpretation. Within the breed, selection for freedom from skin folds or for very low skin-fold values should bring about very rapidly both a low average skin-fold value and a reduction of extremely wrinkly segregates to the point where they practically disappear. Breeding finewool breeds to the smooth breeds results in the almost complete removal of wrinkles in the first generation. The wrinkly offspring may show up again in $F_2$, but if there is any appreciable selection toward the smooth type in succeeding generations the wrinkly offspring will be extremely rare. This will be true so long as the wrinkly parental type is not backcrossed into the crossbred stock. In other words, phenotypic selection either within the breed or among crossbreds should result in rapid progress in the removal of skin folds. If complete elimination, genotypically as well as phenotypically is desired, progeny testing would be useful in the later generations of selection. If this is not considered necessary selection alone may be ample.

## Summary and Conclusions

Skin folds were recorded and evaluated on 760 rams and 915 ewes of the Rambouillet breed. The records were taken on freshly shorn yearlings. The males had significantly greater skin-fold values than the females. The skin-fold values of all body regions were highly and significantly correlated with each other, with total skin folds and with total minus the part correlated.

Regression coefficients for estimating the total skin folds from the record of a part differed by one in each case from those using total minus the part. Either may be used, but that using total skin folds is simpler. The neck regions, top and bottom, may be used either separately or together with a fairly high degree of reliability to replace the record of the entire animal.

Analysis of variance and covariance of parent-offspring groups was made with the progeny of 29 sires. This showed a significant influence of sires. Correlations of other relatives, i.e. dam to daughter, dam to son, half brothers to half brothers, and of half sisters to half sisters were highly significant, and estimates of 45.6 percent and of 51.2 percent heritable portion were found, indicating that definite progress may be expected from selection for or against this character.

A few crosses of Rambouillet rams to Corriedale ewes (smooth) were also studied. It is tentatively proposed that lack of skin folds is due to dominant multiple genes, the number not being determined but probably not being extremely large.

It is concluded from both phases of the study that skin folds may be easily reduced to a low point by selection alone. Progeny tests would be necessary only if complete elimination is desired, or if the objective is an intermediate type.

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