STUDIES OF THE INHERITANCE

OF WOOL CHARACTERS AND FLEECE ANALYSIS

IN SHEEP.

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This thesis is divided into two parts. The first part deals with Wool Inheritance in Hampshire x Rambouillet Crossbreds and the second part with Fleece Analysis using samples from the fleeces of Border Leicester and Cheviot ewes.

The first part deals with experimental work carried on by the writer at the Wyoming Agricultural Experiment Station, the data of which has been analysed during the course of study in Edinburgh, and the second part deals with research work carried on by the writer while in residence at the Institute of Animal Genetics of Edinburgh University in fulfillment of the regulations governing the Doctor of Philosophy degree.

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STUDIES OF THE INHERITANCE OF WOOL CHARACTERS AND FLEECE ANALYSIS IN SHEEP.

PART ONE.

INHERITANCE OF WOOL CHARACTERS IN HAMPSHIRE x RAMBOUILLET CROSSBRED SHEEP.

INTRODUCTION

The Art of Sheep Breeding

When one considers that since the time of Jacob (Gen. 30:31-43), at least six thousand years, man has been accumulating skill and experience in the art of sheep breeding, it is not surprising that he has been able to develop and establish by selection the diverse types and breeds of sheep that are known today. A breeder can make a startling change in a flock within a comparatively short period of time by changing the standard used for selection. This change of type effectively shows the constant variability of expression of the large number of multiple factors, responsible in their combination and manifestation for the utility characters of the sheep. Selection is an extremely powerful agency for changing the characteristics of an animal, and has been the most essential instrument used by successful live stock breeders.

Robert Bakewell (1725-1795) was the first live stock breeder to effect a marked change in the methods used for the improvement of live stock. He was very rigid in his selection of breeding stock and paid particular attention to the propensity of his sheep to fatten regardless of their size, and these quick maturing sheep invariably gave a high dressing percent when butchered. He was the first to practice ram leasing with the privilege of recalling those whose progeny showed them to be outstanding sires. Thus,he was able to retain a larger number of his best rams and give them a chance to prove their breeding ability or prepotency,when such a procedure would have been very difficult in an individual flock. Bakewell is most often associated with the system of in-and-in breeding, which he was the first to use with marked success,with the result that the system became firmly established in live stock breeding. The new methods instituted and so effectively demonstrated by Bakewell,started a new era in live stock breeding.

The successful sheep breeder is an artist of the highest order,for he is working,not with an inert, easily moulded clay,but with a vibrant multitude of living cells,which in their intricate manifestations go to make up the living animal known as the sheep.

The duties and obligations of the live stock brdeder are outlined exceptionally well in the following verses by Alexander:

"Yours is the task to mate and to mold,
Living things for your gain and pleasure;
To find and to fuse the purest gold,
Nature hoards as a hidden treasure.
Yours is the heritage handed down,
A trust without limit or measure;
To make,not to mar,to win renown---
Fail not in the brave endeavor.

Yours is the art and the work to blend,
Living things in beauty together;
Yours is the power to ruin or mend---
The bonds that ye bind none can sever.
A sacred trust are these living things,
To be carelessly dealt with never!
And faithful stewardship surely brings,
Rich reward that shall live forever!"

The art of sheep breeding, with a wealth of accumulated experience and skill, handed down from generation to generation over a period of at least six thousand years, has given the sheep breeder of the present time a heritage of untold value. It has been developed through the selection, for breeding purposes, of those individuals which are best suited in the eyes of the person selecting them, for the particular use to which they are to be put. Inasmuch as a sire's blood appears in more individuals of the next generation, than that of any particular dam, the former has become the more important individual, to be selected with the greatest care. Excellence in the female stock is usually more of a collective rather than an individual quality, as is the case with sires.

The method of using the progeny test to determine the general genetic character and specific usefulness of a sire, has been the keystone of the art of sheep breeding, as well as other classes of live stock. By a process of "trial and error" the prepotent and useful sires' sons of one generation have become the sires of the next generation and the progenitors of a satisfactory type of sheep. To a certain extent, particularly in purebred flocks, the same process is carried out with the dams.

The Science of Sheep Breeding.

The employment of the progeny test is of necessity slow and expensive and if science could offer means of analysis whereby the potentialities of an individual could be recognized with considerable accuracy, a new era in sheep and live stock breeding would result.

The first step is to develop suitable methods for an accurate analysis of the utility characters of the animals under investigation. In sheep breeding, excellence in mutton conformation, fleece quality, hardiness, prolificacy, early maturity, and pelt and fur (i.e. Karakule) quality are the factors which determine the usefulness of the sheep. The emphasis placed on these factors, individually and collectively varies in different localities and environments and is largely dependent on the economic balance between the relative prices obtained for wool on the one hand and mutton on the other. Hardiness, prolificacy, and early maturity are closely associated with economic and environmental conditions and are indispensable when efficient dual-purpose sheep for the production of both mutton and wool are required. At the present time pelt and fur qualities enter in only as by-products of mutton or for a specialized trade in Persian Lamb and similar products.

Physical measurement of dimensional characters of the wool fibre offers one means for the analysis of one of the important utility characters of the sheep. Frölich, Spoettel and Tänzer (1929), Roberts (1930) and Burns (1927 and 1930), give the application, technique and interpretation of fleece analysis with particular reference to the measurement of length, fineness and density(number of fibres per unit area of skin) of wool.

Crossbreeding of sheep has always been a difficult yet fascinating problem for the sheep breeder, who is intrigued with the uniformly excellent results shown by the first cross, only to be chagrined at the results obtained, should an attempt be made to establish the excellent type of the first cross by interbreeding the individuals of this cross. The first cross seems to show all of the good characters of both parents with none of their bad points, but when interbred the characters due to segregation and recombination result in all degrees of variability and undesirable recessives. It takes years of careful selection and mating to establish an intermediate or crossbred type, so that it will breed true to type without an excessive amount of variability; in fact it is likely to take longer than the life span of the breeder who undertakes it.

Lonsdale (1926) proposed the establishment of a fine woolled type of sheep in England by cross-breeding, close selection and interbreeding. He gives a summary of the methods used in the development of the existing types and breeds of crossbred sheep which has been supplemented by Burns (1927) who gives a list of more recent crossbred types of sheep bred in America. Thilo (1922) describes the stud flock of Mele sheep developed at Neunkirchen in Northern Germany, which resulted from a cross of carefully selected Border Leicester rams on Merino ewes. The writer recently visited Neunkirchen and a number of Merinofleischschaf and Fleischwollschaf flocks in Germany and was very much impressed by the striking results they have obtained in combining into a true-breeding type, the contrasting characters of fine wool and excellent mutton conformation, and at the same time developing a very prolific and early maturing sheep. The Corriedale and Polwarth are well established breeds, with Flock Book Associations. The Corriedale originated in the South Island of New Zealand and has the blood of Lincoln, English Leicester and Border Leicester on the sire's side and Australian Merino on the dam's side. The Polwarth originated in Victoria, Australia and was obtained by crossing Lincoln rams on Australian Merino ewes, and then "back-crossing" the crossbred progeny to Australian Merino rams, and setting the "Comeback" type thus obtained by selection and interbreeding.

Fundamental knowledge of the underlying genetic factors which determine the utility characters of the sheep would be of great value in the establishment of pure lines of individuals approaching the homozygous condition.

One contribution science could make to the art of sheep breeding would be the development of accurate methods of fleece analysis, the interpretation of which could be used as a basis for the selection of breeding stock, thus reducing the expense and time required for an accurate progeny test insofar as fleece characters would be concerned. Although fleece analysis is now only in its preliminary stages, the great importance of uniformity not only between different areas of the body but also within a restricted area on the body is quite apparent.

The results herein reported are presented with the hope that they may add their cumulative effect to the store of information at present available on fleece analysis and wool inheritance.

REVIEW OF LITERATURE.

Wool Inheritance Studies in Scotland.

Nichols (1925) investigated the common belief that the Half-Bred Sheep, a crossbred resulting from the use of Border Leicester rams on Cheviot ewes, breeds true to type, with no segregation of characters in the second filial generation. The experiment showed conclusively that there is considerable segregation. The outstanding features of fleece inheritance in this cross are the almost complete dominance of the Cheviot frill or collar and the segregating of types in the second filial generation. However, the extreme parental types rarely occur in the second filial generation, probably due to the fact that the Half-Bred type has been bred for many years in certain flocks.

Wool Inheritance Studies in Austria and Germany.

Adametz (1917, 1918, 1920) studied wool inheritance in the Rambouillet x Karakule cross and found a great diversity of types in the second filial generation due probably to the mixed wool character of the Karakule fleece. There was no marked blending in the first filial generation. In the second filial generation one animal was a typical Rambouillet. Adametz also refers to some French crossbreeding work with the Leicester x Merino cross, in which the crossbreds showed in 1865 and 1880, reversion to the original Merino and Leicester types which were first crossed in 1840.

Voeltz (1922) made a study of wool inheritance in a flock of native Pommeranian ewes (a mixed wool type) graded up with purebred Oxford rams. The mixed wool type was dominant to the lustrous crimpy wool of the Oxford. The mixed type of wool in the second filial generation could not be differentiated from the same type of wool in the original Pommeranians showing that this type of wool is very stable, having been set by many generations of breeding and selection. He concludes that in the Pommeranian x Oxford cross there is very little evidence of a blended inheritance.

Voeltz (1922) also studied Mele wool (Merino x Border Leicester) and a Cotswold x Wurtemberg cross and concluded as follows:

"The fact that in the Meles no uniformity of wool type has been attained despite the fact that they have been bred for more than ten years, and further, that the medulla-containing beard hair of the Pommeranian native sheep has not been eliminated after five generations of selective breeding, prove in concordance with the results of former investigators (Adametz and others) that pure blended inheritance is hard to achieve."

In direct opposition to the statements of "Adametz and Voeltz are the writings of Baur and Kronacher (1919), Terho, and Pauly. These investigators found no greater variation in wool type in Meles, a Merino x Border Leicester cross, than they found in any breed which has been developed by careful selection over a period of years.

Kronacher (1925, 1926) more recently gives a resumé of further work with the Mele sheep which upholds his original contention of blended inheritance in the greater number of individuals in the test. The average wool fibre diameter of one hundred Mele sheep was 29.48 micra (11.61 ten thousandths of an inch). The average wool fibre diameter of the Merinos 22.86 Micra (9.00 ten thousandths of an inch), while the average wool fibre diameter of the Border Leicester was 41.37 micra (16.29 ten thousandths of an inch).

Spoettel (1925) found the F_1 generation of the Moufflon x Merino cross to be similar in wool fineness to their Merino parentage, with a few intermediate. The F_2 generation of the same cross gave further variability toward both extreme parental types. The same writer reports similar results with the Somali x Merino cross.

Wool Inheritance Studies in Roumania.

Constantinescu and Contescu report on wool inheritance studies in crosses of the various breeds of Roumanian native sheep. They found a blended type of inheritance in wool fineness.

Wool Inheritance Studies in the United States.

Davenport and Ritzman (1928) report on a series of crossbreeding tests beginning in 1907, and their results were summarized as follows:

In clean weight of fleece there is undoubtedly segregation, but the results are complicated.

Concerning wool fineness, all of the first filial (F_1) generation gave an intermediate measurement. Although in the case of the Hampshire x Rambouillet cross, the first filial (F_1) generation had coarse wool approaching the type of their Hampshire parents.

In the second filial (F_2) generation wool fineness is more variable than in the first filial generation. The Hampshire x Rambouillet cross is more variable in fineness in the second filial generation than in the Southdown x Rambouillet. However, this fact is due to the closer selection of parents in the latter cross, for an intermediate wool fineness.

In the third filial generation, due to a very close selection of parents, there is still less variation in wool fineness.

So it would seem that there is no permanent blending of wool fineness in the first filial generation.

In the second filial generation the fineness of fleece varied according to the fleece character of the parental first filial generation. Evidently x Rambouillet cross gave all degrees of wool character from one extreme to the other. On the other hand the Meles, which have resulted from a cross of purer wool types, did not show so much variation. The results reported by Spoettel (1925) bring out the fact that a more variable type of inheritance of wool fineness occurs with mixed or primitive wool type parentage, than with sheep whose progenitors had a similar or more stable wool type.

The writer has followed closely the various attempts by livestock breeders in the United States to establish new types of sheep by crossbreeding, and has seen the sheep of these new types. Those breeders who were very careful in the selection of their foundation animals have had the most success in breeding uniform crossbreds. It would seem that uniform crossbred types could be more easily produced if the parental stock were not only carefully selected, but also closely inbred and selected for a few generations before making the cross; thus tending to obtain homozygous individuals in the purebred generation before attempting the crossbreeding operation. The writer, during a recent visit to Germany, noted that the sheep breeders there have been remarkably successful in obtaining a uniform type of crossbred sheep in the Fleischwollschaf, and it is quite possible that one of the main underlying reasons for their success was the remarkable homogeneity of the multiple factors and not simple unit characters determine the inheritance of wool fineness.

In crimp there is partial dominance, so that there must be more than one factor involved.

There is positive correlation between the per cent of crimp and the length of the fibre, due to the fact that in general the more crimp the longer the fibre when stretched taut.

Russell (1919), and later Darlow (no date) report on a series of crossbreeding tests beginning in 1909. In these tests the crossbreds were not mated among themselves to produce the second and third filial generations. Only the first filial generation was produced, and these animals were then crossed back with the parental breeds in an attempt to develop a type of sheep particularly adapted to Oklahoma conditions. The breeds used in this experiment were Shropshires, Dorsets, and Rambouillets.

The following results are quoted directly from the summary:

"The fineness factors influencing weight of fleece appear to blend."

"Smooth skins and folds blend, with a slight tendency to folds in the first cross."

"The fineness of wool and folds seem to go together in inheritance."

Wool Inheritance Studies in Russia.

The work of Belehov and Reinbot is referred to later in this paper as it has a direct bearing on the experiment herein reported.

So it would seem that the question of blended wool inheritance is open to controversy. However, in looking over the data of the various investigators one can not help seeing how the first, second, and third filial generations of crossbreds were affected by the selection of the parental stock. One investigator may have picked the finer fleeced individuals and another the coarser fleeced individuals and the following generations would be affected accordingly. Some investigators had only a dozen crossbred animals representing only the first filial generation. Other investigators had from forty to one hundred animals representing the first, second, and third filial generations.

One investigator, with animals most of which were homozygous, would get less variation in the crossbred generations than would another investigator who had more animals which were heterozygous in fleece character. This is strikingly illustrated in the Mele sheep and in the Rambouillet x Karakule cross reported by Adametz. The mixed wool type represented in this case by the Karakule is a heterozygous wool type and the first and second filial generations of the Karakule pure merino flocks which in many instances had been bred for one hundred years, using only sires bred in their own particular flock.

OBJECTS OF EXPERIMENT

1. To determine, if fineness of fleece is a simple Mendelian character.

2. To find out if the fibres from the fleeces of crossbred sheep are more or less uniform in character than those from the fleeces of their purebred parents; in other words, to find out if the wool character fineness blends in crossbreeding.

3. To learn if density of fleece, measured by the number of fibres per half inch square of skin surface is inherited in the Mendelian fashion.

METHOD OF EXPERIMENTATION

Animals Used: Sixteen purebred Rambouillet ewes, two or three years old, and sixteen purebred Hampshire ewes, two or three years old, were used for the foundation females. Two high class registered, mature Rambouillet rams, and two high class registered mature Hampshire rams furnished the breeding rams.

The ewes were divided as follows:

Check Group No. 1	Two Hampshire ewes
Check Group No. 2	Two Hampshire ewes
Check Group No. 3	Two Rambouillet ewes
Check Group No. 4	Two Rambouillet ewes

Crossbred Group No. 1 - Six Hampshire ewes

Crossbred Group No. 2 Six Hampshire ewes

Crossbred Group No. 3 Six Rambouillet ewes

Crossbred Group No. 4 Six Rambouillet ewes

First Year Mating Schedule

Check Group No. 1

Two Hampshire ewes to Hampshire ram No. 1

Check Group No. 2

Two Hampshire ewes to Hampshire ram No. 2

Check Group No. 3

Two Rambouillet ewes to Rambouillet ram No. 1

Check Group No. 4

Two Rambouillet ewes to Rambouillet ram No. 2

Crossbred Group No. 1

Six Hampshire ewes to Rambouillet ram No. 1

Crossbred Group No. 2

Six Hampshire ewes to Rambouillet ram No. 2

Crossbred Group No. 3

Six Rambouillet ewes to Hampshire ram No. 1

Crossbred Group No. 4

Six Rambouillet ewes to Hampshire ram No. 2

Second Year Mating Schedule

Check Group No. 1

Two Hampshire ewes to Hampshire Ram No. 2

Check Group No. 2

Two Hampshire ewes to Hampshire Ram No. 1

Check Group No. 3

Two Rambouillet ewes to Rambouillet ram No. 2.

Check Group No. 4

Two Rambouillet ewes to Rambouillet ram No. 1.

The first filial generation crossbred progeny from the original purebred breeding stock were crossed in the fall of the second year as follows:

Group 1 lambs to Group 2 lambs

Group 2 lambs to Group 4 lambs

Group 3 lambs to Group 1 lambs

Group 3 lambs to Group 4 lambs

Owing to unforseen and unavoidable circumstances the actual number of crossbreds produced was smaller than planned.

Record of Actual Progeny.

First Filial Generation Born in April and May 1922.

Ear Tag No.	Sex	Sire	Dam	Disposal
263	Ewe	Hamp. 35821	Ramb. 151	Sold Apr 1924
---	Ewe	" "	" "	Died Apr 3,1922
266	Ram	" "	Ramb. 210	
264	Ewe	" "	Ramb. 122	Sold Apr 1924
265	Ewe	" "	" "	Sold Apr 1924
267	Ewe	Ramb. 116838	Hamp. 82547	Sold Apr 1924
268	Ram	" "	Hamp. 58094	Sold Oct 13,1923
269	Ram	Hamp. 35821	Ramb. 203	Sold Jan.1,1923
270	Ram	" "	" "	Sold Jan.1,1923

Ear Tag No.	Sex	Sire	Dam	Disposal
273	Ewe	Hamp. 36236	Ramb. 12	Sold Apr 1924
274	Ram	" "	" "	Sold Oct.13,1923
---	Ewe	Ramb. 116838	Hamp. 72600	Died Apr.18,1922
282	Ewe	Hamp. 35821	Ramb. 5163	Sold Apr. 1924
284	Ram	Ramb. 116838	Hamp. 82548	Sold Jan.1,1923
285	Ewe	Ramb. 116838	Hamp. 82548	Sold Apr. 1924
286	Ewe	Hamp. 36236	Ramb. 116	Sold Apr. 1924
288	Ewe	Hamp. 36236	Ramb. 207	Sold Apr. 1924
289	Ram	Ramb. 116838	Hamp. 68697	Sold Jan. 1,1923
290	Ewe	Ramb. 116838	Hamp. 68697	Sold Apr. 1924
---	Ram	Ramb. 132649	Hamp. 72598	Died May 7,1922
291	Ram	Ramb. 132649	Hamp. 68707	Sold Jan.1,1923
292	Ram	Ramb. 132649	Hamp. 68707	Died Sept.11,1923
293	Ram	Ramb. 132649	Hamp. 68692	Sold Janl,1923
294	Ram	Hamp. 35821	Ramb. 5	Sold Jan.1,1923
---	Ram	" "	" "	Died May 18,1922
295	Ram	Ramb. 132649	Hamp. 114	Sold Jan.1,1923

Purebred Generation Born in February,March, & April 1923.

Ear Tag No.	Ewe	Sire	Dam	Disposal.
317	Ram	Hamp. 36236	Hamp. 82547	Sold Oct.13,1923
318	Ewe	" "	" "	
321	Ram	Hamp. 35821	Hamp. 68707	
322	Ewe	Hamp. 36236	Hamp. 84382	
323	Ewe	Hamp. 35821	Hamp. 68692	Sold Oct. 1923

Purebred Generation Continued

Ear Tag No.	Sex	Sire	Dam	Disposal
324	Ewe	Ramb. 132649	Ramb. 224	
325	Ewe	Hamp. 35821	Hamp. 82546	
332	Ewe	Hamp. 36236	Hamp. 65227	Died Nov.17,1923
333	Ewe	Hamp. 36236	Hamp. 65227	Sold Oct. 1923
336	Ewe	Hamp. 36236	Hamp. 68697	Sold Mar.29,1924
337	Ewe	Hamp. 36236	Hamp. 68697	Sold Nov.14,1923
338	Ram	Ramb. 132649	Ramb. CSA 16	Sold Oct.1,1923
339	Ram	Ramb. 132649	Ramb. CSA 16	Sold Oct. 1,1923
343	Ewe	Ramb. 132649	Ramb. 255	Sold Oct. 1923
346	Ram	Hamp. 36236	Hamp. 58094	Sold Dec. 15,1923
347	Ram	Hamp. 36236	Hamp. 947	Sold Dec. 15,1923
348	Ewe	Hamp. 36236	Hamp. 947	Sold Oct. 1923
349	Ram	Hamp. 36236	Hamp. 82548	Sold Dec. 13,1923
351	Ewe	Hamp. 36236	Hamp. 68699	
354	Ram	Ramb. 116838	Ramb. 116	Sold Oct. 1,1923
355	Ewe	Ramb. 116838	Ramb. 116	
356	Ewe	Ramb. 116838	Ramb. 207	
359	Ram	Ramb. 132649	Ramb. 5163	Sold Oct. 1,1923
360	Ewe	Ramb. 132649	Ramb. 5163	
361	Ram	Ramb. 116838	Ramb. 74	Sold Dec. 15,1923
362	Ram	Ramb. 116838	Ramb. 74	Sold Oct. 1,1923
364	Ewe	Ramb. 116838	Ramb. CSA 12	Sold Dec. 15,1923
370	Ram	Ramb. 116838	Ramb. 5453	Sold Oct. 1923
371	Ewe	Ramb. 116838	Ramb. 5453	
376	Ewe	Ramb. 132649	Ramb. 210	Sold Oct. 1923
377	Ewe	Ramb. 132649	Ramb. 5065	Sold Oct. 1,1923

Second Filial Generation. Born in February 1924

Ear Tag No.	Sex	Sire	Dam	Disposal
421	Ewe	No. 268	No. 267	Sold. Aug. 6,1925
---	Ram	No. 268	No. 267	Died. Feb. 10,1924
422	Ewe	No. 268	No. 290	Sold. Aug. 6,1925
423	Ram	No. 268	No. 290	Sold. Feb. 24,1925
424	Ewe	No. 274	No. 282	Sold. Aug. 6,1925
425	Ram	No. 274	No. 263	Sold. Feb. 24,1925
429	Ewe	No. 268	No. 286	Sold. Aug. 6,1925
433	Ewe	No. 274	No. 265	Sold. Aug. 6,1925
434	Ram	No. 274	No. 265	Sold. Feb. 24,1925
436	Ram	No. 268	No. 285	Sold. Feb. 24,1925
441	Ram	No. 268	No. 273	Died. Jan. 1925
442	Ewe	No. 268	No. 273	Sold. Aug. 6,1925
443	Ewe	No. 274	No. 264	Sold. Aug. 6,1925
444	Ram	No. 274	No. 264	Died. Feb. 22,1924

<u>Wool Samples Available for Study</u>

Rambouillet			Hampshire		
Ear Tag Number	Sex	Years	Ear Tag Number	Sex	Years
CSA 5	Ewe	1921	114	Ewe	1922
CSA 12	Ewe	1921:1922	163	Ewe	1921
CSA 16	Ewe	1921	164	Ewe	1921
116	Ewe	1921:1925	170	Ewe	1921
122	Ewe	1921	36236	Ram	1922
149	Ewe	1921	58094	Ewe	1921

Wool Samples Available for Study. Continued

Rambouillet			Hampshire		
Ear Tag Number	Sex	Years	Ear Tag Number	Sex	Years
151	Ewe	1921	68693	Ewe	1921
207	Ewe	1922	68697	Ewe	1921
210	Ewe	1921	68699	Ewe	1921
5065	Ewe	1921	68707	Ewe	1921
5163	Ewe	1921	72598	Ewe	1921
5380	Ewe	1921	72600	Ewe	1921:1922
5453	Ewe	1921			
116838	Ram	1922			
132649	Ram	1921			

First Filial Generation			Second Filial Generation		
Ear Tag No.	Sex	Years	Ear Tag No.	Sex	Years
263	Ewe	1923:1924	421	Ewe	1925:1926
264	Ewe	1923:1924	422	Ewe	1925:1926
265	Ewe	1923:1924	423	Ram	1925
266	Ram	1923	424	Ewe	1925:1926
267	Ewe	1923:1924:1925	425	Ram	1925
268	Ram	1923:1925	429	Ewe	1925:1926
273	Ewe	1923:1924:1925	433	Ewe	1925
274	Ram	1923:1925	434	Ram	1925
282	Ewe	1923:1924	436	Ram	1925
285	Ewe	1923:1924:1925	442	Ewe	1925:1926
286	Ewe	1923:1924:1925	443	Ewe	1925:1926

Wool Samples Available for Study. Cont'd.

First Filial Generation.

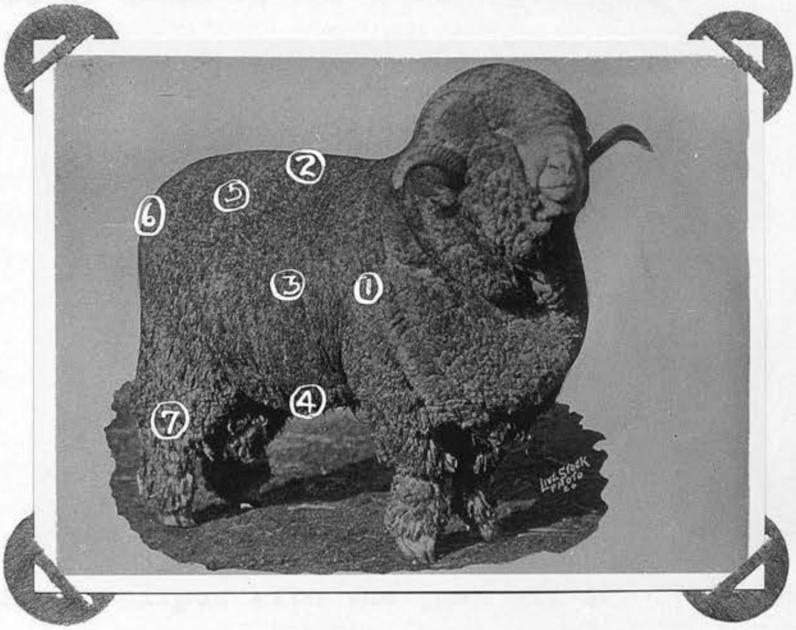
	Ear Tag Number	Sex	Years
	288	Ewe	1923:1924:1925
	290	Ewe	1923:1924
	292	Ram	1923

It will be noticed that a number of wool samples were not available for study. When the writer took over the experiment in July 1924, it had been in progress since 1921. Through unavoidable circumstances some of the samples had been lost. None of the frequency data of the wool samples measured prior to 1924 were available for studies in uniformity of fineness.

Method of Taking Wool Samples.

Seven body regions were selected for taking samples. These body regions are shown in the following Fig. No: 1.

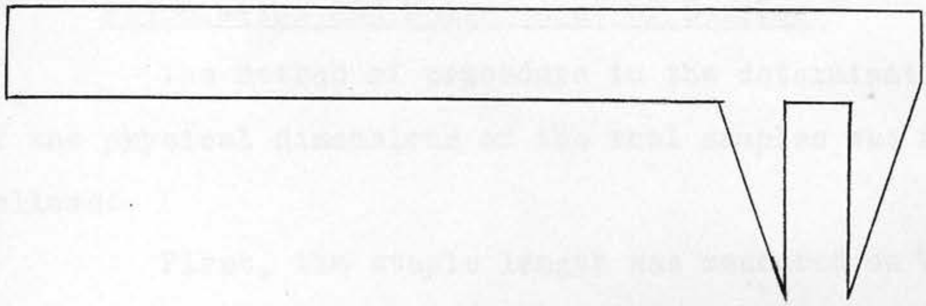
Fig. I.



Body Regions from which Samples were taken.

1. Shoulder
2. Back
3. Side
4. Belly
5. Hip
6. Dock
7. Thigh

These samples were taken with a pair of eigineer's calipers which separated the wool growing on a skin surface one-half inch square. One of these calipers is shown in the following diagram:



In taking the samples, the wool was folded back and a caliper with the jaws set one-half inch apart was pushed into the wool perpendicular to the fold and the fibres inside of the jaws were carefully separated from the rest of the surrounding wool. Then another caliper with the same half-inch opening between its jaws, was pushed through the wool at a right angle across the jaws of the first caliper and again the fibres inside of the jaws were carefully separated from the surrounding wool. When the sample inside the jaws was separated, it was grasped with the fingers, the calipers were withdrawn and the sample was cut off close to the skin with a pair of curved scissors. The sample thus obtained represented the wool fibres growing on a skin surface one-half inch square, or one-quarter of a square inch in area.

As each sample was cut free from the skin it was placed in an envelope labeled with the sheep's number, sex, and the body location from which the sample was taken.

Preparation and Measurement of Samples

The method of procedure in the determination of the physical dimensions of the wool samples was as follows:

First, the staple length was measured on a steel rule graduated in tenths of an inch. The sample was then washed in a standard soap solution made up as follows: 1 pound of olive fig scouring soap, and ½ pound of soda ash made up to ten gallons of solution. The solution was kept at a temperature of from 130 to 140 degrees Fahrenheit according to the grease content of the sample. During the first part of the experiment cold benzol was used for degreasing the samples, but it was found that benzol would not remove the gums and flake-like waxes which occurred in the finer Rambouillet wools. This gum or wax affected the weight of the sample and made the calculated density greater, for the calculation of density is based on the comparative weights of a fractional part of the sample (100 fibres) and the entire sample.

Five fibres were then measured to determine the fibre length (stretched so that no crimp remains), to the nearest tenth of an inch and the number of crimps per half inch. The number of crimps per half inch was determined by holding the fibre over a piece of black cardboard in which a half inch square notch had been cut. The number of crimps per half inch were counted at the tip, base, and middle of each of the 5 fibres and the average of the three counts was taken as the average number of crimps per half inch for that particular fibre.

The Measurement of Fineness.

The tip of the sample was clipped off so as to have all of the fibres as near the same length as possible. The sample was then placed in a small folded cardboard holder; the fibres were spread apart on one side and the individual fibres were drawn out, one by one, in order, from the same side of the sample. As these fibres were drawn out each one was placed between the jaws of the micrometer (this micrometer has been described by Burns and Koehler, 1925), holding the fibre stretched taut with one end between the thumb and third finger and the other end between the first and second fingers of the left hand as shown in Fig. No. 2. The micrometer spindle was turned up slowly until the jaws of the micrometer lay up snugly against the side of the fibre, and the ratchet in the end of the spindle clicked twice. One soon gets the feel of the ratchet and can judge the speed of rotation so that the same speed can be used to measure the fibres, as is used in checking the zero point of the micrometer. This micrometer

Figure No. 2.

MICROMETER CALIPER

reads in units of ten thousandths of an inch, each of the smallest divisions on the edge of the drum representing one unit. One hundred fibres were measured from each sample and the measurements were recorded in the following form:

	Size of Fibre .0001 Inch (V)	Frequency (F)	Product (FV)	
	3	2	6	
	4	14	56	
	5	21	105	
	6	36	216	
	7	20	140	
	8	7	56	
	Totals	100	579	

Mean Fineness of 100 fibres

5.79 ten-thousandths of an inch

The micrometer has already been compared with microscopic measurements by Burns and Koehler, who found the difference to be one ten-thousandth of an inch; the micrometer measurement giving the smaller value.

Method of Determining Density

The density of wool fibres, or number of wool fibres per one-half inch square of skin surface was determined as follows: As the fibres were measured for fineness they were saved by placing them in a wool fibre box. This box was an ordinary cigar box lined with black paper so the wool fibres could easily be seen. When 100 fibres had been measured they were taken from the fibre box and rolled together into a ball. These 100 fibres as well as the remaining portion of the original wool sample were put into a weighing bottle and the cover put on, making the contents of the bottle less susceptible to outside atmospheric conditions. The tared bottle was weighed with both wool samples in, and weighed again after the 100 fibre bundle had been removed. All weights were taken with an analytical balance. Differences in moisture content of the samples would not be so important as with absolute weights, for in this case the weights are only for comparative purposes. The following specific case of calculated density should help to illustrate the method.

Weight of Weighing Bottle	(W_b)	38.2537 grams
Weight including both wool sample and 100-fibre bundle	(W_e)	38.596 grams
Weight with 100-fibre bundle removed	(W_r)	38.5908 grams
Weight of 100-fibre bundle $(W_{100}) = (W_e)-(W_r)$		.0052 grams
Weight of entire sample including 100-fibre bundle $(W_t) = (W_e)-(W_b)$		.3423 grams

Calculated Density, or number of fibres per half inch square of skin surface. $D = \frac{(W_t)}{(W_{100})} \times 100$ 6583

The writer tested the weighing method against an actual count of the same sample, first calculating the density by weight ratios (3799 fibres per half inch square of skin surface) and then actually counting all of the fibres in the sample (3560 fibres). The difference between the results (239 fibres) is not a large one and is much smaller than the sampling error which is next to be described.

Error of Sampling for Density Determination

Number of Fibres per half inch square surface of skin

In order to determine the accuracy of the sampling method for density, duplicate samples were taken from the right shoulder on five different breeds of sheep, so as to have represented the different types of wools.

Accuracy of Sampling for Density Determination

Breed	Age	Sex	Ear Tag No.	Calculated Density Sample One	Sample Two	Difference
Ramb.	3	Ewe	432	4777	4677	100
Ramb.	4	Ewe	281	3527	3587	60
Ramb.	4	Ewe	255	3454	5009	1555
Ramb.	1	Ewe	606	5972	7214	1242
Ramb.	Lamb	Ram	754	2690	3017	327
Average Difference for Rambouillets						657
Corr.	2	Ewe	2139	2719	3027	308
Corr.	2	Ewe	465	3564	2640	924
Corr.	2	Ewe	2091	5515	5143	372

Average Difference for Corriedales 535

Accuracy of Sampling for Density Determination

Contiuned

Breed	Age	Sex	Ear Tag No.	Calculated Density		
				Sample One	Sample Two	Difference
Hamp.	3	Ewe	351	2650	2796	146
Hamp.	3	Ewe	325	2641	2684	43
Hamp.	5	Ewe	87950	2123	1754	369
Hamp.	1	Ewe	614	2278	2776	498
Hamp.	Lamb	Ram	714	2021	1900	121
Average Difference for Hampshires						235
Oxford	4	Ewe	230	1857	2065	208
Oxford	4	Ewe	277	2081	2140	59
Oxford	3	Ewe	335	1655	1881	226
Average Difference for Oxfords						164
Linc.	1	Ewe	631	1545	2350	805
Linc.	Lamb	Ram	752	3714	3124	590
Average Difference for Lincolns						698
Total Difference for 18 sheep					7953	
Average Difference for 18 sheep					442	

The difference in density in duplicate samples was highest in the Lincolns and lowest in the Oxfords. The average difference for the entire lot of sheep was 442 fibres.

Using the statistical methods of Fisher, as adapted to machine calculation by Lush, the following table of variance was obtained:

Accuracy of Sampling for Density Determination

Table of Variance.

Variation due to	Degrees of Freedom	Standard Deviation	Mean Variance	Gross Variance
All Causes	35	1349.39	1820855	63729932
Sample Trend	1	118.01	250667	250667
Balance	34	1366.40	1867037	63479265
Animal Difference	17	1332.71	3552219	60387718
Remainder	17	426.45	181856	3091547

Standard Error of Sampling 426 fibres.

Not a significant difference as $\frac{1}{o}$ equals 1.3

In this method of calculation all factors influencing variation such as sample trend and animal difference are removed leaving only the actual error of sampling. The standard error represents the weighted standard deviation, with all of the outside factors influencing sample difference removed mathematically, except the calculated differences of duplicate differences in samples resulting from errors of sampling. In order that the method of calculation may be clear the formulas are given on Page 32, as they have been developed for machine calculation. However, two additional references to Lush 'et all', are given in the list of literature cited, which deal with cattle but give his machine calculation method for determining the standard error.

Formulas used in the Table of Variance

Variation due to	Degrees of Freedom	Standard Deviation	Mean Variance	Gross Variance
All Causes	a	p	k	f
Sample Trend	b	q	l	g
Balance	c	r	m	h
Animal Difference	d	s	n	i
Remainder	e	t	o	j

a One less than the total number of observations

b One less than the total number of sets of samples

c a - b

d One less than the total number of samples

e c - d

f $(\Sigma A^2 + \Sigma B^2) - \frac{(\Sigma A + \Sigma B)^2}{36}$

g $\frac{(\Sigma A)^2 + (\Sigma B)^2}{18} - \frac{(\Sigma C)^2}{36}$

h f - g

i $\frac{\Sigma C^2}{2} - \frac{(\Sigma C)^2}{36}$

j h - i

k f/a

l g/b

m h/c

n i/d

o j/e

$\sqrt{}$ = Square Root

p $\sqrt{k}$

q $\sqrt{l/18}$ i.e. $\sqrt{\frac{el}{18}}$

r $\sqrt{m}$

s $\sqrt{n/2}$ i.e. $\sqrt{\frac{n}{2}}$

t $\sqrt{o}$

ΣA = Sum of first Column (Sample One in Table on Page 29)
ΣB = Sum of second column (Sample Two in Table on Page 29)
ΣC = Sum of third column (Sample One plus Sample Two in Table on Page 29)

ΣA^2 = Sum of Squares of first column.
ΣB^2 = Sum of Squares of second column.
ΣC^2 = Sum of Squares of third column.

How Many Fibres should be measured to determine Fineness?

In order to test the effect of measuring more than one set of 100 fibres for the determination of the average thickness of fibre four different samples were measured keeping records of each set of 100 fibres measured from each sample up to a total number measured of 500 fibres. The results obtained are shown below:

Frequency	Size in ten-thousandths of an inch										
	2	3	4	5	6	7	8	9	10	11	Mean
Sample No. 1											
1st 100		7	15	31	25	12	6	2	1	1	5.57
2nd 100		6	30	38	14	7	4	1			5.02
3rd 100		7	30	35	15	11	2				4.99
4th 100		12	22	35	18	6	7				5.05
5th 100		11	34	31	16	5	3				4.79
All 500		43	131	170	88	41	22	3	1	1	5.08
Sample No. 2											
1st 100		8	26	37	14	9	4	2			5.10
2nd 100		9	36	34	11	6	3	1			4.82
3rd 100		8	29	32	18	9	2	1	1		5.06
4th 100	1	10	32	32	16	6	2	1			4.83
5th 100		13	25	37	14	6	4	1			4.91
All 500	1	48	148	172	73	36	15	6	1		4.94

-43 249 230.57
+2 148 147.96
-1 135 134.99
+5 175 174.75
-21 141 136.59
+42 862 858.472
176 175.00
822
1.588

How many Fibres should be measured to determine Fineness?

Continued

Frequency	Size in ten-thousandths of an inch										
	2	3	4	5	6	7	8	9	10	11	Mean
Sample No. 3											
1st 100		12	28	28	21	6	5				4.96
2nd 100		17	27	32	13	8	2	1			4.78
3rd 100	1	13	30	36	14	4	1	0	1		4.71
4th 100		20	32	25	11	6	4	2			4.71
5th 100	5	25	26	26	7	5	6				4.44
All 500	6	87	143	147	66	29	18	3	1		4.72
Sample No. 4											
1st 100		1	6	16	30	18	15	13	1		6.60
2nd 100			10	19	29	16	18	6	2		6.39
3rd 100		1	7	20	24	25	11	10	2		6.48
4th 100		1	12	28	28	18	11	2			5.91
5th 100		8	18	26	17	15	12	3	1		5.66
All 500		11	53	109	128	92	67	34	6		6.21

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Cumulative Means of Fineness

No. of fibres measured	100	200	300	400	500
Sample No. 1	5.57	5.30	5.19	5.16	5.08
Sample No. 2	5.10	4.96	4.99	4.95	4.94
Sample No. 3	4.96	4.87	4.82	4.79	4.72
Sample No. 4	6.60	6.50	6.49	6.35	6.21
	2.23	1.63	1.49	1.25	.95

In all cases the measurement of 500 fibres gave a smaller average or mean fineness than when only 100 fibres were measured. The differences for the four samples were .49, .16, .24, and .39. When 500 fibres were measured instead of only 100 the probable error of the mean was reduced by half. This would be expected from the fact that the probable error calculation depends upon the number of fibres measured and the error is reduced in the ratio of the square root of the number of fibres measured. The fact that as more fibres were measured the mean fineness became smaller, as is strikingly shown in the cumulative means of fineness, would indicate that even though all of the fibres were drawn in order from the same side of the sample, the tendency was to pick the coarser fibres first. The error due to the number of fibres measured was so small in proportion to the differences of mean fineness between the purebred and crossbred generations that the measurement of 100 fibres was considered sufficient for making comparisons of fineness in this study. The standard deviation of mean fineness of the different sets of 100 from the entire 500 was from .1162 to .2596 while the differences in fineness of the purebred and crossbred generations varied from 1.144 to 1.289. Thus if the maximum variation due to 100 fibres being measured instead of 500 it would be only one-fifth of the minimum difference in mean fineness between the crossbred and purebred generations.

Roberts (1930) used a formula $n = (\frac{c}{s_1})^2$ to calculate the number of fibres to measure in order to come within a prescribed limit of error. In this formula n = necessary number of fibres to measure; c = coefficient of variability or per cent of standard deviation; and s_1 = per cent of standard error. The usual accuracy desired in wool fineness work is a ten per cent difference exceeded by chance once in 250 times. The constant figure for s_1 for this selected limit of accuracy is 2.457. The application of this formula to the data of the four samples just considered gives the following results:

Necessary Number of Fibres to be Measured

	1st 100	2d 100	3d 100	4th 100	5th 100	All 500
Sample No. 1	125	100	90	115	110	115
Sample No. 2	115	110	115	110	115	115
Sample No. 3	115	125	120	135	190	140
Sample No. 4	90	90	90	80	140	100

Average figure for all four samples 135

The same formula may be applied to the size frequency distributions of the Hampshire and Rambouillet purebred generations and the Crossbred generations, which will be found in Table No. 7 of the appendix. Those samples of each purebred and cross bred generation showing the greatest and least variability (largest and smallest figures for C) were selected and used for calculating the following data;

Necessary Number of Fibres to measure for Fineness

Breed and Sex	Number of Samples	Maximum Necessary Number	Minimum Necessary Number	Mean Necessary Number
Rambouillet				
Ewes	6	185	25	80
Rams	1	100	40	60
Hampshire				
Ewes	2	125	40	60
Rams	1	115	45	70
F_1 Generation				
Rams	3	135	35	70
Ewes	20	220	20	75
F_2 Generation				
Ewes	13	215	35	95
Rams	5	225	25	80
All Fifty Samples		225	20	80

The use of the standard error formula for calculating the number of fibres to measure in order to fall within the limits of a certain prescribed error, confirmed the results obtained by the use of the probable error method. The necessary number of fibres to be measured, in all cases where mean figures were used was well below the 100 fibre number standard which was used in all of the fibre measurement work in this experiment.

At the same time as the number of fibres to be measured was determined a study was made of the effect of using the various sets of 100 fibres as a basis for the calculation of the density.

How Many Sets Of 100 Fibres Should Be Used As a Basis For Calculating Density By Proportionate Weights?

Calculated Density

Number of fibres per ½ inch square on skin surface

	100-fibre bundles used as a basis for calculation					
Sample	1st 100	2nd 100	3rd 100	4th 100	5th 100	All 5
No. 1	4777	5415	5296	5244	5360	5218
No. 2	4677	5280	4776	5079	4842	4931
No. 3	6119	6267	6630	6332	6940	6458
No. 4	2719	2796	2728	2956	2926	2825

Calculated Density

Cumulative Results

	Number of 100-fibre bundles used				
Sample	One	Two	Three	Four	Five
No. 1	4777	5096	5162	5183	5218
No. 2	4677	4979	4911	4953	4931
No. 3	6119	6193	6339	6337	6458
No. 4	2719	2758	2748	2800	2825

Inasmuch as fineness and density are correlated a reverse relationship would be expected between these wool characters and the methods by which they are determined. As more 100-fibre bundles were used as a basis for the calculation of density the figure increased. The variation by the method of least squares gave a maximum of 293 in Sample No. 3 and a minimum of 99 in Sample No. 4. The figures for the other two samples were; 228 for Sample No. 1, and 219 for Sample No. 2. The crossbred generations varied from their purebred parental generations by around 2000 fibres so these differences due to technique in number of bundles weighed had no significant bearing on the results obtained.

RESULTS

Inheritance of Fineness

The original data concerning the Inheritance of Fineness will be found in Tables 1, 6, and 7 of the Appendix. The figures given in the following table are the means of all seven body areas of the first fleece from each sheep, using the mean fineness of each body area sample as a unit for the purpose of calculating the means, probable errors, and coefficients of variability (per cent standard deviation), which were calculated by means of the standard formulas of statistical methods as adapted to machine calculation. The number of fleeces available for study varied in each individual and in order to have each individual exerting an equal influence in each generation, the first fleece was used to furnish the wool samples for these wool studies.

Inheritance of Fineness

	Mean Fineness .0001 Inch	Coefficient of Variability Pér cent
15 Rambouillet Sheep	6.815 ± .070	17.23 ± .828
14 Hampshire Sheep	9.212 ± .121	18.06 ± .959
14 F_1* Generation Sheep	8.250 ± .069	12.22 ± .598
11 F_2* Generation Sheep	7.274 ± .072	12.85 ± .710

* F_1 equals First Filial

* F_2 equals Second Filial

The F_1 Generation was intermediate in wool fineness between their Rambouillet and Hampshire parents. The two F_1 Generation sires (Nos. 268 and 274) used were both intermediate in wool fineness and were quite close to the average figure for all of the sheep of this generation. The F_2 Generation was very similar to its Rambouillet parentage in wool fineness. A statistical treatment of the data shows the F_1 Generation to be very definitely intermediate in wool fineness with significant differences from both parental generations, the differences being from four to seven times the maximum allowable error (three times the probable error of mean fineness for the F_1 Generation). A similar treatment of the data for the F_2 Generation shows it to be very close in wool fineness to its Rambouillet grandparents, the difference being only twice the maximum allowable error, and far removed from its Hampshire grandparents, the difference in this instance being nine times the maximum allowable error. There would seem to be a strong tendency for the Rambouillet wool type to predominate in the F_2 Generation, as each individual sheep of this generation was fine woolled rather than intermediate in wool type. Both of the crossbred generations were more uniform in wool fineness than their purebred parental generations, as shown by the smaller coefficients of variability. The differences between the coefficients are significant as they are larger than the maximum allowable error. The coefficient of variability in this instance gives an index of the variation or divergence of the different sheep within the same generation using the average fineness figure of all seven body areas. The F_1 Generation were an excellent type of sheep being large in size and carrying a high yielding 58^s-60^s Quality fleece of staple[1] length. The F_2 Generation tended to be smaller than the F_1 Generation and had finer wool, in fact almost as fine as their Rambouillet grandparents. It is probable, however, that by selection the stock breeder could keep wool fineness blended in cross breeding operations, as has been done in practice. The Mele sheep mentioned by Thilo (1922) are a fine example, along with the Corriedale, of how distinct types of wool can be bred and maintained from the same original parentage. The Corriedale was selected for a 56^s Quality wool while the Mele, originally with a

[1] "staple" is here used as a commercial word meaning wool of combing length.

wool type similar to the Corriedale, has been selected for a finer wool of 60^s-64^s quality. Range sheepmen of Wyoming have found in the last few years, that they can keep their flocks more uniform by dividing the breeding flock into three types of sheep; the fine, intermediate, and coarse woolled. By mating each of the three types of ewes with the proper type of rams they can keep their flocks more uniform in fineness of fleece than they could by using the old system of alternately using fine and coarse woolled breeds of rams, changing the breed when they felt their flocks were becoming too fine or too coarse in fleece to suit environmental or market conditions.

Inheritance of Density.

Number of Fibres per half inch square surface of skin.

The detailed data concerning the Inheritance of Density will be found in Tables 2 and 6 of the Appendix. The figures given below have been calculated in a similar way to those given in the Fleece Fineness table in the preceding section.

	Average Density No. of Fibres.	Coefficient of Variability Per cent.
15* Rambouillet Sheep	6148 ± 153	37.61 ± 1.993
14 Hampshire Sheep	2254 ± 63	37.71 ± 2.224
14 F_1 Generation Sheep	4003 ± 97	23.91 ± 1.217
11* F_2 Generation Sheep	3736 ± 92	32.12 ± 1.916

Both of the crossbred generations were intermediate in density as compared with their purebred parental generations, showing a blended inheritance. There was no significant difference between the F_1 and F_2 Generations. A statistical treatment of the data for the F_1 Generation showed it to be definitely intermediate to its purebred parents for the differences in density were from five to seven times the maximum allowable error. A similar treatment of the data for the F_2 Generation showed the differences from the grandparental generations to be from four to twelve times the maximum allowable error again showing distinctive differences from both grand parental generations and denoting a uniformly blended inheritance of density. The figures for the coefficients of variability showed that the F_1 Generation did not have as great variation in density among the different individuals of the generation, as did the purebred or F_2 generations, which bears out the same relationship as was found in the study of fleece fineness. The variation differences between the purebred generations and the F_2 Generation were not significant, but the F_1 Generation was significantly different from both the purebred and F_2 generations.

Inheritance of Staple Length

Average Length of Staple in Inches

The original data concerning the inheritance of staple length will be found in Tables 3 and 6 of the Appendix.

	Staple Length in Inches	Coefficient of Variability Per Cent
15 Rambouillet Sheep	2.975 ± .048	24.24 ± 1.199
14 Hampshire Sheep	3.478 ± .056	22.11 ± 1.192
14 F_1 Generation Sheep	3.196 ± .027	12.48 ± 0.610
11 F_2 Generation Sheep	2.791 ± .030	13.97 ± 0.773

The staple length in all individuals represents twelve months of growth. Although there was not a great difference, it would seem that there was a slight tendency for the staple length to be intermediate in the F_1 Generation and to become shorter in the F_2 Generation. A mathematical treatment of the differences showed the crossbred generations to differ from their purebred parents, the differences being from two to eight times the maximum allowable errors. In variation among the individual sheep of each generation, the crossbred generations were again more uniform than their purebred parental generations, the differences being five times as great as the maximum allowable error.

Inheritance of Fibre Length

Average Stretched Fibre Length in Inches

The original data concerning the inheritance of fibre length will be found in Tables 4 and 6 of the Appendix.

	Fibre Length in Inches	Coefficient of Variability Per Cent
13* Rambouillet Sheep	4.596 ± .084	24.76 ± 1.374
14 Hampshire Sheep	5.364 ± .097	24.22 ± 1.357
7* F_1 Generation Sheep	4.271 ± .068	16.41 ± 1.148
11 F_2 Generation Sheep	4.029 ± .045	14.37 ± 0.797

Both of the crossbred generations had less length of fibre than their purebred parental generations. The differences were more significant in the F_2 than in the F_1 generation. The crossbred generations **showed** less variability, and the differences were quite significant being eight times the maximum allowable error.

Inheritance of Crimp

Number of Crimps per Inch

The original data concerning the inheritance of crimp will be found in Tables 5 and 6 of the Appendix.

	Number of Crimps per Inch	Coefficient of Variability Per Cent
15 Rambouillet Sheep	15.346 ± .249	24.50 ± 1.213
14 Hampshire Sheep	9.988 ± .195	26.86 ± 1.479
14 F_1 Generation Sheep	11.816 ± .217	26.89 ± 1.387
11 F_2 Generation Sheep	12.675 ± .188	19.31 ± 1.089

Both of the crossbred generations were intermediate in crimp between their purebred parental generations. The differences were from three to six

* Fibre length data for the other animals not available.

times the maximum allowable error, which indicated a definite blending. In uniformity between individuals of the same generation, the F_2 Generation were much more uniform than either of the purebred generations or the F_1 Generation. There was no significant difference between the Rambouillet, Hampshire, and F_1 Generations but the F_2 Generation differed from the others by one and a half times the maximum allowable error.

The Effect of the Breed of the Sire
On Fleece Fineness of F_1 Generation

	Mean Fineness .0001 Inch	Coefficient of Variability
2 Rambouillet Sires	8.076 ± .091	6.22 ± .797
5 F_1 Generation Sheep	8.072 ± .114	12.41 ± 1.015
4 Hampshire Dams	10.092 ± .278	19.15 ± 2.018
2 Hampshire Sires	10.188 ± .181	7.45 ± 1.264
9 F_1 Generation Sheep	8.349 ± .085	11.94 ± 0.727
7 Rambouillet Dams	6.676 ± .101	15.61 ± 1.090

Although the F_1 Generation were intermediate in fleece fineness, still the Rambouillet wool type predominated. The differences were much smaller between the F_1 Generation and their Rambouillet Sires or Dams than they were between the F_1 Generation and their Hampshire Sires or Dams. The F_2 Generation was almost as fine of fleece as their Rambouillet grandparents as is shown by the following figures:

	Mean Fineness .0001 Inch
15 Rambouillet Sheep	6.815 ± .070
14 Hampshire Sheep	9.212 ± .121
14 F_1 Generation Sheep	8.250 ± .069
11 F_2 Generation Sheep	7.272 ± .072

The results obtained would indicate that the Rambouillet wool type predominated over the Hampshire wool type in this crossbreeding experiment. The Rambouillet sires had more influence on the crossbred generations than the Rambouillet dams.

The F_2 Generation individuals showed a very interesting separation of body and wool characters which are normally associated together. Three of the F_2 Generation individuals, Ear Tag Nos. 422, 442, and 443 are shown in Figures 3, 4, and 5.

In F_2 ewe No. 442 the Hampshire colour markings were most pronounced, yet the sloping rump and fine, dense wool of the Rambouillet were also conspicuous.

In F_2 ewe No. 422 the head and colour markings resembled the Hampshire; the body conformation was that of a Hampshire but the wool was similar to that of a Rambouillet.

F_2 ewe No. 443 had all the characteristics of a purebred Rambouillet, but the wool was coarser than either of the other ewes shown in the photographs.

Figure No. 3.

F_2 EWE NO. 422

Hampshire x Rambouillet.

An Intermediate Type.

Black Nose, Brown Ears, and Body Conformation of Hampshire.

Fine Wool of Rambouillet.

Photo by Courtesy of

United States Department of Agriculture.

Figure No. 4.

F_2 EWE NO. 442

Hampshire x Rambouillet.

Black Head, Ears and Legs of Hampshire.

Sloping Rump and Fine, Dense Wool of Rambouillet.

Photo by Courtesy of

United States Department of Agriculture.

Figure No. 5.

F_2 EWE NO. 443

Hampshire x Rambouillet

Shows Remarkable Similarity in Conformation

and Wool Type to a Purebred Rambouillet.

Photo by Courtesy of

United States Department of Agriculture.

Segregation of Body and Fleece Characters.

A compilation of the averages of seven body reas for two fleeces for each of the ewes shown in he photographs gave the following average figures for leece fineness and **density:**

	Mean Fineness .0001 Inch	Average Density No. of fibres per ½ inch square of skin surface
F_2 Ewe No. 442	6.150	4144
F_2 Ewe No. 422	6.976	3495
F_2 Ewe No. 443	7.466	3522

The wedge shaped appearance of the staples f wool on F_2 Ewe No. 442 would indicate a fleece of reat density which fact is confirmed by the laboratory nalysis. The other two fleeces are more difficult to udge by eye but both show a fine wool character.

Body and fleece characters were not inherited s unit characters for the Hampshire body appeared with Rambouillet fleece.

Variation in Fleece Fineness from Year to Year.

Data on fineness were available for the first econd, and third fleeces of five crossbred ewes of the l Generation.

	Mean Fineness .0001 Inch	Coefficient of Variability Per Cent
First Fleece	7.903 ± .067	7.43 ± ..603
Second Fleece	7.286 ± .102	12.30 ± 1.007
Third Fleece	7.192 ± .106	12.97 ± 1.064

The second and third fleeces were finer than the first fleece and the differences were significant. However, the maximum difference (.711) was much smaller than the differences in fineness between the purebred and crossbred generations (.459 to 1.938) except in the single instance of the F_2 Generation approaching so closely in fineness their Rambouillet grandparents.

Variation in Fleece Density from Year to Year

	Average Density Number of Fibres per half-inch square of skin area	Coefficient of Variability Per Cent
First Fleece	4713 ± 167	31.15 ± 2.745
Second Fleece	4378 ± 165	33.12 ± 2.948
Third Fleece	4168 ± 171	36.01 ± 3.257

The differences in density were not as large as the maximum allowable error and it would not make a great difference which fleece were used in making a study of the inheritance of density.

Only one of the original purebreds was available for study when the writer took over the experiment. This animal was Rambouillet Ewe No. 116 and data were available on her second and sixth fleeces. The figures given here are the averages of seven body areas.

	Mean Fineness .0001 Inch	Coefficient of Variability Per Cent
Second Fleece	7.113 ± .127	6.97 ± 1.262
Sixth Fleece	5.500 ± .152	10.85 ± 1.980

The difference in fineness is considerably larger than the maximum allowable error showing a decided tendency for the fleece to become finer as the animal increases in age.

A study was also made of the relationship of density of wool to the age of the sheep using the samples from Rambouillet Ewe No. 116.

	Average Density Number of Fibres per half-inch square of skin area	Coefficient of Variability Per Cent
Second Fleece	7545 ± 570	29.61 ± 5.785
Sixth Fleece	5841 ± 553	37.12 ± 7.562

The maximum allowable error is as great as the difference in density so there is no significant difference in density in this ewe between the second and sixth fleeces. In looking over the coefficient of variability figures the interesting fact is observed that as the fleeces become finer they also become more variable.

The Relationship between Crimp and Fineness of Fleece

The data in the following table is taken from the fleece samples of all of the crossbred and purebred sheep included in this experiment.

The Relationship between Crimp and Fineness of Fleece.

Fineness .0001 Inch / Crimps per Inch	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
4								2	2	2	6	4	1	17
6					2	1	6	7	4	6	4	2		32
8			1	3	1	7	10	15	16	13	4	2		72
10			2	8	17	37	27	27	22	8	5	2	1	156
12	1		11	17	37	48	30	31	10	3	5	5	1	199
14		5	13	19	48	51	33	20	8	1				198
16	1	4	11	27	38	31	9	4	1					126
18		12	23	35	11	7	2							90
20	1	12	16	17	5	5	2							58
22	1	4	12	6	1	1								25
24			6	3	2									11
26			2	1	1									4
28			1		2									3
30				1										1
32		1												1
34														0
36		1												1
38				1										1
40		1												1
Total	4	40	99	137	165	188	119	106	63	33	24	15	3	996

<u>Coefficient of Correlation</u> = $-.6563 \pm .012$

There is a very high negative coefficient of correlation (.6563) which indicates a very strong tendency for the fineness of fleece to decrease as the number of crimps increase and vice versa. The elliptical shape of the data on the table gives a fine illustration of the so-called "swarm", typical of a negative correlation. The elliptical "swarm" of a negative correlation lies from the lower left hand corner to the upper right hand corner of a correlation table. Similarly the elliptical "swarm" of a positive correlation lies from the upper left hand corner to the lower right hand corner. When there is no definite correlation the "swarm" becomes circular rather than elliptical in outline and lies in the center of the correlation table.

CONCLUSIONS

Inheritance of Fleece Fineness

The results obtained are shown graphically in Chart One on an adjacent page. These results are in agreement with the published results of Kronacher (1925,1926), Terho (1923), and Pauly (1919) in that there was a blended inheritance in the F_1 Generation. The fine wool type of the Rambouillet predominated in the F_2 Generation.

Inheritance of Fleece Density

The results obtained are shown graphically in Chart Two on an adjacent page. Both crossbred generations were intermediate in fleece density, showing a typical blended inheritance. These results have been confirmed by Froelich, Spoettel, and Taenzer (1929) who quote from an unpublished paper of Burns.

Inheritance of Staple Length.

The results obtained are shown graphically in Chart Three on Page 56. The F_1 Generation were intermediate while the F_2 Generation were shorter in staple than their Rambouillet grandparents.

Inheritance of Fibre Length.

The results obtained are shown graphically in Chart Four on Page 57. Both of the crossbred generations had shorter length of fibre than either of their parental generations.

Inheritance of Crimp.

The results obtained are shown graphically in Chart Five on Page 58. Both of the crossbred generations were intermediate to their purebred parental generations in the number of crimps per inch, showing a definite blended inheritance.

The Effect of Breed of Sire on Fleece Fineness.

The results obtained are shown graphically in Chart Six on Page 59. Davenport and Ritzman (1928) reported in their crossbreeding work with Hampshires and Rambouillets that the Hampshire wool type predominated in the F_1 Generation. The results at Wyoming are contradictory to those obtained by

CHART ONE

INHERITANCE OF FLEECE FINENESS

Hampshire x Rambouillet.

.0001 Inch Units

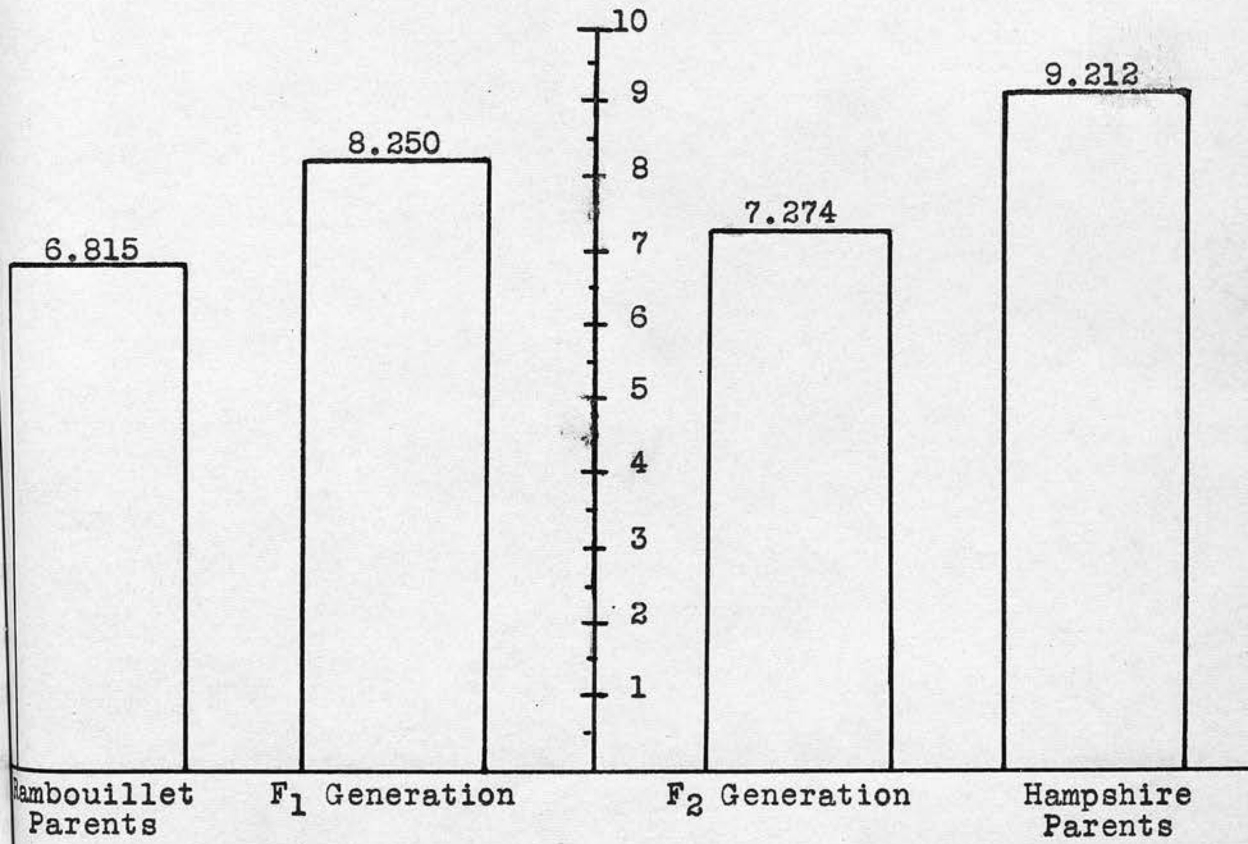


CHART TWO

INHERITANCE OF FLEECE DENSITY

Hampshire x Rambouillet.

Number of Fibres per half inch
square Area of Skin Surface

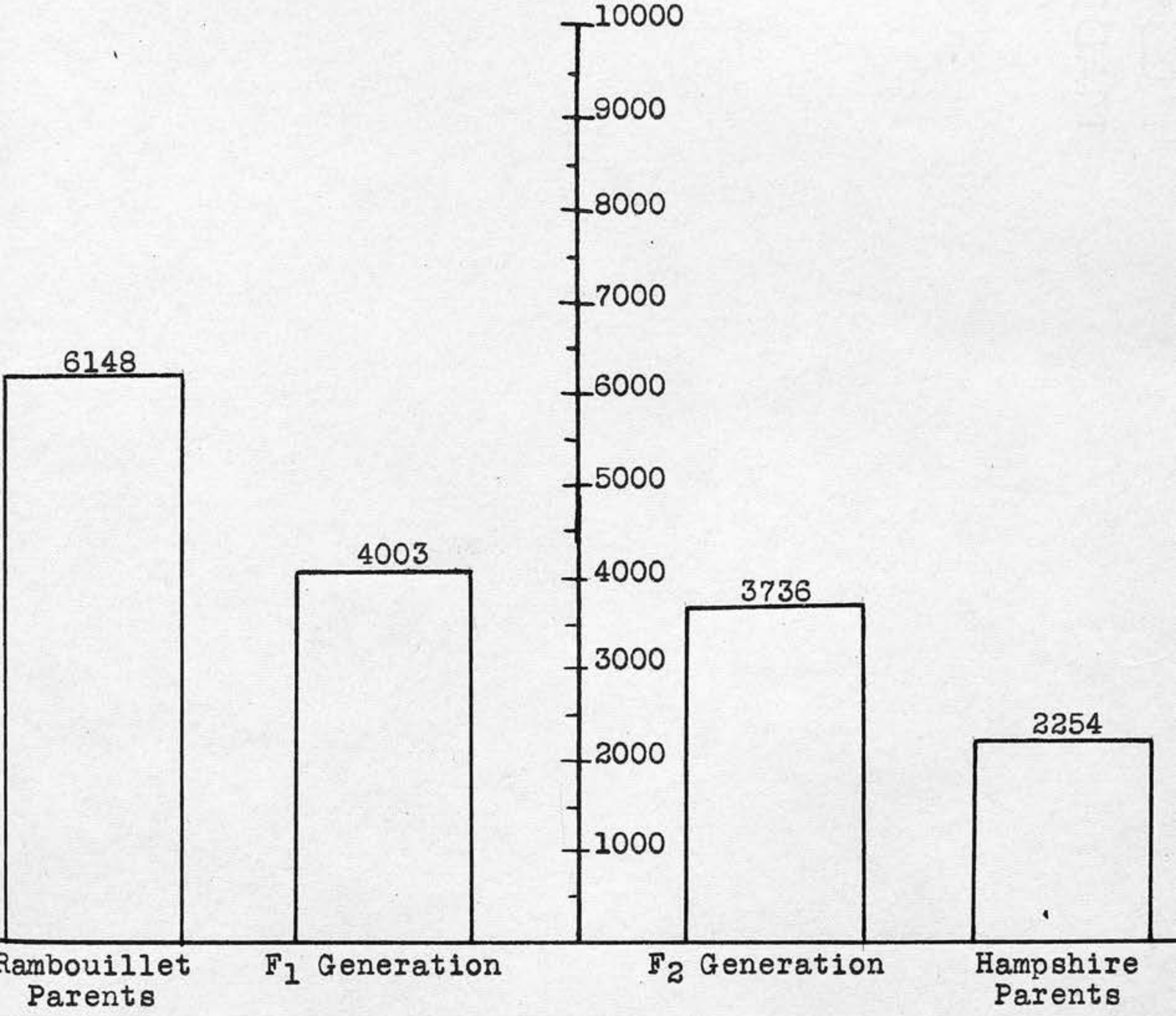


CHART THREE

INHERITANCE OF STAPLE LENGTH

Hampshire x Rambouillet.

Inches

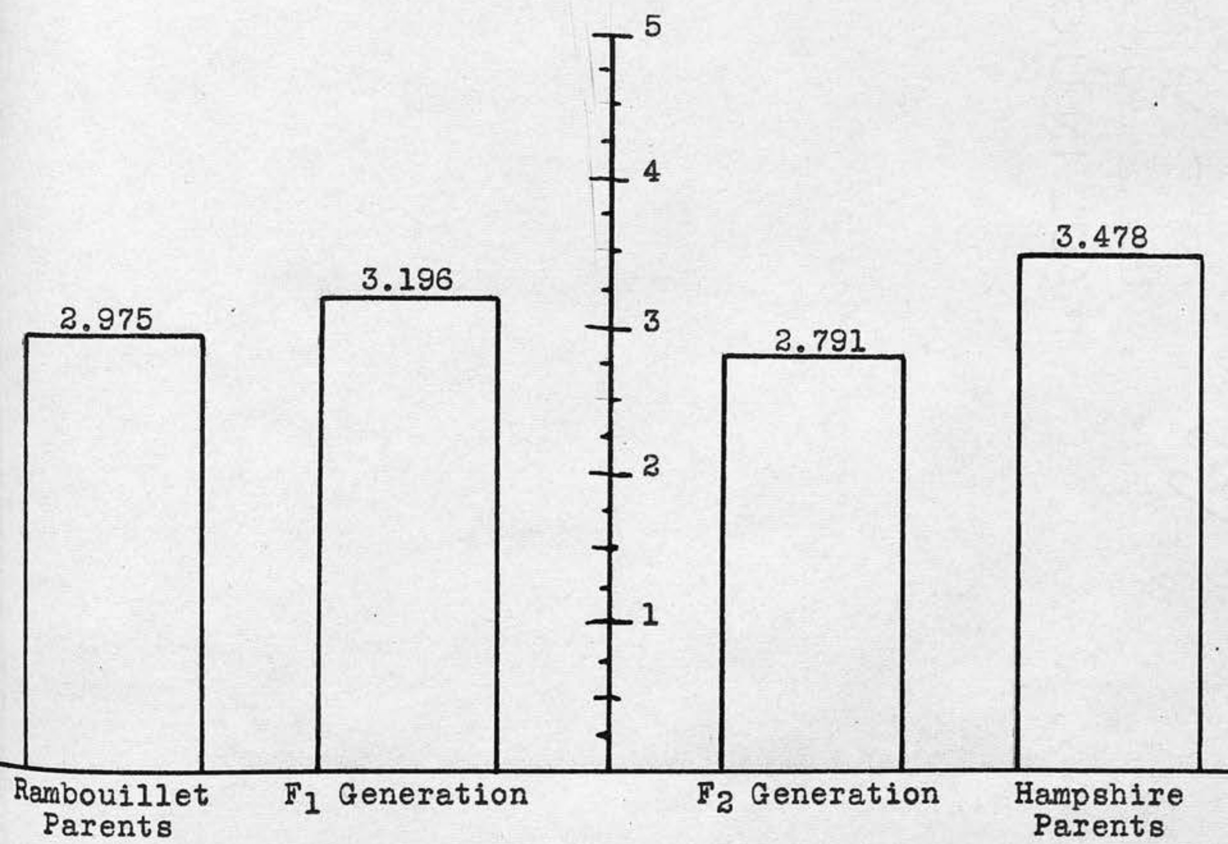


CHART FOUR

INHERITANCE OF FIBRE LENGTH

Hampshire x Rambouillet.

Inches

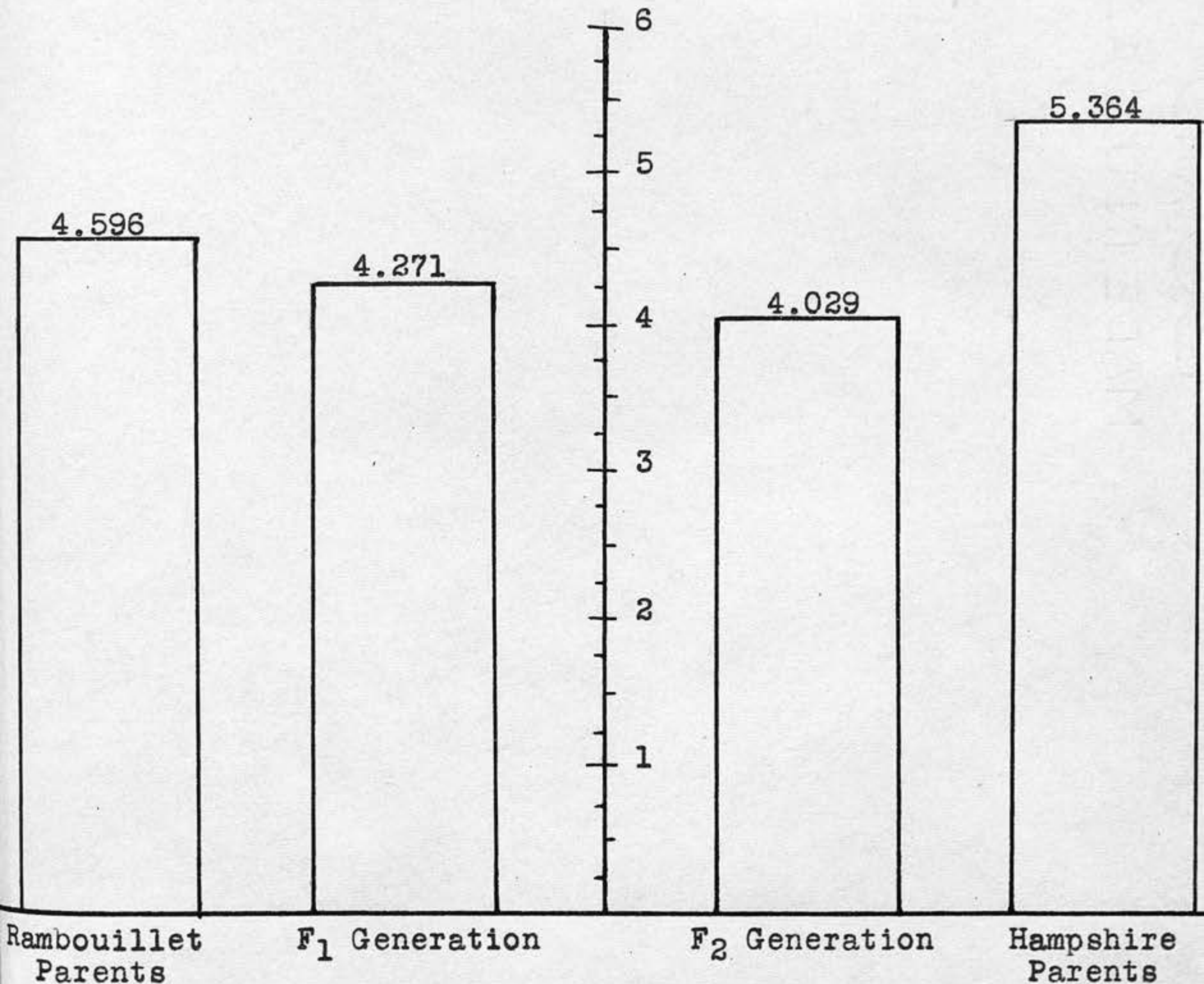


CHART FIVE

INHERITANCE OF CRIMP

Hampshire x Rambouillet.

Number of Crimps per Half Inch

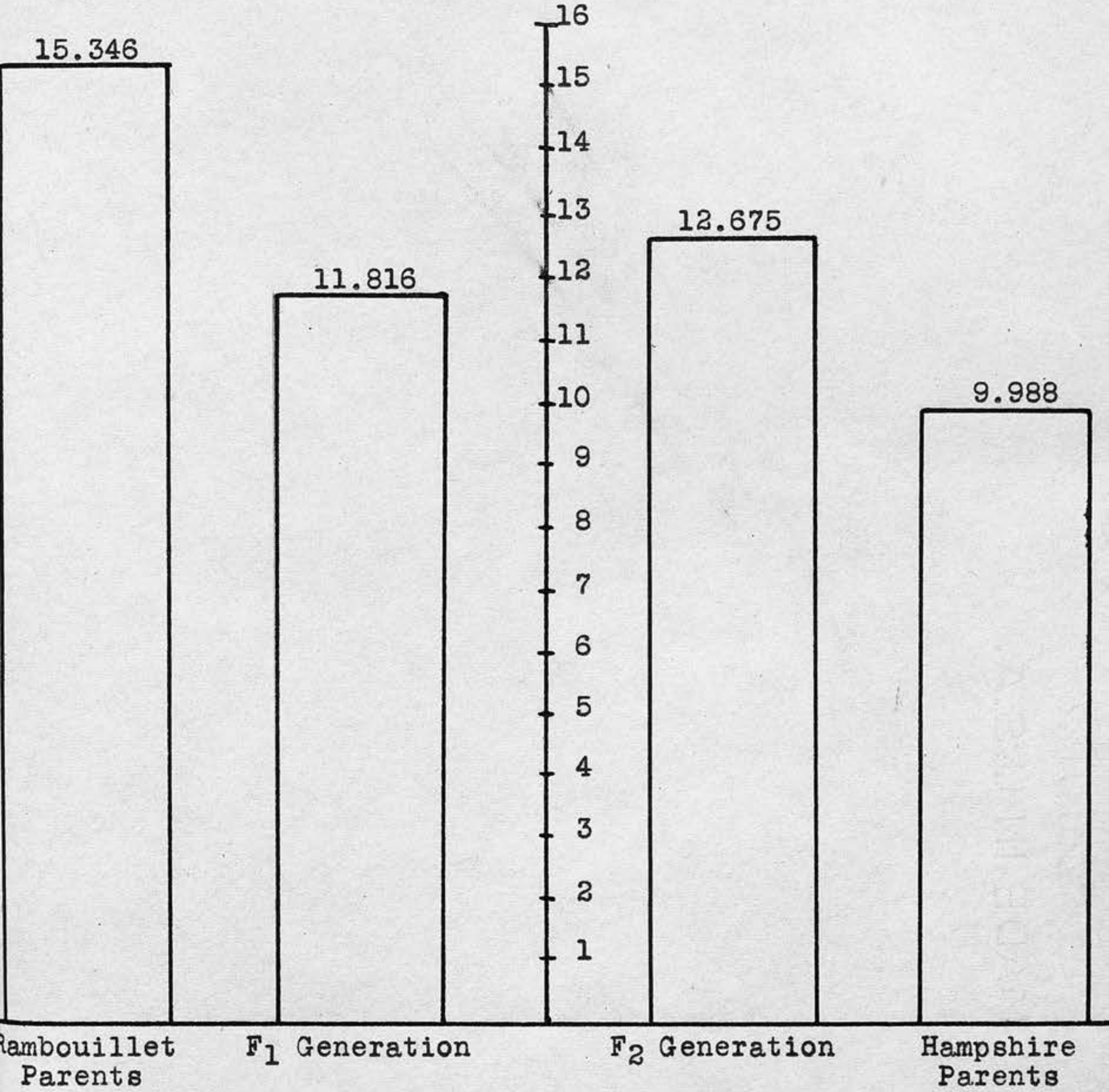


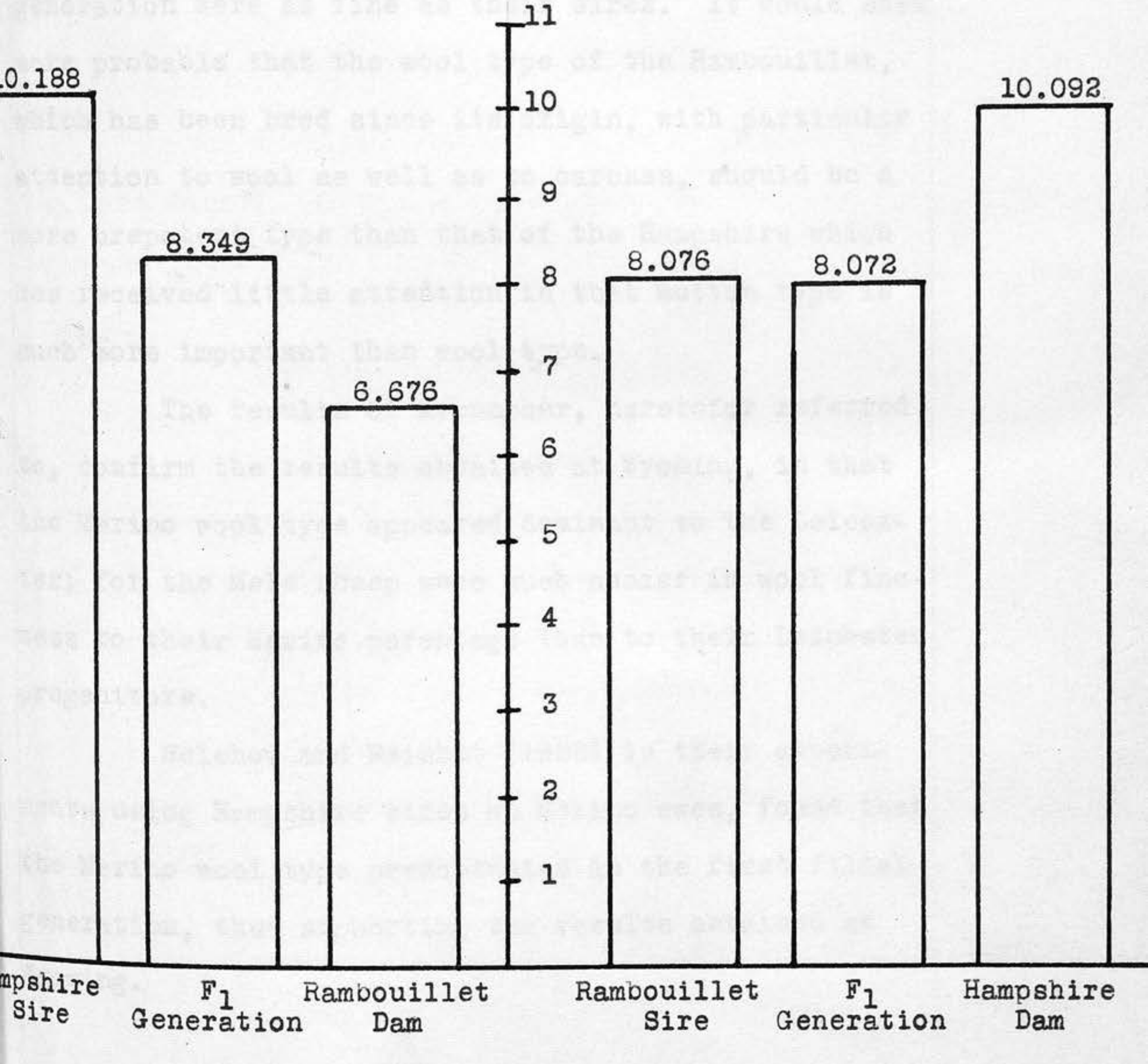
CHART SIX

EFFECT OF BREED OF SIRE ON

FLEECE FINENESS OF F_1 GENERATION

Hampshire x Rambouillet.

.0001 Inch Units



Davenport and Ritzman. However, Davenport and Ritzman used only Hampshire sires while both Hampshire and Rambouillet sires were used at Wyoming. In neither of the crossbred generations was fleece fineness of the first filial generation nearer to the Hampshire parentage than to the Rambouillet parentage, and when Rambouillet sires were used the crossbred generation were as fine as their sires. It would seem more probable that the wool type of the Rambouillet, which has been bred since its origin, with particular attention to wool as well as to carcass, should be a more prepotent type than that of the Hampshire which has received little attention in that mutton type is much more important than wool type.

The results of Kronacher, heretofor referred to, confirm the results obtained at Wyoming, in that the Merino wool type appeared dominant to the Leicester; for the Mele sheep were much nearer in wool fineness to their Merino parentage than to their Leicester progenitors.

Belehov and Reinbot (1928) in their experiments using Hampshire sires on Merino ewes, found that the Merino wool type predominated in the first filial generation, thus supporting the results obtained at Wyoming.

Variation in Fleece Fineness from Year to Year

The results obtained are shown graphically in Chart Seven. The often repeated observation that a sheep's fleece becomes finer as the animal grows older is confirmed by the results of this experiment. The refinement of fleece is particularly striking in the case of the Rambouillet Ewe No. 116.

Variation in Fleece Density from Year to Year.

The results obtained are shown graphically in Chart Eight. As the age increases the density of fleece decreases.

The Relation of Crimp to Fineness.

The high negative correlation confirms the results reported by Hultz (1927) and contradicts the published results of Völtz (1921). Völtz only worked with a few fibres. The writer found little correlation in certain sets of 100 fibres, but the greater majority of fibres showed a definite relationship which was reflected in the rather high correlation coefficient obtained with the entire lot of fibres.

CHART SEVEN

VARIATION IN FLEECE FINENESS FROM YEAR TO YEAR

Hampshire x Rambouillet.

.0001 Inch Units

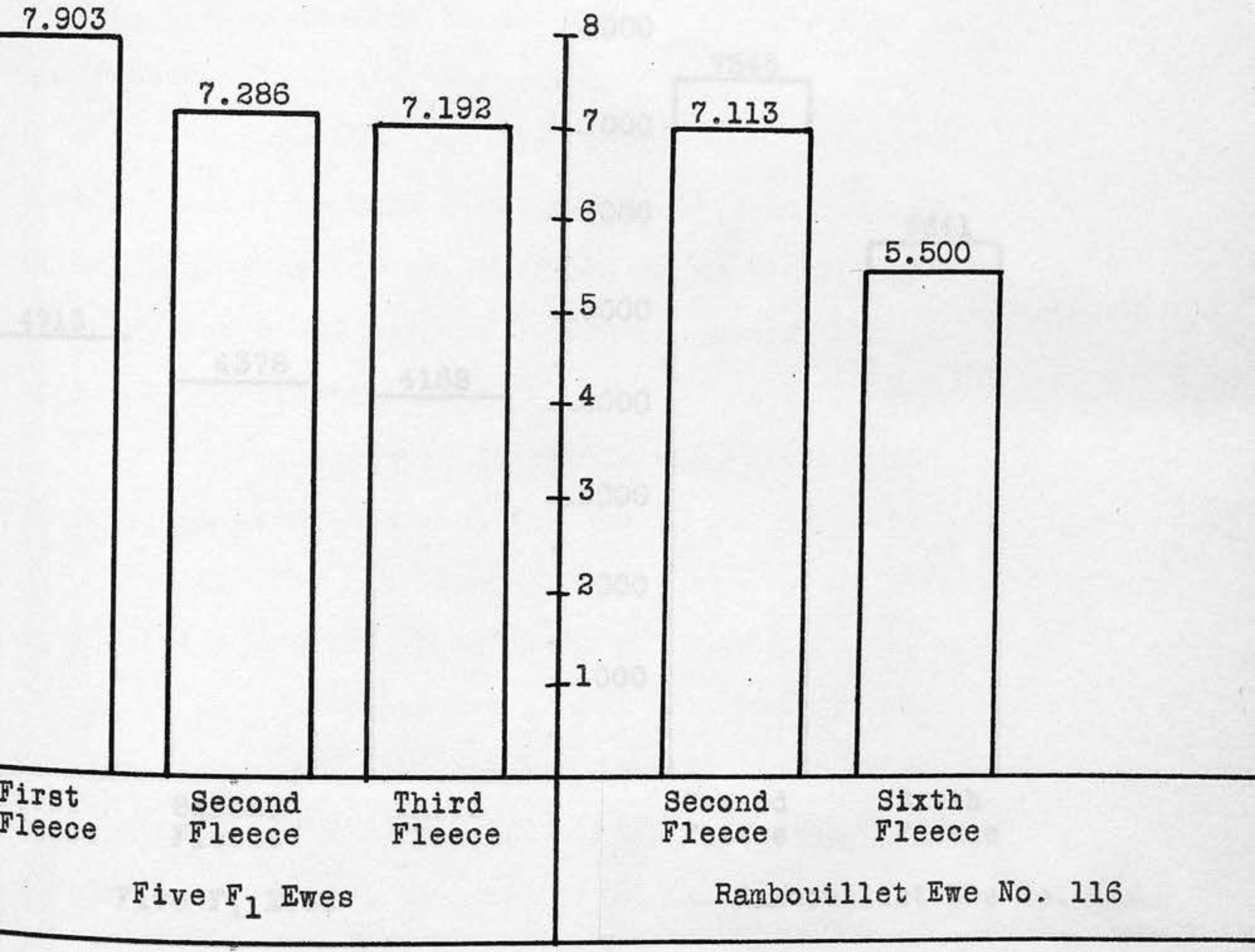
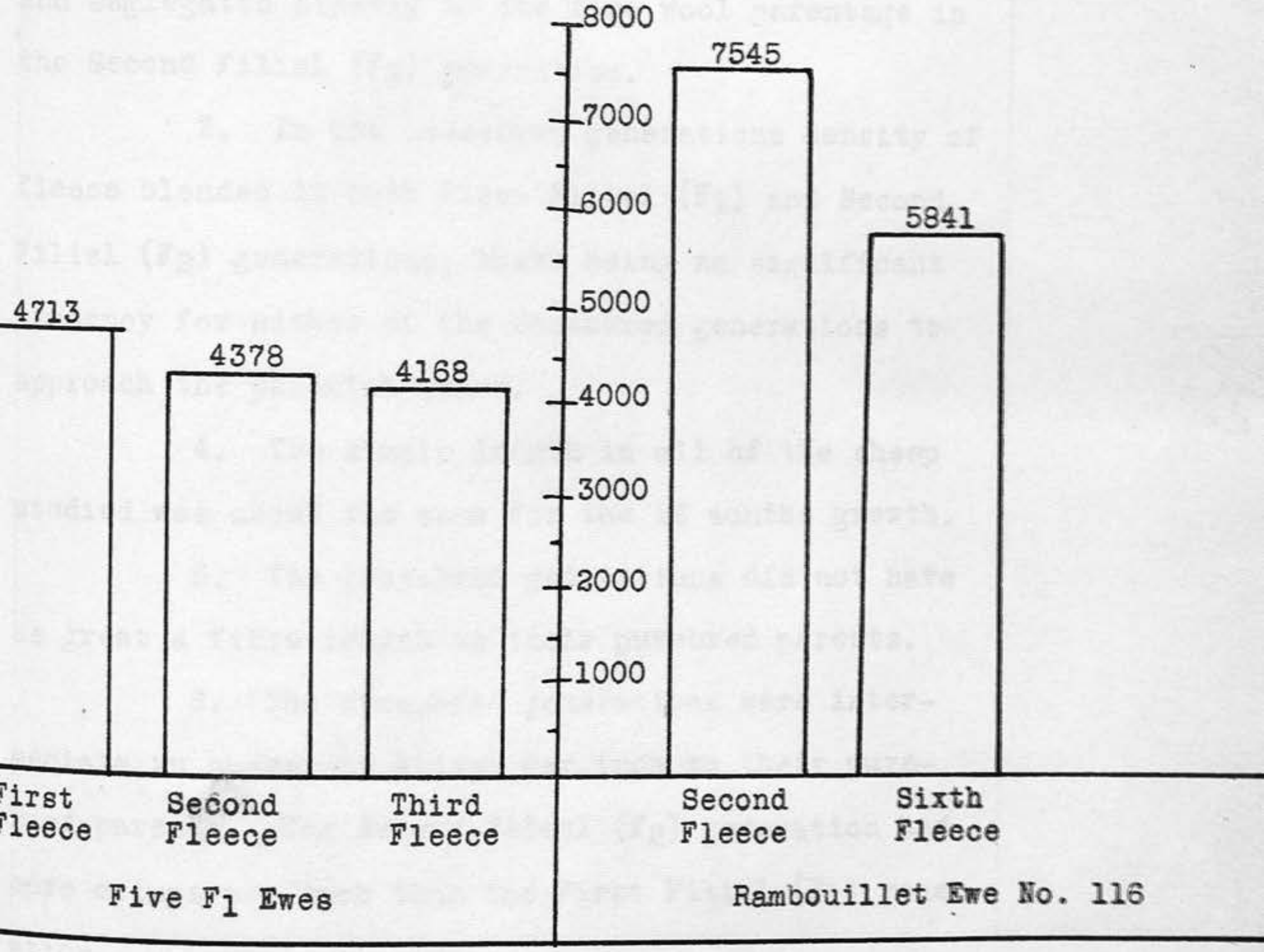


CHART EIGHT

VARIATION IN FLEECE DENSITY FROM YEAR TO YEAR

Hampshire x Rambouillet.

Number of Fibres per half inch square Area of Skin Surface



SUMMARY.

1. The result of the measurement of fineness of fleece indicates that it acts as a multiple factor in fleece inheritance.

2. In the crossbred generations fineness of fleece blended in the First Filial (F_1) generation and segregated cleanly to the fine wool parentage in the Second Filial (F_2) generation.

3. In the crossbred generations density of fleece blended in both First Filial (F_1) and Second Filial (F_2) generations, there being no significant tendency for either of the crossbred generations to approach the parental types.

4. The staple length in all of the sheep studied was about the same for the 12 months growth.

5. The crossbred generations did not have as great a fibre length as their purebred parents.

6. The crossbred generations were intermediate in number of crimps per inch to their purebred parents. The Second Filial (F_2) generation had more crimps per inch than the First Filial (F_1) generation.

7. Rambouillet sires have more influence on the First Filial generation than do Hampshire sires as regards fineness of fleece.

8. A sheep's fleece has a tendency to become finer as the individual increases in age.

9. A sheep's fleece has a tendency to become less dense as the individual increases in age.

10. There was a definite relationship between crimp and fleece fineness in the crossbred generations, as shown by a high negative correlation coefficient.

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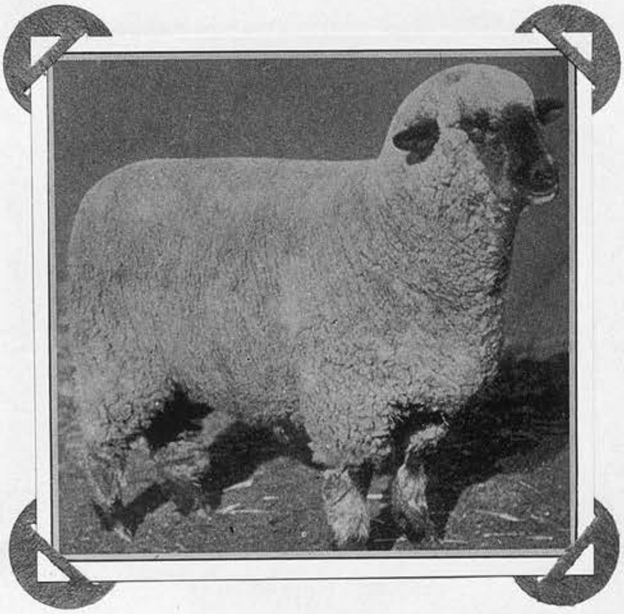
PICTORIAL SUPPLEMENT.

Illustrating

Visual Body and Fleece Characters
of the Parental and Crossbred
Generations of the Hampshire-
Rambouillet Crossbred Sheep used
in the Wool Inheritance Experiment.

Figure No. 6.



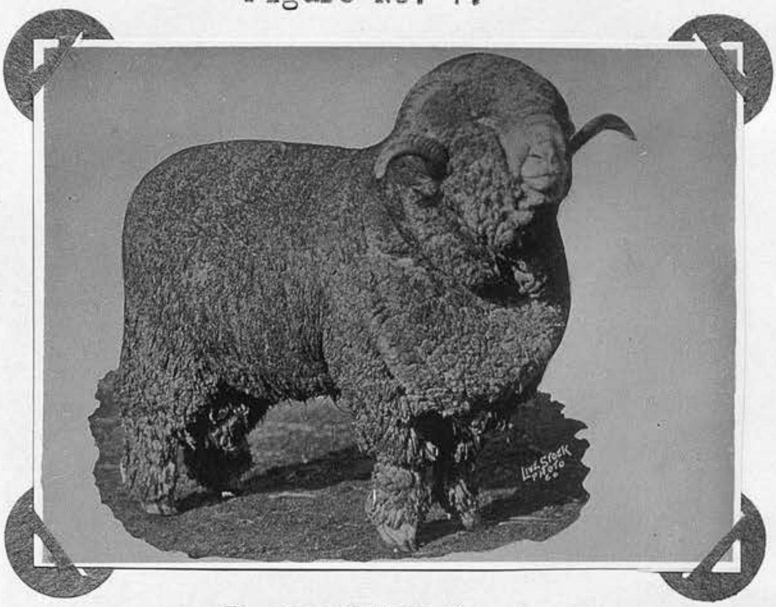
Hampshire Ewe.

Photo by Courtesy of

the

University of Wyoming.

Figure No. 7.



Rambouillet Ram.

Photo by Courtesy of

The

University of Wyoming.

Figure No. 8.

F_1 RAM NO. 268

HAMPSHIRE x RAMBOUILLET

ONE OF THE SIRES OF THE F_2 GENERATION

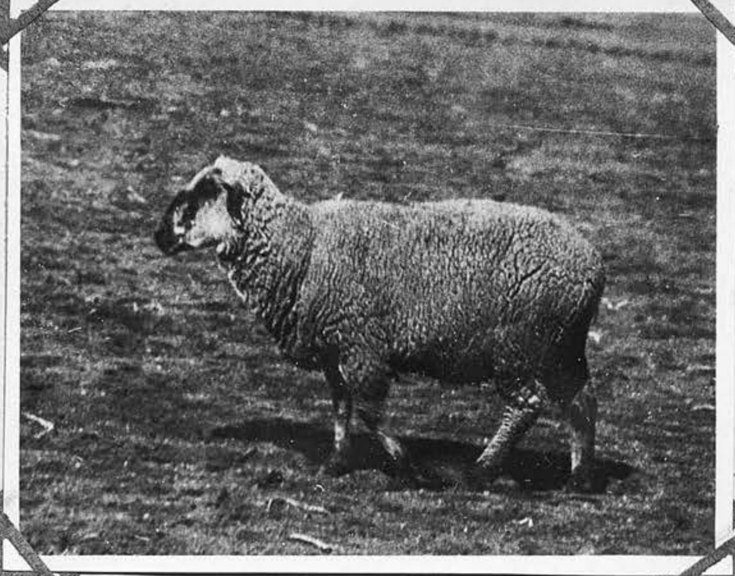
Figure No. 9.

F_1 RAM NO. 274

HAMPSHIRE x RAMBOUILLET

ONE OF THE SIRES OF THE F_2 GENERATION

Figure No. 10.



TWO TYPICAL F_1 EWES

HAMPSHIRE x RAMBOUILLET

Figure No. 11.

Figure No. 12.

LAMBS OF THE F_2 GENERATION

Hampshire x Rambouillet

Note various types of heads from

Typical Rambouillet to Hampshire.

Photo by Courtesy of

United States Department of Agriculture.

Figure No. 13.

LAMBS OF THE F_2 GENERATION

Hampshire x Rambouillet.

The apron-like fold of Rambouillet appears combined with Hampshire head and body characters.

Photo by Courtesy of

United States Department of Agriculture.

Figure No. 14.

THE F_2 GENERATION

Hampshire x Rambouillet.

The largest F_2 lamb compared with a

purebred Hampshire lamb of the same age.
Front View
Photo by Courtesy of

United States Department of Agriculture.

Figure No. 15.

THE F_2 GENERATION

Hampshire x Rambouillet.

The largest F_2 lamb compared with a purebred Hampshire lamb of the same age.

Side View.

Photo by Courtesy of

United States Department of Agriculture.

Figure No. 16.

ONE OF THE F_2 GENERATION LAMBS

Hampshire x Rambouillet.

Showing both Hampshire and Rambouillet characters.

Photo by Courtesy of

United States Department of Agriculture.

Figure No. 17.

THREE LAMBS OF THE F_2 GENERATION

Hampshire x Rambouillet.

Showing Variation in Head and Body Type.

Photo by Courtesy of

United States Department of Agriculture.

Appendix.

TABLE NO. 1.

STUDIES IN THE INHERITANCE OF FINENESS.

Average of seven samples from each animal.

BREED	SEX	Number of Sheep	Average Fineness in .0001 Inch	FINENESS	
				Maximum	Minimum
Rambouillet	Ewes	13	6.619 ±.080	9.57	4.69
Rambouillet	Rams	2	8.076 ±.091	9.03	7.29
All Rambouillets		15	6.815 ±.078	9.57	4.69
Hampshire	Ewes	12	9.112 ±.130	13.08	5.91
Hampshire	Rams	2	10.188 ±.181	11.52	9.45
All Hampshires		14	9.212 ±.121	13.08	5.91
F_1 Generation.	Ewes	10	7.929 ±.076	10.66	6.13
F_1 Generation.	Rams	4	9.053 ±.085	10.56	7.95
All F_1 Generation.		14	8.250 ±.069	10.66	6.13
F_2 Generation.	Ewes	7	7.466 ±.084	9.45	5.69
F_2 Generation.	Rams	4	6.939 ±.121	8.64	5.21
All F_2 Generation.		11	7.274 ±.072	9.45	5.21

Appendix.

TABLE NO. 2.

STUDIES ON THE INHERITANCE OF DENSITY.

Average of seven samples from each animal.

BREED	SEX	Number of Sheep	Average Number of fibres per 1/2 in. sq. of skin.	DENSITY Maximum	DENSITY Minimum
Rambouillet	Ewes	13	6245 ± 166	13984	2643
Rambouillet	Rams	2	5522 ± 340	11059	2376
All Rambouillets		15	6148 ± 153	13984	2376
Hampshire	Ewes	12	2272 ± 66	6146	650
Hampshire	Rams	2	2054 ± 160	2932	1079
All Hampshires		14	2254 ± 63	6146	650
F_1 Generation	Ewes	10	4188 ± 123	8394	1375
F_1 Generation	Rams	4	3543 ± 122	5762	1655
All F_1 Generation		14	4003 ± 97	8394	1375
F_2 Generation	Ewes	7	3725 ± 121	6930	1346
F_2 Generation.	Rams	4	3755 ± 139	5934	1692
All F_2 Generations		11	3736 ± 92	6930	1346

Appendix.

TABLE NO. 3.

STUDIES ON THE INHERITANCE OF STAPLE LENGTH

Breed	Sex	Number of sheep	Av. Staple lgth. 12 mos. growth	STAPLE LENGTH	
				Maximum	Minimum
Rambouillet	Ewes	13	2.989 ±.052	5.0	1.5
Rambouillet	Rams	2	2.886 ±.103	3.5	2.0
All Rambouillets		15	2.975 ±.048	5.0	1.5
Hampshire	Ewes	12	3.576 ±.056	5.5	2.0
Hampshire	Rams	2	2.525 ±.075	3.0	2.0
All Hampshires		14	3.478 ±.056	5.5	2.0
F_1 Generation	Ewes	10	3.200 ±.031	4.0	2.3
F_1 Generation	Rams	4	3.186 ±.058	4.0	2.1
All F_1 Generation		14	3.196 ±.027	4.0	2.1
F_2 Generation	Ewes	7	2.855 ±.033	3.5	2.0
F_2 Generation	Rams	4	2.679 ±.057	3.3	1.7
All F_2 Generation		11	2.791 ±.030	3.5	1.7

Appendix.

TABLE NO. 4.

STUDIES ON THE INHERITANCE OF FIBRE LENGTH

Average of Seven Samples from Each Animal.

BREEDS	SEX	Number of sheep.	Average Fibre lgth. 12 mos. growth	FIBRE LENGTH	
				Maximum	Minimum
Rambouillet	Ewes	11	4.667 ± .089	7.7	2.7
Rambouillet	Rams	2	3.829 ± .174	4.7	2.7
All Rambouillets		13	4.596 ± .084	7.7	2.7
Hampshire	Ewes	12	5.452 ± .103	8.0	3.5
Hampshire	Rams	2	4.563 ± .235	6.3	3.1
All Hampshires		14	5.364 ± .097	8.0	3.1
F_1 Generation	Ewes	10	4.374 ± .069	6.3	2.5
F_1 Generation	Rams	4	3.657 ± .143	4.3	2.5
All F_1 Generation		14	4.271 ± .068	6.3	2.5
F_2 Generation	Ewes	7	4.129 ± .045	5.2	3.0
F_2 Generation	Rams	4	3.854 ± .089	5.0	2.3
All F_2 Generation		11	4.029 ± .045	5.2	2.3

Appendix.

TABLE NO. 5.

STUDIES ON THE INHERITANCE OF CRIMP.

BREED	SEX	Number of sheep	Average numb. of crimps per inch.	CRIMPS PER INCH	
				Maximum	Minimum
Rambouillet	Ewes	13	15.178 ± .267	28	9
Rambouillet	Rams	2	16.429 ± .642	20	12
All Rambouillets		15	15.346 ± .249	28	9
Hampshire	Ewes	12	10.013 ± .207	16	6
Hampshire	Rams	2	9.750 ± .556	14	6
All Hampshires		14	9.988 ± .195	16	6
F_1 Generation	Ewes	10	11.543 ± .220	20	6
F_1 Generation	Rams	4	12.500 ± .512	22	8
All F_1 Generations		14	11.816 ± .217	22	6
F_2 Generation	Ewes	7	12.449 ± .200	16	8
F_2 Generation	Rams	4	13.071 ± .376	18	8
All F_2 Generations		11	12.675 ± .188	18	8

INDEX

APPENDIX TABLE NOS. 6 and 7.

(As Appendix Tables Nos. 6 and 7 are arranged by breeds but not chronologically, the following index will prove useful in referring to the fleece measurements of individual sheep.)

Breed	Ear Tag No.	Sex	Fleece	Page No. Table 6.	Page No. Table 7.
HAMPSHIRE	114	Ewe	1922	81	96
"	163	Ewe	1921	83	
"	164	"	1921	82	
"	170	"	1921	82	
"	35821	Ram	1923	83	
"	36236	"	1922	83	95
"	58094	Ewe	1921	80	
"	68693	"	1921	82	
"	68697	"	1921	81	
"	68699	"	1921	82	
"	68707	"	1921	81	
"	72598	"	1921	82	
"	72600	"	1921	81	
"	72600	"	1922	81	96
"	82548	"	1923	81	
RAMBOUILLET	CSA 5	"	1921	77	
"	CSA 12	"	1921	78	94
"	CSA 12	"	1922	78	94
"	CSA 16	"	1921	80	95
"	116	"	1921	78	
"	116	"	1925	78	95
"	116	"	1926	78	95
"	122	"	1921	77	
"	149	"	1921	79	
"	151	"	1921	77	
"	207	"	1922	79	94
"	210	"	1921	77	
"	5065	"	1921	79	95
"	5065	"	1926	80	95
"	5163	"	1921	77	
"	5380	"	1921	79	
"	5453	"	1921	79	
"	116838	Ram	1921		94
"	116838	"	1922	80	
"	132649	"	1921	80	
FIRST FILIAL GENERATION	263	Ewe	1923	87	
"	263	"	1924	87	101
"	264	"	1923	86	100
"	264	"	1924	87	100
"	265	"	1923	87	100
"	265	"	1924	87	100
"	266	Wether	1923	88	

INDEX

APPENDIX TABLE NOS. 6 and 7

(Continued)

eed	Ear Tag No.	Sex	Fleece	Page No.	
				Table 6.	Table 7.
RST ILIAL GENERATION	267	Ewe	1923	88	
"	267	"	1924	88	99
"	267	"	1925	88	100
"	268	Ram	1923	89	
"	268	"	1925	89	
"	273	Ewe	1923	86	97
"	273	"	1924	86	97
"	273	"	1925	86	97
"	274	Ram	1923	89	96
"	274	"	1925	89	96
"	282	Ewe	1923	83	99
"	282	"	1924	83	99
"	285	"	1923	85	
"	285	"	1924	85	98
"	285	"	1925	85	98
"	286	"	1923	85	
"	286	"	1924	85	99
"	286	"	1925	86	99
"	288	"	1923	84	
"	288	"	1924	84	98
"	288	"	1925	84	98
"	290	"	1923	84	97
"	290	"	1924	84	98
"	292	Wether	1923	88	
COND FILIAL ENERATION	421	Ewe	1925	91	103
"	421	"	1926	91	103
"	422	"	1925	90	102
"	422	"	1926	90	102
"	423	Wether	1925	92	101
"	424	Ewe	1925	90	101
"	424	"	1926	90	102
"	425	Wether	1925	92	104
"	429	Ewe	1925	92	103
"	429	"	1926	92	103
"	433	"	1925	91	103
"	434	Wether			
"	Fleece	Samples	1925	92	104
"	Pelt	Samples	1925	93	104
"	436	Wether	1925	93	104
"	442	Ewe	1925	89	101
"	442	"	1926	90	101
"	443	"	1925	91	102
"	443	"	1926	91	102

Appendix.

TABLE NO. 6.

* Breed and No.	Sex	Year	Sample Location	Staple length in inches.	Fibre length in inches	Crimps per inch.	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
R-151	Ewe	1921	Shoulder	2.3	4.5	21	4726	7.83
			Side	3.1	5.3	16	9094	4.69
			Back	3.3	5.7	14	7484	4.72
			Belly	2.3	5.7	16	2745	5.43
			Hip	3.4	5.7	16	6615	5.64
			Thigh	3.0	5.3	12	1365	8.99
			Dock	2.0	3.3	12	10005	5.10
Average of 7 samples				2.8	5.1	15.3	6005	6.06
R-210	Ewe	1921	Shoulder	3.0	4.5	15	5324	6.88
			Side	2.7	3.7	18	5260	7.40
			Back	2.5	3.3	19	5538	6.46
			Belly	2.1	3.6	21	4605	7.03
			Hip	3.0	4.1	17	9021	6.59
			Thigh	3.0	4.3	10	4137	9.60
			Dock	2.7	4.3	18	8716	7.22
Average of 7 samples				2.7	4.0	16.9	6086	7.31
R-122	Ewe	1921	Shoulder	3.0	4.5	16	8032	6.42
			Side	2.7	4.5	20	6300	6.27
			Back	2.5	4.0	16	6200	8.59
			Belly	3.0	4.5	16	4085	6.93
			Hip	3.3	4.5	28	6159	6.00
			Thigh	2.5	4.0	8	4600	7.71
			Dock	3.0	4.5	12	8610	6.85
Average of 7 samples				2.9	4.4	16.6	6282	6.97
R-5163	Ewe	1921	Shoulder	3.5	6.0	22	12991	6.36
			Side	3.5	4.7	23	10432	6.40
			Back	3.5	5.5	21	6281	6.33
			Belly	3.0	4.7	19	5295	6.26
			Hip	3.5	5.3	18	8591	5.88
			Thigh	2.7	4.3	17	9553	6.37
			Dock	3.3	5.5	18	5476	5.95
Average of 7 samples				3.3	5.1	19.7	8374	6.22
R-CSA 5	Ewe	1921	Shoulder	2.5		14	5792	7.31
			Side	2.7		14	4687	6.58
			Back	2.3		12	7786	6.94
			Belly	2.5		12	5857	7.40
			Hip	2.5		16	6982	6.57
			Thigh	2.5		12	5306	8.19
			Dock	2.3		14	8245	6.99
Average of 7 samples				2.5		13.4	6379	7.14

* R-Rambouillet H-Hampshire F_1-First Crossbred Generation F_2-2nd Crossbred Generation.

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches.	Fibre length in inches	Crimps per inch.	Density (No. fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch
R-CSA12	Ewe	1921	Shoulder	3.1	4.5	20	5876	5.47
			Side	2.7	4.3	20	5664	5.77
			Back	2.5	3.6	14	5979	5.20
			Belly	2.5	4.1	16	2785	5.99
			Hip	2.6	3.7	16	4615	5.54
			Thigh	2.6	3.9	16	5130	6.36
			Dock	2.3	3.1	12	6193	6.23
Average of 7 samples				2.6	3.9	16.3	5177	5.79
R-CSA12	Ewe	1922	Shoulder	3.0	3.9	20	7735	6.60
			Side	2.9	4.7	22	5505	7.70
			Back	2.7	4.3	22	10240	6.27
			Belly	3.0	3.5	16	4353	8.34
			Hip	2.6	3.3	10	6143	6.74
			Thigh	2.5	3.7	18	5391	8.39
			Dock	2.4	2.7	10	17576	6.88
Average of 7 samples				2.7	3.7	16.9	8135	7.27
R-116	Ewe	1921	Shoulder	3.0	4.5	21	7941	6.96
			Side	3.0	4.7	14	6477	7.60
			Back	2.5	4.0	18	6900	6.42
			Belly	2.7	4.7	19	5100	7.03
			Hip	2.5	4.0	13	8145	6.67
			Thigh	2.7	4.3	12	5818	8.00
			Dock	2.5	4.3	12	12435	7.11
Average of 7 samples				2.7	4.4	15.6	7545	7.11
R-116	Ewe	1925	Shoulder	2.4	3.3	18	8426	5.07
			Side	2.2	3.0	16	9275	5.41
			Back	2.0	2.7	14	5603	4.71
			Belly	1.9	4.1	18	3477	6.36
			Hip	2.0	2.9	16	5427	4.90
			Thigh	2.0	2.4	16	3014	6.14
			Dock	1.6	2.9	10	5567	5.91
Average of 7 samples				2.0	3.0	15.4	5827	5.50
R-116	Ewe	1926	Shoulder	2.6	3.5	13	8400	5.75
			Belly	2.2	3.3	13	6874	6.79
			Thigh	2.2	3.4	12	5820	6.41
Average of 3 samples				2.3	3.4	12.7	7031	6.32

Appendix.

TABLE NO. 6.

reed nd No.	Sex	Year	Sample Location	Staple length in inches.	Fibre length in inches.	Crimps per inch.	Density (No. Fibres per ½ in. sq. of skin.	Mean Fineness in ten thousandths of an inch
-207	Ewe	1922	Shoulder	2.5	4.3	18	13984	5.12
			Side	2.4	3.5	20	6487	5.34
			Back	2.5	3.7	20	10225	5.14
			Belly	2.4	5.3	16	4494	6.52
			Hip	2.5	3.5	18	4890	5.47
			Thigh	2.6	4.7	14	7209	6.59
			Dock	2.3	3.0	14	11708	6.34
Average of 7 samples				2.5	4.0	16.0	8428	5.79
-5453	Ewe	1921	Shoulder	4.5		14	7543	7.40
			Side	4.0		14	7756	6.35
			Back	4.0		12	4866	6.12
			Belly	3.3		12	3086	9.08
			Hip	4.0		12	4131	7.11
			Thigh	3.7		12	5222	6.86
			Dock	3.5		12	7303	6.59
Average of 7 samples				3.9		12.6	5701	7.07
R-5380	Ewe	1921	Shoulder	4.5	7.7	14	4401	9.07
			Side	3.7	6.5	9	6434	8.90
			Back	4.5	6.5	14	4832	7.28
			Belly	3.3	7.3	11	6588	7.98
			Hip	4.0	8.0	12	5194	9.20
			Thigh	4.5	6.7	10	3950	9.57
			Dock	4.0	7.0	10	6570	9.07
Average of 7 samples				4.1	7.1	11.4	5424	8.72
R-149	Ewe	1921	Shoulder					
			Side	2.7	5.0	19	6550	6.63
			Back	2.5	4.0	17	7438	5.80
			Belly	2.7	4.0	19	10259	5.46
			Hip	2.5	4.0	19	6300	6.43
			Thigh	2.5	4.5	17	5556	6.67
			Dock	2.5	3.5	18	5698	6.57
Average of 6 samples				2.6	4.2	18.2	6967	6.26
R-5065	Ewe	1921	Shoulder	5.0	7.0	14	4407	5.88
			Side	4.8	6.5	10	3412	6.04
			Back	4.0	5.5	9	4481	6.22
			Belly	3.5	4.8	10	3804	6.34
			Hip	4.5	5.8	9	3153	6.86
			Thigh	4.5	5.5	11	4487	5.46
			Dock	4.0	5.3	12	4766	6.79
Average of 7 samples				4.3	5.8	10.7	4073	6.23

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches.	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch
R-5065	Ewe	1926	Shoulder	2.6	3.6	14	9914	6.22
			Belly	2.0	3.4	15	5028	7.15
			Thigh	2.7	5.2	11	5367	6.60
Average of 3 samples				2.4	4.4	13.3	6769	6.66
R-OSA16	Ewe	1921	Shoulder	1.5	4.3	18	5797	5.53
			Side	2.4	3.6	16	2643	5.52
			Back	2.3	3.7	16	3996	5.87
			Belly	1.7	2.7	16	3009	5.96
			Hip	2.4	3.6	16	6529	5.98
			Thigh	2.2	3.2	14	5166	5.54
			Dock	2.3	3.0	10	7274	5.79
Average of 7 samples				2.1	3.4	15.1	4916	5.74
R-132649	Ram	1921	Shoulder	3.5		16	8339	7.70
			Side	3.5		16	5954	8.38
			Back	3.3		16	3883	7.29
			Belly	3.5		18	4376	8.66
			Hip	3.5		16	5328	8.18
			Thigh	3.5		12	2376	9.03
			Dock	3.3		12	5991	8.64
Average of 7 samples				3.4		15.1	5178	8.27
R-116838	Ram	1922	Shoulder	2.5	3.3	20	7107	7.98
			Side	2.3	4.7	12	5186	7.39
			Back	2.0	2.7	18	11059	7.72
			Belly	2.3	3.5	26	4718	8.51
			Hip	2.3	3.6	16	3869	7.50
			Thigh	2.5	4.3	14	4707	8.07
			Dock	2.4	4.7	18	4416	8.01
Average of 7 samples				2.3	3.8	19.1	5866	7.88
H-58094	Ewe	1921	Shoulder	3.0	4.0	8	2223	8.94
			Side	3.0	4.0	8	2637	9.53
			Back	3.3	4.0	8	2969	8.54
			Belly	3.0	4.0	8	839	9.94
			Hip	2.7	3.7	10	2447	10.48
			Thigh	2.7	3.5	10	1816	10.77
			Dock	3.5	4.5	8	2017	13.08
Average of 7 samples				3.0	4.0	8.6	2135	10.18

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch
H-72600	Ewe	1921	Shoulder	3.5	5.0	10	3325	8.02
			Side	3.0	4.0	8	2385	8.16
			Back	3.0	4.5	12	3619	8.14
			Belly	2.7	4.3	8	2821	8.14
			Hip	3.0	4.0	8	2110	8.77
			Thigh	3.5	5.0	8	2643	9.84
			Dock	3.0	4.0	10	1245	7.98
Average of 7 samples				3.1	4.4	9.1	2593	8.44
H-72600	Ewe	1922	Shoulder	3.0	4.3	14	3900	7.97
			Side	2.5	4.5	10	1581	8.36
			Back	3.0	4.3	10	4306	8.40
			Belly	2.6	5.3	6	1787	9.93
			Hip	2.7	4.3	14	2857	8.09
			Thigh	2.9	4.7	10	1299	9.30
			Dock	2.7	3.5	8	3744	9.21
Average of 7 samples				2.8	4.4	10.3	2782	8.75
H-82548	Ewe	1923	Shoulder	3.2	4.8	8		10.10
H-68697	Ewe	1921	Shoulder	4.0	5.0	10	2792	12.07
			Side	4.5	6.0	9	1705	11.59
			Back	5.0	7.4	8	1417	11.43
			Belly	2.0	5.5	6	771	11.63
			Hip	4.3	6.5	7	900	11.34
			Thigh	4.3	6.3	7	1357	13.47
			Dock	5.5	6.7	7	1960	12.89
Average of 7 samples				4.2	6.2	7.7	1557	12.06
H-68707	Ewe	1921	Shoulder	4.0	6.0	10	6146	7.11
			Side	3.5	5.5	10	1715	8.23
			Back	3.5	6.0	12	2512	7.68
			Belly	2.7	5.3	14	1164	6.70
			Hip	3.0	5.0	10	2169	8.63
			Thigh	3.0	5.0	6	3026	8.10
			Dock	2.7	5.5	7	2364	9.78
Average of 7 samples				3.2	5.5	9.9	2728	8.03
H-114	Ewe	1922	Shoulder	3.3	4.9	16	3069	6.23
			Side	2.8	4.5	12	1088	7.21
			Back	3.3	4.7	14	2748	6.68
			Belly	2.8	4.1	12	1260	7.83
			Hip	3.1	4.3	14	1891	7.37
			Thigh	2.5	4.1	14	1409	7.99
			Dock	3.0	4.1	10	1830	8.73
Average of 7 samples				3.0	4.4	13.1	1899	7.43

Appendix.

TABLE NO. 6.

eed d No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
.72598	Ewe	1921	Shoulder	3.5		13	3555	8.06
			Side	3.1		12	2075	7.95
			Back	3.3	5.0	13	3600	7.76
			Belly	2.5	4.5	16	1116	8.69
			Hip	3.3		12	3350	8.57
			Thigh	3.0		10	3000	9.58
			Dock	2.9		10	3327	9.81
Average of 7 samples				3.1	4.8	12.3	2860	8.63
-68699	Ewe	1921	Shoulder	4.0	5.5	8	2950	8.22
			Side	3.5	6.0	8	2300	8.46
			Back	4.5	6.0	10	2810	8.97
			Belly	3.3	5.0	10	1507	11.30
			Hip	4.0	6.0	8	1885	9.58
			Thigh	4.0	5.0	6	1502	9.62
			Dock	3.0	4.0	6	1500	11.39
Average of 7 samples				3.8	5.4	8.0	2065	9.65
-164	Ewe	1921	Shoulder	2.7	3.5	12	3035	7.86
			Side	3.0	4.0	14	1188	7.65
			Back	3.5	6.3	16	2834	8.95
			Belly	2.3	4.0	18	2593	5.91
			Hip	3.3	6.0	10	2048	7.41
			Thigh	3.7	6.7	8	1647	10.36
			Dock	4.0	5.7	10	2447	9.95
Average of 7 samples				3.2	5.2	12.6	2256	8.30
-68693	Ewe	1921	Shoulder	4.5	6.0	12	3381	9.04
			Side	4.7	6.0	12	1445	9.27
			Back	4.5	7.0	14	2278	8.69
			Belly	4.0	5.5	14	650	11.02
			Hip	4.6	6.0	12	2640	10.58
			Thigh	4.0	5.0	8	2488	12.18
			Dock	4.0	6.0	12	2296	11.30
Average of 7 samples				4.3	5.9	12.0	2168	10.30
I-170	Ewe	1921	Shoulder	4.5	6.0	8	3082	6.96
			Side	4.5	6.3	12	3081	7.05
			Back	4.5	6.0	8	3629	8.20
			Belly	3.5	4.7	8	1940	9.19
			Hip	4.3	6.3	8	2125	8.22
			Thigh	4.5	8.3	6	2512	9.30
			Dock	4.3	6.0	8	1962	8.58
Average of 7 samples				4.3	6.2	8.3	2619	8.21

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
H-163	Ewe	1921	Shoulder	3.7	5	12	2955	6.68
			Side	3.7	6	8	2078	6.37
			Back	4.5	8	8	2473	8.53
			Belly	3.5	6	10	2231	10.13
			Hip	4.0	8	8	1634	7.75
			Thigh	5.5	11	8	1672	11.21
			Dock	4.3	7	8	1761	11.32
Average of 7 samples				4.2	7.3	8.9	2115	8.86
H-35821	Ram	*1923	Shoulder No. 1	3.1	4.2	10		9.72
			Shoulder No. 2	3.4	4.6	10		10.00
			Shoulder No. 3	2.4	4.2	10		9.73
Average of 3 samples				3.0	4.3	10.0		9.82
H-36236	Ram	1922	Shoulder	2.1	3.1	10	2932	9.45
			Side	2.6	4.0	14	1591	9.59
			Back	2.9	3.7	8	2760	9.66
			Belly	2.0	5.3	10	2310	10.68
			Hip	2.6	6.3	12	1549	9.60
			Thigh	2.5	5.5	8	1079	11.18
			Dock	2.5	4.3	6	2156	11.52
Average of 7 samples				2.5	4.6	9.7	2054	10.24
F_1-282	Ewe	1923	Shoulder	3.0	3.7	14	5602	6.54
			Side	2.9	3.7	14	4019	6.76
			Back	3.0	4.3	12	4178	6.25
			Belly	2.3	2.5	10	1598	7.13
			Hip	2.7	3.8	12	3761	6.76
			Thigh	2.7	3.4	12	3003	7.47
			Dock	2.8	3.5	10	5749	6.54
Average of 7 samples				2.8	3.6	12.0	3987	6.78
F_1-282	Ewe	1924	Shoulder	2.6	3.8	12	5489	6.65
			Side	2.7	3.7	12	4500	6.76
			Back	2.5	4.2	10	4984	6.77
			Belly	2.4	2.8	14	3134	7.61
			Hip	2.6	3.7	14	3002	7.11
			Thigh	2.0	2.9	10	4222	7.33
			Dock	2.5	3.3	10	5129	6.55
Average of 7 samples				2.5	3.5	11.7	4351	6.97

* No regular samples available so writer measured ~~up~~ some samples which were taken for determining shrinkage.

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches.	Fibre length in inches	Crimps per inch.	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_1-290	Ewe	1923	Shoulder	3.9	4.5	14	4278	6.41
			Side	3.4	4.5	14	4690	6.13
			Back	3.4	4.4	16	3591	6.17
			Belly	3.5	5.1	14	2368	6.64
			Hip	3.7	6.3	14	2917	7.26
			Thigh	3.5	4.5	14	3955	6.99
			Dock	3.5	4.5	14	4088	7.34
Average of 7 samples				3.6	4.8	14.3	3698	6.71
F_1-290	Ewe	1924	Shoulder	2.9	4.5	18	4737	7.70
			Side	2.7	4.5	18	5082	7.69
			Back	3.1	4.3	22	4701	7.44
			Belly	2.7	4.4	12	1585	8.53
			Hip	3.0	4.5	12	3898	8.71
			Thigh	2.6	4.3	18	2656	8.71
			Dock	3.1	5.5	6	4130	9.50
Average for 7 samples				2.9	4.6	15.1	3827	8.33
F_1-288	Ewe	1923	Shoulder	2.7		9	5120	7.74
			Side	3.0		10	3970	7.12
			Back	3.0		9	6064	7.12
			Belly	2.7		10	1666	9.26
			Hip	3.0		9	4603	8.05
			Thigh	3.0		10	4584	8.84
			Dock	2.5		9	4155	7.54
Average for 7 samples				2.8		9.4	4309	8.0
F_1-288	Ewe	1924	Shoulder	2.5	4.1	16	4986	7.03
			Side	2.4	4.0	16	3195	6.84
			Back	2.3	3.5	20	3700	6.40
			Belly	2.3	3.5	12	1782	8.51
			Hip	2.5	4.0	20	4818	6.89
			Thigh	2.3	3.7	12	7013	7.13
			Dock	2.3	3.1	12	4145	7.57
Average for 7 samples				2.4	3.7	15.4	4232	7.20
F_1-288	Ewe	1925	Shoulder	2.2	2.7	16	5972	5.85
			Side	2.1	3.0	14	5785	6.24
			Back	2.1	2.6	12	3634	6.16
			Belly	2.0	3.0	14	2903	7.74
			Hip	2.0	2.7	14	3878	6.64
			Thigh	2.0	3.0	12	3135	6.69
			Dock	2.4	2.7	8	2969	7.38
Average for 7 samples				2.1	2.8	12.9	4039	6.67

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_1-285	Ewe	1923	Shoulder	3.7		12	5815	7.40
			Side	3.5		12	3478	7.45
			Back	3.5		9	4606	7.44
			Belly	2.5		10	1375	8.10
			Hip	3.7		12	3392	7.87
			Thigh	3.5		10	3131	8.03
			Dock	3.5		7	6782	7.82
Average of 7 samples				3.4		10.3	4083	7.73
F_1-285	Ewe	1924	Shoulder	3.0	4.0	16	5370	5.87
			Side	2.6	4.6	14	4506	5.90
			Back	2.7	5.3	14	7332	6.57
			Belly	2.4	4.5	12	2378	8.34
			Hip	3.1	5.9	16	3592	5.78
			Thigh	2.7	4.7	10	4565	6.38
			Dock	2.7	5.3	6	3889	7.46
Average of 7 samples				2.7	4.9	12.6	4519	6.61
F_1-285	Ewe	1925	Shoulder	2.8	3.3	14	8177	5.85
			Side	2.5	3.5	16	3629	6.07
			Back	2.5	3.7	14	3084	5.66
			Belly	2.0	3.7	16	1886	7.16
			Hip	2.4	3.4	12	3200	6.54
			Thigh	2.8	4.9	8	3185	7.69
			Dock	2.4	3.8	4	3487	7.82
Average of 7 samples				2.5	3.8	12	3807	6.68
F_1-286	Ewe	1923	Shoulder	3.3		10	7944	7.68
			Side	3.0		12	4174	8.46
			Back	3.3		12	6255	7.69
			Belly	2.7		16	4676	8.65
			Hip	2.7		10	5791	8.15
			Thigh	3.0		8	5821	9.55
			Dock	2.7		8	6948	7.95
Average of 7 samples				3.0		10.9	5944	8.30
F_1-286	Ewe	1924	Shoulder	2.5	3.9	16	5064	6.64
			Side	2.4	4.5	16	5229	6.35
			Back	2.7	4.6	18	5478	6.51
			Belly	2.5	4.1	16	1925	8.40
			Hip	2.7	4.3	18	4886	7.51
			Thigh	2.6	4.0	14	3046	8.49
			Dock	1.9	3.6	8	6529	8.44
Average for 7 samples				2.5	4.1	15.1	4594	7.48

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_1-286	Ewe	1925	Shoulder	2.7	3.1	16	6767	6.25
			Side	2.4	3.1	16	5281	7.22
			Back	2.4	3.2	14	5160	6.29
			Belly	2.3	3.3	10	2933	7.98
			Hip	2.3	3.0	14	4450	6.82
			Thigh	2.2	3.1	14	5761	7.18
			Dock	2.0	2.8	12	5192	7.80
Average for 7 samples				2.3	3.1	13.7	5078	7.08
F_1-273	Ewe	1923	Shoulder	3.3	4.5	18	6583	6.75
			Side	3.3	4.0	20	4763	7.45
			Back	2.7	3.3	18	4080	7.07
			Belly	2.5	3.3	12	3926	8.40
			Hip	3.0	4.0	16	3602	7.68
			Thigh	3.3	4.0	10	2786	7.72
			Dock	2.9	4.3	10	3503	8.39
Average for 7 samples				3.0	3.9	14.9	4178	7.64
F_1-273	Ewe	1924	Shoulder	2.7	4.0	14	4624	7.85
			Side	2.4	3.6	18	4117	7.43
			Back	2.5	4.1	18	4092	7.30
			Belly	1.9	3.0	18	2654	8.36
			Hip	2.5	3.3	14	4686	6.89
			Thigh	2.6	3.9	14	4558	8.70
			Dock	2.5	3.6	12	4150	8.52
Average for 7 samples				2.4	3.6	15.4	4126	7.86
F_1-273	Ewe	1925	Shoulder	2.7	3.5	16	4652	6.63
			Side	2.4	3.1	16	3514	7.54
			Back	2.2	3.0	12	2514	7.39
			Belly	1.9	2.6	14	3614	8.38
			Hip	2.1	3.0	12	2464	7.42
			Thigh	2.5	3.9	12	2898	8.96
			Dock	1.9	2.7	8	2015	9.95
Average for 7 samples				2.2	3.1	12.9	3096	8.04
F_1-264	Ewe	1923	Shoulder	2.2	4.1	8	3662	9.00
			Side	3.0	4.4	10	2346	8.96
			Back	3.0	5.3	8	2249	10.41
			Belly	2.9	4.4	12	2176	8.68
			Hip	3.2	5.3	10	2733	10.66
			Thigh	3.0	4.0	10	2224	8.40
			Dock	3.3	4.6	6	4910	8.91
Average for 7 samples				3.1	4.6	9.1	2900	9.29

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_1-264	Ewe	1924	Shoulder	3.0	4.5	10	6175	7.86
			Side	2.8	3.9	10	4241	8.75
			Back	2.6	4.3	10	2400	8.56
			Belly	2.3	3.6	12	2129	9.36
			Hip	2.5	4.9	10	2664	8.31
			Thigh	2.5	3.7	10	2995	8.57
			Dock	2.7	3.8	10	3043	8.61
Average of 7 samples				2.6	4.1	10.3	3378	8.57
F_1-265	Ewe	1923	Shoulder					
			Side	3.6	4.8	14	3748	8.90
			Back	3.5	4.7	12	3085	8.11
			Belly	2.9	4.5	16	2505	8.92
			Hip	3.7	5.1	12	3788	9.01
			Thigh	3.6	4.9	12	3668	9.05
			Dock	3.2	4.7	14	3057	8.84
Average of 6 samples				3.4	4.8	13.3	3309	8.81
F_1-265	Ewe	1924	Shoulder	3.3	4.4	14	4096	8.32
			Side	3.4	4.7	14	3944	8.34
			Back	3.0	4.8	12	3765	7.87
			Belly	3.0	5.0	12	2421	8.75
			Hip	3.1	4.6	12	3965	8.42
			Thigh	3.0	4.9	10	3536	9.31
			Dock	2.7	3.5	14	2781	8.27
Average of 7 samples				3.1	4.6	12.6	3358	8.47
F_1-263	Ewe	1923	Shoulder	3.5	4.5	11	8394	7.69
			Side	4.0	4.7	14	3164	8.16
			Back	3.5	4.5	10	6368	7.93
			Belly	3.5	5.0	12	1667	8.26
			Hip	3.5	4.5	12	5243	8.19
			Thigh	4.0	5.5	9	2411	9.91
			Dock	3.5	4.0	11	2880	7.74
Average for 7 samples				3.6	4.7	11.3	4304	8.27
F_1-263	Ewe	1924	Shoulder	2.7	3.7	16	4150	7.47
			Side	2.3	3.3	16	3220	7.19
			Back	2.7	3.9	16	5539	7.12
			Belly	1.9	3.7	14	2643	8.36
			Hip	2.6	4.2	12	5072	7.14
			Thigh	2.5	3.4	14	2877	9.91
			Dock	2.2	3.3	12	6665	7.13
Average for 7 samples				2.4	3.6	14.3	4309	7.76

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_1-267	Ewe	1923	Shoulder	3.5		10	5672	7.68
			Side	3.3		10	5324	8.06
			Back	3.3		11	4450	7.86
			Belly	3.0		12	2584	8.45
			Hip	3.3		8	6023	7.36
			Thigh	3.5		8	5744	8.12
			Dock	3.3		10	5570	7.69
Average for 7 samples				3.3		9.9	5052	7.89
F_1-267	Ewe	1924	Shoulder	3.0	4.1	14	7706	7.32
			Side	2.9	5.2	8-	3242	7.53
			Back	2.8	4.5	14	3615	5.84
			Belly	2.4	3.4	14	2577	7.21
			Hip	2.7	4.0	10	4131	6.34
			Thigh	2.8	3.7	10	2873	8.62
			Dock	2.5	3.8	8	6800	8.09
Average for 7 samples				2.7	4.1	11.1	4421	7.28
F_1-292	Wether	1923	Shoulder	3.7		12	3725	9.14
			Side	3.7		10	4139	9.51
			Back	3.7		12	4721	9.51
			Belly	2.7		8	1846	10.21
			Hip	3.5		8	5762	9.16
			Thigh	3.5		8	1930	10.04
			Dock	3.7		10	4887	9.35
Average for 7 samples				3.5		9.7	3859	9.56
F_1-267	Ewe	1925	Shoulder	3.1	4.3	14	7419	7.02
			Side	2.7	4.4	12	5246	6.58
			Back	3.0	4.4	10	5725	6.98
			Belly	2.5	4.1	14	3516	8.08
			Hip	2.6	3.9	14	4502	7.19
			Thigh	2.9	4.3	10	3139	8.68
			Dock	2.4	3.9	8	4187	7.88
Average for 7 samples				2.7	4.2	11.7	4819	7.49
F_1-266	Wether	1923	Shoulder	3.0		10	3611	8.75
			Side	3.0		9	2976	9.80
			Back	3.0		10	4116	8.77
			Belly	2.7		8	1655	10.12
			Hip	3.0		9	2970	9.12
			Thigh	3.0		8	3397	9.77
			Dock	3.0		8	3944	8.49
Average for 7 samples				3.0		8.9	3238	9.26

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch.	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_1-268	Ram	1923	Shoulder	3.7		16	3052	8.34
			Side	3.7		14	3440	8.49
			Back	4.0		16	3891	8.15
			Belly	3.3		16	3664	8.59
			Hip	3.5		16	4365	8.19
			Thigh	3.3		12	2015	8.67
			Dock	3.5		14	4432	8.91
Average of 7 samples				3.6		14.9	3551	8.48
F_1-268	Ram	1925	Shoulder	2.8	3.6	12	2650	7.84
			Side	3.5	4.9	14	2124	7.91
			Back	2.5	4.7	14	3103	7.10
			Belly	3.0	4.9	12	1430	8.77
			Hip	2.5	4.7	14	3033	7.81
			Thigh	3.0	4.6	6	1455	8.79
			Dock	3.1	4.6	4	3159	9.97
Average of 7 samples				2.8	4.6	10.9	2422	8.31
F_1-274	Ram	1923	Shoulder	2.7	3.5	18	3799	7.95
			Side	2.7	4.3	12	2417	8.56
			Back	2.7	3.6	18	3512	8.32
			Belly	2.1	2.5	20	3135	8.94
			Hip	3.3	3.7	16	4172	8.90
			Thigh	2.9	4.3	22	3207	10.56
			Dock	2.6	3.7	10	4420	9.16
Average of 7 samples				2.7	3.7	16.6	3523	8.91
F_1-274	Ram	1925	Shoulder	2.5	3.9	14	3564	7.37
			Side	2.3	3.7	14	3338	7.17
			Back	2.2	3.8	8	2870	7.03
			Belly	2.2	3.4	14	2597	8.33
			Hip	2.4	3.7	10	2080	7.65
			Thigh	2.4	4.1	12	3419	7.63
			Dock	2.6	4.1	8	3946	7.63
Average of 7 samples				2.4	3.8	11.4	3116	7.46
F_2-442	Ewe	1925	Shoulder	3.2	5.1	16	5337	6.74
			Side	2.5	4.3	16	2108	6.54
			Back	3.5	4.5	16	3350	6.91
			Belly	2.6	3.0	16	3352	6.74
			Hip	3.4	4.0	16	6508	5.69
			Thigh	2.5	4.1	14	2487	6.42
			Dock	3.0	3.7	12	4161	7.14
Average of 7 samples				3.0	4.1	15.1	3900	6.60

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_2-442	Ewe	1926	Shoulder	3.0	4.7	14	5820	5.04
			Side	2.8	4.6	18	3256	5.08
			Back	2.9	5.3	12	3945	5.76
			Belly	2.5	4.8	14	6292	6.05
			Hip	2.9	4.7	16	4993	5.45
			Thigh	2.6	5.1	12	3035	6.07
			Dock	2.8	4.3	4	3418	6.47
Average of 7 samples				2.8	4.8	12.9	4387	5.70
F_2-424	Ewe	1925	Shoulder	3.1	3.8	10	6038	7.51
			Side	2.8	4.2	12	4655	7.73
			Back	3.3	5.2	12	3764	7.28
			Belly	2.8	3.7	10	4912	7.91
			Hip	3.1	4.1	8	5646	7.63
			Thigh	2.7	3.5	8	4489	8.27
			Dock	3.0	4.0	10	4673	7.64
Average for 7 samples				3.0	4.1	10.0	4882	7.71
F_2-424	Ewe	1926	Shoulder	2.9	4.3	14	4791	5.78
			Side	2.6	4.1	12	4650	6.36
			Back	2.4	4.3	12	4351	6.08
			Belly	2.4	4.4	12	4048	6.16
			Hip	2.5	3.9	12	3599	6.15
			Thigh	2.4	4.5	12	4388	6.66
			Dock	2.1	2.7	10	3624	6.16
Average for 7 samples				2.5	4.0	12.0	4207	6.19
F_2-422	Ewe	1925	Shoulder	2.7	3.7	14	3251	7.30
			Side	2.4	4.4	12	4358	6.87
			Back	2.6	4.9	14	2903	7.48
			Belly	2.0	4.2	14	3134	5.84
			Hip	2.8	3.9	14	2895	7.34
			Thigh	2.6	4.4	10	2543	8.57
			Dock	2.3	3.6	12	3188	6.84
Average for 7 samples				2.5	4.2	12.9	3182	7.18
F_2-422	Ewe	1926	Shoulder	2.6	4.3	14	5256	6.13
			Side	2.4	4.0	14	3618	6.78
			Back	2.5	4.8	10	3310	6.10
			Belly	2.0	4.6	10	3196	6.99
			Hip	2.5	4.0	10	4802	6.62
			Thigh	2.4	4.8	12	4433	6.94
			Dock	2.4	4.1	6	2040	7.86
Average for 7 samples				2.4	4.4	10.9	3808	6.77

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_2-443	Ewe	1925	Shoulder	3.2	4.0	12	2854	7.34
			Side	3.1	4.3	12	3611	8.31
			Back	3.0	3.7	10	5106	6.52
			Belly	2.8	4.2	14	3673	7.84
			Hip	3.0	4.5	12	4160	7.52
			Thigh	3.0	4.4	12	3579	9.45
			Dock	2.9	3.8	12	2320	8.55
Average for 7 samples				3.0	4.1	12.0	3615	7.93
F_2-443	Ewe	1926	Shoulder	3.2	4.9	14	4742	5.86
			Side	2.9	4.5	12	3519	6.50
			Back	2.6	4.1	10	3410	6.46
			Belly	2.5	3.8	14	2639	6.92
			Hip	2.8	4.3	10	3074	7.21
			Thigh	3.1	4.4	8	3143	8.72
			Dock	2.3	3.7	6	3430	7.32
Average for 7 samples				2.8	4.2	10.6	3430	7.00
F_2-433	Ewe	1925	Shoulder	3.0	4.1	14	5208	7.64
			Side	2.7	4.0	12	2304	8.82
			Back	2.9	4.6	12	3865	8.56
			Belly	2.2	3.0	10	4419	9.05
			Hip	2.7	3.6	12	1844	9.05
			Thigh	2.5	3.7	12	1695	7.30
			Dock	2.7	3.3	10	1346	7.18
Average for 7 samples				2.7	3.8	11.7	2954	8.23
F_2-421	Ewe	1925	Shoulder	3.0	4.5	14	6930	6.62
			Side	2.6	4.1	16	3771	5.87
			Back	2.8	5.0	14	2454	6.47
			Belly	2.5	4.3	14	3400	6.86
			Hip	3.0	4.8	14	3841	6.52
			Thigh	2.6	4.6	14	3116	7.42
			Dock	3.1	4.1	10	4128	8.55
Average for 7 samples				2.8	4.5	13.7	3963	6.90
F_2-421	Ewe	1926	Shoulder	2.9	4.9	16	4359	6.09
			Side	2.3	3.9	14	6394	6.46
			Back	2.3	4.3	14	4015	6.02
			Belly	2.0	4.7	14	2196	7.00
			Hip	2.6	4.3	12	6957	5.91
			Thigh	2.5	4.3	12	4155	6.79
			Dock	2.7	3.9	6	5834	7.94
Average for 7 samples				2.5	4.3	12.6	4844	6.60

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per $\frac{1}{2}$ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_2-429	Ewe	1925	Shoulder	3.3	3.9	14	3377	7.30
			Side	3.2	4.3	12	4434	7.21
			Back	3.4	4.4	12	3474	7.44
			Belly	2.7	3.9	12	2252	7.69
			Hip	3.1	4.4	12	3291	7.84
			Thigh	3.0	4.4	10	2316	9.14
			Dock	3.0	4.1	10	5999	7.37
Average for 7 samples				3.1	4.2	11.7	3592	7.71
F_2-429	Ewe	1926	Shoulder	3.0	4.5	10	6655	6.77
			Side	2.5	4.1	12	4270	5.92
			Back	2.5	4.6	12	3961	6.76
			Belly	2.4	3.9	14	2961	6.72
			Hip	2.6	4.1	10	3658	7.19
			Thigh	2.9	4.6	10	3855	7.44
			Dock	2.5	3.8	6	5287	7.06
Average for 7 samples				2.6	4.2	10.6	4382	6.83
F_2-423	Wether	1925	Shoulder	3.3	5.0	14	4688	7.64
			Side	2.6	3.5	12	3354	7.80
			Back	3.0	4.8	14	1692	8.19
			Belly	1.9	4.1	16	2389	6.77
			Hip	2.7	4.7	14	3616	7.74
			Thigh	3.1	4.2	14	3133	8.04
			Dock	2.0	2.5	16	3706	7.44
Average for 7 samples				2.7	4.1	14.3	3225	7.66
F_2-425	Wether	1925	Shoulder	3.0	3.9	10	4992	6.40
			Side	2.8	3.7	10	2409	7.74
			Back	2.8	3.8	12	4760	7.49
			Belly	1.7	2.7	16	2443	6.41
			Hip	3.0	4.0	12	2818	7.88
			Thigh	3.0	3.9	10	2627	7.50
			Dock	2.0	2.3	8	3384	7.96
Average of 7 samples				2.6	3.5	11.1	3348	7.34
F_2-434 Fleece Samples	Wether	1925	Shoulder	3.2	4.8	14	5646	5.60
			Side	2.7	4.0	10	4708	6.87
			Back	2.5	4.0	10	2639	6.32
			Belly	2.3	3.9	14	4788	7.68
			Hip	2.9	4.3	12	4191	6.89
			Thigh	2.9	4.5	10	3296	8.64
			Dock	2.0	2.4	8	5338	5.47
Average of 7 samples				2.6	4.0	11.1	4372	6.78

Appendix.

TABLE NO. 6.

Breed and No.	Sex	Year	Sample Location	Staple length in inches	Fibre length in inches	Crimps per inch	Density (No. Fibres per ½ in. sq. of skin	Mean Fineness in ten thousandths of an inch.
F_2-434 Pelt Samples	Wether	1925	Shoulder	3.3	4.6	12	4375	6.37
			Side	3.2	4.5	12	3174	6.81
			Back	2.8	4.5	12	6664	7.63
			Belly	3.2	4.6	12	3115	7.51
			Hip	3.0	4.3	12	3044	8.10
			Thigh	3.0	4.3	12	2430	7.27
			Dock	2.0	2.6	6	4629	7.14
Average of 7 samples				2.9	4.2	11.1	3919	7.26
F_2-436	Wether	1925	Shoulder	3.0	3.9	18	5934	5.41
			Side	2.8	4.1	16	2739	5.75
			Back	3.3	4.3	18	3274	5.21
			Belly	2.0	3.4	18	4932	5.77
			Hip	2.9	4.2	14	4264	6.71
			Thigh	2.8	3.9	16	3962	6.22
			Dock	2.8	3.1	10	3426	6.75
Average of 7 samples				2.8	3.9	15.7	4076	5.97

Appendix.

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

*Frequency distribution of Fineness Classes in each breed by individuals and body location.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	Mean Fineness
R-Ram	Shoulder			2	10	24	37	11	14	0	1	1		7.98
16838	Side			2	30	32	16	7	10	2	1			7.39
1921	Back				11	42	23	13	10	1				7.72
	Belly				5	15	35	19	22	3	1			8.51
	Hip			6	21	33	20	9	4	3	3	1		7.50
	Thigh			6	17	23	19	12	9	6	6	2		8.07
	Dock				14	32	20	18	9	5	1	0	1	8.01
All 7	samples			16	108	201	170	89	78	20	13	4	1	7.88
R-Ewe	Shoulder			15	36	25	22	2						6.60
CSA12	Side			1	12	29	39	13	5	1				7.70
1922	Back		3	29	31	22	8	6	0	0	1			6.27
	Belly				3	13	41	33	10					8.34
	Hip			6	38	38	14	2	2					6.74
	Thigh				5	23	32	17	15	7	1			8.39
	Dock			12	37	23	11	11	4	0	0	1		6.88
All 7	samples		3	64	162	173	167	84	36	8	2	1		7.27
R-Ewe	Shoulder			47	26	12	3							5.47
CSA12	Side		12	49	28	9	6	3	1					5.77
1921	Back		4	49	11	10	2	1	1					5.20
	Belly		26	23	49	26								5.99
	Hip		2	49	27	10	4	1						5.54
	Thigh		9	29	33	18	14	5	1					6.36
	Dock		1	25	41	21	9	2	0	1				6.23
All 7	samples		54	271	215	106	38	12	3	1				5.76
R-Ewe	Shoulder	2	23	46	22	5	1	1						5.12
207	Side	1	11	56	20	10	1	1						5.34
1922	Back	1	25	46	19	6	2	1						5.14
	Belly		1	19	36	24	13	5	2					6.52
	Hip		16	45	22	11	5	1						5.47
	Thigh		1	23	34	21	8	7	4	2				6.59
	Dock		5	29	27	19	10	7	2	1				6.34
All 7	samples	4	82	264	180	96	40	23	8	3				5.79

* Frequency Distributions are not available on a number of individuals whose sample measurements were completed prior to the writer taking over the experiment.

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean Fineness
R-Ewe	Shoulder	6	26	40	16	7	5											5.07
116	Side		14	47	26	10	3											5.41
1925	Back	14	41	22	9	11	3											4.71
	Belly			13	49	27	11											6.36
	Hip	13	31	32	8	10	5	1										4.90
	Thigh	1	14	23	28	16	11	3	2	0	1	1						6.14
	Dock	1	24	35	11	7	9	3	8	1	1							5.91
All 7	Samples	35	150	212	147	88	47	7	10	1	2	1						5.50
R-Ewe	Shoulder	3	12	35	25	14	5	5	1									5.75
116	Belly			5	28	51	15	1										6.79
1926	Thigh			21	41	20	14	2	2									6.41
All 3	Samples	3	12	61	94	85	34	8	3									6.32
R-Ewe	Shoulder	8	25	32	21	10	4											5.12
5065	Side	12	26	32	15	8	6	1										5.03
1921	Back	2	20	32	27	11	7	1										5.50
	Belly		6	40	44	4	2	3	0	0	1	1						5.61
	Hip		5	25	33	12	11	10	2	1	1							6.48
	Thigh		7	26	30	19	13	3	1	1								6.23
	Dock		4	25	24	18	14	8	6	1								6.66
All 7	samples	22	93	212	194	82	57	26	9	3	2							5.82
R-Ewe	Shoulder		3	29	28	26	11	3										6.22
5065	Belly			3	23	40	26	6	2									7.15
1926	Thigh	2	10	25	17	15	16	6	3	3	2	1						6.60
All 3	samples	2	13	57	68	81	53	15	5	3	2	1						6.66
R-Ewe	Shoulder	3	16	40	19	15	4	1	2									5.53
CSA16	Side	1	20	38	20	13	4	4										5.52
1921	Back	3	22	18	25	15	11	3	3									5.87
	Belly		11	30	24	25	8	1	1									5.96
	Hip		13	39	17	8	16	5	2									5.98
	Thigh	1	22	35	19	13	7	3										5.54
	Dock	6	23	26	12	16	6	4	6	1								5.79
All 7	samples	14	127	226	136	105	56	21	14	1								5.73
H-Ram	Shoulder			1	7	7	14	17	28	13	10	1	2					9.45
36263	Side			1	10	12	14	13	19	10	4	10	2	5				9.59
1922	Back				3	11	12	22	22	13	8	6	2	0	1			9.66
	Belly					3	9	12	20	20	25	7	4					10.68
	Hip			2	5	12	15	16	16	14	9	7	1	3				9.60
	Thigh					4	11	13	16	14	11	12	9	5	4	0	1	11.18
	Dock						8	6	21	18	13	19	7	5	1	2		11.52
All 7	samples			4	25	49	83	99	142	102	80	62	27	18	6	2	1	10.25

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean Fineness
H-Ewe	Shoulder				11	24	33	23	7	2						7.97
72600	Side			2	14	14	26	15	21	5	3					8.36
1922	Back			3	6	20	29	19	11	8	4					8.40
	Belly				2	4	18	17	18	22	13	6				9.93
	Hip			2	13	19	23	27	15	1						8.09
	Thigh			4	8	7	17	15	17	15	14	3				9.30
	Dock				1	12	21	20	30	12	1	3				9.21
All 7	samples			11	55	100	167	136	119	65	35	12				8.75
H-Ewe	Shoulder		7	26	31	20	8	6	1	1						6.23
114	Side		5	5	19	26	27	16	2							7.21
1922	Back		4	13	28	29	19	6	1							6.68
	Belly		1	3	15	24	24	20	9	4						7.83
	Hip			3	21	37	23	10	3	3						7.37
	Thigh		2	10	12	25	17	8	12	6	6	1	0	1		7.99
	Dock				4	20	24	24	15	9	2	0	2			8.73
All 7	samples		19	60	130	181	142	90	43	23	8	1	2	1		7.43
F_1 Ram	Shoulder			5	12	23	26	17	13	3	0	1				7.95
274	Side				8	24	27	12	14	9	2	3	1			8.56
1923	Back			4	18	19	18	13	11	10	2	4	1			8.32
	Belly				2	11	24	28	27	5	3					8.94
	Hip			2	12	16	16	14	19	9	6	4	1	1		8.90
	Thigh				1	4	13	15	24	11	15	7	4	5	1	10.56
	Dock			4	15	10	22	5	11	10	12	5	4	2		9.16
All 7	samples			15	68	107	146	104	119	57	40	24	11	8	1	8.90
F_1 Ram	Shoulder	1	0	8	18	29	22	15	6	0	1					7.37
274	Side			13	23	25	21	10	7	1						7.17
1925	Back		1	17	28	19	15	12	5	1	2					7.03
	Belly			1	7	17	29	25	21							8.33
	Hip			8	16	29	19	11	12	5						7.65
	Thigh		2	19	15	17	12	11	13	7	3	1				7.63
	Dock			14	13	27	22	9	3	7	4	0	1			7.63
All 7	samples	1	3	80	120	163	140	93	67	21	10	1	1			7.54

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean Fineness
F_1 Ewe 273 1923	Shoulder	25	27	23	12	3	7	2	1							6.75
	Side	10	23	29	13	9	11	2	2	1						7.45
	Back	22	32	16	8	6	8	2	5	1						7.07
	Belly	5	8	11	32	15	20	9								8.40
	Hip	9	23	28	14	5	11	4	2	2	2					7.68
	Thigh	7	26	27	13	7	5	7	7	0	1					7.72
	Dock	7	17	23	16	9	9	5	4	2	2	3	0	1	1	8.39
All 7	samples	86	156	157	108	54	71	31	21	6	5	3	0	1	1	7.64
F_1 Ewe 273 1924	Shoulder	7	17	24	24	9	9	6	1	3						7.85
	Side	9	23	25	20	9	10	4								7.43
	Back	16	33	18	8	8	8	3	3	1	2					7.30
	Belly	1	9	29	22	13	13	6	6	1						8.36
	Hip	22	26	26	9	8	3	5	1							6.89
	Thigh	1	16	28	10	16	10	5	6	5	4	1				8.70
	Dock	3	14	24	21	11	8	3	6	7	3					8.52
All 7	samples	59	138	172	114	74	61	32	23	17	9	1				7.86
F_1 Ewe 273 1925	Shoulder	7	20	25	23	9	9	6	1							6.63
	Side	3	19	11	17	18	13	10	7	2						7.54
	Back	1	28	18	17	8	9	4	4	8	1	1	0	1		7.39
	Belly		4	8	15	25	25	14	8	1						8.38
	Hip	1	14	21	20	14	17	7	5	1						7.42
	Thigh		5	10	12	18	14	20	6	8	4	2	1			8.96
	Dock		6	15	10	8	12	9	6	8	6	5	7	8		9.95
All 7	samples	12	96	108	114	100	99	70	37	28	11	8	8	9		8.04
F_1 Ewe 290 1923	Shoulder	10	26	19	18	17	5	5								6.41
	Side	15	25	25	16	10	6	1	2							6.13
	Back	12	29	19	19	13	7	1								6.17
	Belly	2	24	20	21	28	5									6.64
	Hip		13	25	13	28	14	7								7.26
	Thigh		27	14	20	22	8	7	2							6.99
	Dock	1	22	20	14	15	10	9	7	1	1					7.34
All 7	samples	40	166	142	121	133	55	30	11	1	1					6.71

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	15	Mean Fineness
F_1 Ewe 290 1924	Shoulder			2	23	22	29	7	14	3					7.70
	Side			3	24	18	28	14	9	4					7.69
	Back			3	24	34	13	18	7	1					7.44
	Belly				6	19	28	20	18	8	1				8.53
	Hip				6	21	25	15	13	17	3				8.71
	Thigh			1	6	24	20	12	20	12	3	2			8.71
	Dock				2	14	26	15	12	12	8	5	6		9.50
All 7 samples				9	91	152	169	101	93	57	15	7	6		8.33
F_1 Ewe 288 1924	Shoulder		2	16	23	25	15	8	11						7.03
	Side			21	25	24	16	8	5	1					6.84
	Back		8	34	15	18	9	10	6						6.40
	Belly				2	20	33	20	21	3	1				8.51
	Hip		1	21	24	23	15	8	6	1	1				6.89
	Thigh			18	25	15	21	13	5	3					7.13
	Dock			4	20	29	24	10	11	2					7.57
All 7 samples			11	114	134	154	133	77	65	10	2				7.20
F_1 Ewe 288 1925	Shoulder		3	14	31	20	17	10	4	1					5.85
	Side			6	32	17	26	16	2	1					6.24
	Back			11	30	26	10	13	8	2					6.16
	Belly				3	14	25	30	20	8					7.74
	Hip			1	28	25	17	15	9	5					6.64
	Thigh		1	8	22	16	22	15	10	3	2	1			6.69
	Dock			1	8	22	27	19	11	10	2				7.38
All 7 samples			4	41	154	140	144	118	64	30	4	1			6.67
F_1 Ewe 285 1924	Shoulder			6	43	20	22	7	2						5.87
	Side			5	40	29	15	9	1	1					5.90
	Back			6	24	25	17	15	8	3	2				6.57
	Belly				3	4	17	29	27	19	1				8.34
	Hip		3	16	31	23	16	3	6	0	2				5.78
	Thigh		2	13	26	16	18	11	5	5	3	1			6.38
	Dock			3	24	14	18	11	8	8	6	6	2		7.46
All 7 samples			5	49	191	131	123	85	57	36	14	7	2		6.61
F_1 Ewe 285 1925	Shoulder	5	12	23	25	24	10	1							5.85
	Side		12	25	24	25	11	3							6.07
	Back	4	15	32	26	11	7	5							5.66
	Belly			2	18	46	31	2	1						7.16
	Hip		5	33	22	13	12	5	6	3	1				6.54
	Thigh	6	7	16	11	10	7	9	12	14	8				7.69
	Dock		7	19	20	11	5	5	6	13	8	6			7.82
All 7 samples		15	58	150	146	140	83	30	25	30	17	6			6.68

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	Mean Fineness
F_1 Ewe 286 1924	Shoulder			14	38	30	10	6	1	0	1			6.64
	Side		3	20	35	27	11	4						6.35
	Back		2	25	28	22	14	6	3					6.51
	Belly					19	40	26	12	3				8.40
	Hip			5	23	29	23	9	2	8	1			7.51
	Thigh				9	20	28	15	19	4	3	2		8.49
	Dock				8	20	34	19	7	5	3	4		8.44
All 7 samples			5	64	141	167	160	85	44	20	8	6		7.48
F_1 Ewe 286 1925	Shoulder		3	28	30	24	11	3	1					6.25
	Side		1	6	19	37	21	13	3					7.22
	Back		3	30	25	27	10	3	1	1				6.29
	Belly				9	25	32	27	7					7.98
	Hip		1	20	30	23	12	7	2	3	1	1		6.82
	Thigh		3	16	16	21	23	13	6	2				7.18
	Dock			16	23	13	19	7	6	6	4	2	4	7.80
All 7 samples			11	116	152	170	128	73	26	12	5	3	4	7.08
F_1 Ewe 282 1923	Shoulder			18	35	29	12	5	1					6.54
	Side			9	34	35	16	6						6.76
	Back		2	22	37	27	12							6.25
	Belly			1	22	45	27	5						7.13
	Hip		1	13	26	35	19	6						6.76
	Thigh			3	17	31	33	11	5					7.47
	Dock		1	14	37	31	13	3	1					6.54
All 7 samples			4	80	208	233	132	36	7					6.78
F_1 Ewe 282 1924	Shoulder		1	10	40	26	18	5						6.65
	Side		1	10	36	28	18	4	3					6.76
	Back		1	16	23	33	21	4	2					6.77
	Belly			2	9	34	38	15	2					7.61
	Hip		1	8	17	38	25	11						7.11
	Thigh			7	17	31	30	11	4					7.33
	Dock		1	18	28	34	16	3						6.55
All 7 samples			5	71	170	224	166	53	11					6.97
F_1 Ewe 267 1924	Shoulder		1	5	26	30	18	12	4	3	1			7.32
	Side			3	21	32	18	18	7	0	2			7.53
	Back		16	37	17	13	12	4	1					5.84
	Belly			2	27	35	24	8	4					7.21
	Hip	1	7	26	26	15	17	4	4					6.34
	Thigh				4	21	25	25	13	9	2	1		8.62
	Dock			6	14	20	20	18	12	7	3			8.09
All 7 samples		1	24	79	135	166	134	89	45	19	8	1		7.29

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		4	5	6	7	8	9	10	11	12	13	14	15	16	17	Mean Fineness
F_1 Ewe 267 1925	Shoulder	3	15	17	25	24	14	2								7.02
	Side	7	21	24	24	12	6	3	3							6.58
	Back	2	22	21	20	16	8	8	2	1						6.98
	Belly		4	7	23	30	18	15	3							8.08
	Hip	3	21	14	22	19	5	11	3	2						7.19
	Thigh		4	13	17	15	14	16	12	6	2	0	1			8.68
	Dock	1	14	23	17	8	10	13	7	2	1	1	3			7.88
All 7	samples	16	101	119	148	124	75	68	30	11	3	1	4			7.49
F_1 Ewe 264 1923	Shoulder			3	25	19	17	16	7	7	3	3				9.00
	Side			2	12	25	19	20	12	9	1					8.96
	Back				7	16	15	11	18	18	7	6	2			10.41
	Belly				8	41	32	15	2	2						8.68
	Hip			1	2	10	15	23	18	12	10	6	3			10.66
	Thigh		1	12	27	17	13	19	6	1	3	1				8.40
	Dock				21	25	20	18	10	4	2					8.91
All 7	samples		1	18	102	153	131	122	73	53	26	16	5			9.32
F_1 Ewe 264 1924	Shoulder		3	19	23	21	17	13	3	1						7.86
	Side			6	22	23	22	8	10	6	2	0	1			8.75
	Back			14	24	16	11	18	12	1	3	1				8.56
	Belly				1	21	37	29	8	2	2					9.36
	Hip		5	16	18	19	19	9	3	6	4	1				8.31
	Thigh		1	6	16	35	18	8	11	4	1					8.57
	Dock		3	16	24	14	9	11	7	10	5	0	0	0	1	8.61
All 7	samples		12	77	128	149	133	96	54	30	17	2	1	0	1	8.57
F_1 Ewe 265 1923	Shoulder															
	Side				17	35	15	18	7	5	3					8.90
	Back		1	15	21	26	20	11	2	3	1					8.11
	Belly			1	4	26	44	22	2	1						8.92
	Hip			4	12	25	24	19	8	7	0	0	1			9.01
	Thigh		1	4	15	20	23	18	10	4	4	1				9.05
	Dock			9	16	18	24	17	8	5	2	1				8.84
All 6	samples		2	33	85	150	150	105	37	25	10	2	1			8.81
F_1 Ewe 265 1924	Shoulder		1	11	26	22	16	11	7	6						8.32
	Side			7	30	25	15	11	8	3	1					8.34
	Back		2	12	40	16	12	11	6	0	1					7.87
	Belly			4	14	25	31	16	6	4						8.75
	Hip		1	3	30	23	18	14	9	2						8.42
	Thigh		1	3	14	12	19	28	14	8	1					9.31
	Dock			8	27	25	22	11	4	1	2					8.27
All 7	samples		5	48	181	148	133	102	54	24	5					8.47

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		2	3	4	5	6	7	8	9	10	11	12	13	14	Mean Fineness
F_1 Ewe 263 1924	Shoulder				9	15	28	27	11	9	1				7.47
	Side			1	7	27	21	29	11	4					7.19
	Back				9	27	29	23	5	4	3				7.12
	Belly					2	19	39	22	17	1				8.36
	Hip			1	13	21	29	16	14	4	2				7.14
	Thigh					2	7	21	13	20	14	13	5	5	9.91
	Dock				9	26	35	15	8	5	0	1	1		7.13
All 7 samples				2	47	120	168	170	84	63	21	14	6	5	7.76
F_2 Wether 423 1923	Shoulder			1	6	10	23	33	25	2					7.64
	Side				3	15	22	30	19	11					7.80
	Back					12	16	33	19	20					8.19
	Belly				6	30	45	19							6.77
	Hip				6	12	28	24	18	10	2				7.74
	Thigh				1	10	21	28	29	11					8.04
	Dock				13	19	22	20	15	6	4	1			7.44
All 7 samples				1	35	108	177	187	125	60	6	1			7.66
F_2 Ewe 442 1925	Shoulder		1	5	11	30	25	13	13	2					6.74
	Side		1	5	18	23	31	13	8	1					6.54
	Back			6	19	23	21	10	8	8	5				6.91
	Belly				17	25	31	21	6						6.74
	Hip	1	16	10	19	15	15	11	10	2	1				5.69
	Thigh		7	14	17	18	23	8	5	3	4	1	0	2	6.42
	Dock			7	21	16	12	13	17	10	4				7.14
All 7 samples		1	25	47	122	148	158	89	67	26	14	1	0	2	6.63
F_2 Ewe 442 1926	Shoulder		8	28	32	20	8	4							5.04
	Side		16	19	31	20	7	5	0	2					5.08
	Back		8	26	23	15	9	5	5	5	3	1			5.76
	Belly		8	21	19	17	10	7	10	4	4				6.05
	Hip		3	25	32	18	10	10	2						5.45
	Thigh			9	11	26	23	15	11	5					6.07
	Dock		3	20	22	13	12	8	8	9	3	0	1	1	6.47
All 7 samples			46	148	170	129	79	54	36	25	10	1	1	1	5.80
F_2 Ewe 424 1925	Shoulder				4	20	24	32	14	5	1				7.51
	Side				3	10	29	32	21	5					7.73
	Back				9	24	24	25	10	7	1				7.28
	Belly					4	28	43	23	2					7.91
	Hip				11	13	28	17	14	15	2				7.63
	Thigh					10	21	30	17	15	7				8.27
	Dock				3	25	20	24	14	13	1				7.64
All 7 samples					30	106	174	203	113	62	12				7.71

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean Fineness
F_2Ewe 424 1926	Shoulder	1	2	17	25	23	20	9	3								5.78
	Side			8	30	17	21	15	7	1	0	1					6.36
	Back		1	15	28	16	19	15	4	2							6.08
	Belly			3	27	31	29	10									6.16
	Hip			7	29	27	22	11	2	2							6.15
	Thigh		1	9	20	20	18	14	13	3	2						6.66
	Dock			16	25	21	16	14	4	3	1						6.16
All 7	samples	1	4	75	184	155	145	88	33	11	3	1					6.19
F_2Ewe 422 1925	Shoulder				8	19	28	30	10	5							7.30
	Side			2	16	21	30	19	9	3							6.87
	Back			1	11	12	28	25	13	7	2	1					7.48
	Belly			4	27	44	19	6									5.84
	Hip			1	12	23	18	21	14	9	2						7.34
	Thigh				5	8	19	23	21	7	6	4	5	1	1		8.57
	Dock			3	17	24	21	23	8	4							6.84
All 7	samples			11	96	151	163	147	75	35	10	5	5	5	5		7.19
F_2Ewe 422 1926	Shoulder			8	28	34	12	11	5	2							6.13
	Side				21	30	21	13	9	5	1						6.78
	Back		5	20	21	14	17	7	10	5	1						6.10
	Belly				9	39	16	21	10	5							6.99
	Hip		1	5	34	15	16	8	11	7	2	1					6.62
	Thigh			16	20	10	12	17	12	5	5	2	1				6.94
	Dock			1	11	13	17	22	14	15	6	1					7.86
All 7	samples		6	50	144	155	111	99	71	44	15	4	1				6.77
F_2Ewe 443 1925	Shoulder			2	14	16	29	15	10	10	2	1	1				7.34
	Side				3	15	20	19	17	13	6	6	1				8.31
	Back		7	15	17	14	11	20	7	4	2	1	0	2			6.52
	Belly			1	3	8	29	29	18	12							7.84
	Hip			2	16	22	13	15	15	7	6	2	2				7.52
	Thigh					7	11	22	17	15	11	6	4	3	4		9.45
	Dock				4	5	18	26	20	15	7	3	1	0	1		8.55
All 7	samples		7	20	57	87	131	146	104	76	34	19	9	5	5		7.93
F_2Ewe 443 1926	Shoulder		6	20	21	19	12	14	7	1							5.86
	Side			8	21	27	20	13	7	1	2	1					6.50
	Back		1	11	28	17	15	12	6	8	2						6.46
	Belly			1	13	19	27	25	11	3	1						6.92
	Hip			6	13	24	20	15	8	7	2	2	2	1			7.21
	Thigh			1	1	7	23	16	20	13	10	6	2	1			8.72
	Dock			6	13	20	13	24	14	5	1	1	2	0	1		7.32
All 7	samples		7	53	110	133	130	119	73	38	18	10	6	2	1		7.03

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean Fineness.
F_2Ewe 433 1925	Shoulder		1	10	15	23	18	20	10	1	2					7.64
	Side				10	25	21	13	11	3	7	8	0	1	1	8.82
	Back			2	16	22	12	17	10	11	5	4	1			8.56
	Belly				4	11	24	24	21	9	4	3				9.05
	Hip			3	14	14	12	15	15	8	11	5	3			9.05
	Thigh			12	25	28	12	11	4	7	1					7.30
	Dock			18	28	18	13	6	12	4	1					7.18
All 7 samples			1	45	112	141	112	106	83	43	31	20	4	1	1	8.23
F_2Ewe 421 1925	Shoulder		6	25	22	16	16	10	4	1						6.62
	Side		22	28	16	12	19	3								5.87
	Back	3	11	14	21	22	18	10	1							6.47
	Belly		3	13	25	24	26	7	2							6.86
	Hip	1	12	18	14	24	22	7	2							6.52
	Thigh		3	10	16	18	29	17	4	3						7.42
	Dock		1	2	3	12	33	31	9	5	2	1	1			8.55
All 7 samples		4	58	110	117	128	163	85	22	9	2	1	1			6.90
F_2Ewe 421 1926	Shoulder	3	13	29	15	17	16	4	3							6.09
	Side	1	7	22	27	17	15	7	3	1						6.46
	Back	4	16	34	11	11	10	8	5	1						6.02
	Belly		5	18	20	24	11	10	9	2	1					7.00
	Hip		16	35	19	12	10	6	2							5.91
	Thigh	1	11	18	19	16	13	11	8	3						6.79
	Dock			17	12	15	17	15	12	7	3	1	0	1		7.94
All 7 samples		9	68	173	123	112	92	61	42	14	4	1	0	1		6.60
F_2Ewe 429 1925	Shoulder		1	6	20	29	30	8	5	1						7.30
	Side			11	20	28	25	11	4	1						7.21
	Back			14	18	19	23	15	10	1						7.44
	Belly			1	16	18	47	14	4							7.69
	Hip		1	7	16	22	19	14	14	7						7.84
	Thigh			2	6	10	22	17	18	13	10	2				9.14
	Dock			17	20	19	12	20	10	1	1					7.37
All 7 samples			2	58	116	145	178	99	65	24	11	2				7.71
F_2Ewe 429 1926	Shoulder			20	22	31	18	7	1	1						6.77
	Side		5	37	29	20	8	1								5.92
	Back		3	30	24	11	11	10	6	5						6.76
	Belly			9	33	39	15	4								6.72
	Hip		3	13	22	22	19	9	10	1	1					7.19
	Thigh		4	16	17	15	18	15	8	4	2	0	1			7.44
	Dock	3	10	15	12	18	14	16	9	3						7.01
All 7 samples		3	25	140	159	156	103	62	34	14	3	0	1			6.83

TABLE NO. 7.

FREQUENCY DISTRIBUTION DATA.

Fineness in .0001 inch.		3	4	5	6	7	8	9	10	11	12	13	14	15	Mean fineness
F_2 Wether 434 1925 Fleece Sample	Shoulder	2	15	34	27	14	8								5.60
	Side		3	19	34	17	10	3	7	4	3				6.87
	Back		17	36	11	11	7	4	9	2	2	1			6.32
	Belly			2	17	39	21	13	3	0	0	3	1	1	7.68
	Hip		2	31	19	14	13	8	7	4	2				6.89
	Thigh		1	8	11	11	18	19	11	9	5	5	2		8.64
	Dock	17	23	15	18	10	8	6	1	1	1	1			5.47
All 7 samples		19	61	145	137	116	85	53	38	20	13	9	3	1	6.78
F_2 Wether 434 1925 Pelt Sample	Shoulder		4	28	27	20	12	7	2						6.37
	Side	2	2	26	19	17	14	13	3	3	1				6.81
	Back			12	26	15	19	8	10	7	1	0	1	1	7.63
	Belly		2	11	23	20	16	10	11	4	1	2			7.51
	Hip			10	18	16	21	8	12	8	1	5	0	1	8.10
	Thigh			20	20	23	16	5	8	4	3	1			7.27
	Dock		3	18	27	17	10	9	10	3	2	1			7.14
All 7 samples		2	11	125	160	128	108	60	56	29	9	9	1	2	7.23
F_2 Wether 1925 436	Shoulder	4	15	36	28	15	2								5.41
	Back	4	21	41	20	12	2								5.75
	Belly		10	31	35	20	4								5.21
	Hip		1	16	29	30	15	7	2						5.77
	Thigh		3	18	45	23	10	1							6.71
	Dock			12	34	28	21	3	2						6.22
	Side		16	30	26	20	7	1							6.75
All 7 samples		8	66	184	217	148	61	12	4						5.94
F_2 Wether 425 1925	Shoulder	6	27	21	23	15	6	2							6.40
	Side		3	17	29	19	22	7	2	1					7.74
	Back		2	17	30	35	13	3							7.49
	Belly	1	15	41	28	15									6.41
	Hip		3	16	19	30	17	14	1						7.88
	Thigh		2	23	29	27	11	5	2	1					7.50
	Dock		4	16	19	28	13	15	4	1					7.96
All 7 samples		7	45	151	177	169	82	46	9	3					7.34

STUDIES OF THE INHERITANCE

OF WOOL CHARACTERS AND FLEECE ANALYSIS

IN SHEEP.

PART TWO.

FLEECE ANALYSIS
OF
CHEVIOT AND BORDER
LEICESTER SHEEP.

STUDIES OF THE INHERITANCE OF WOOL CHARACTERS AND FLEECE ANALYSIS IN SHEEP.

PART TWO.

F L E E C E   A N A L Y S I S.

Introduction.

The value of some system of fleece appraisal has already been pointed out in the introduction to the Wool Inheritance section of this thesis. (Pp. 4-7)

The literature on sheep breeding contains very few comprehensive, objective analyses of individual fleeces. Most investigators have taken samples from shoulder areas or from three areas; shoulder, side, and thigh, and have used these areas as indices of the entire fleece.

Reimers and Swart (1929) reported a fleece analyses of Merino sheep using samples from the shoulder, back of thigh, side, belly, and two samples from the neck, one from the crest of the fold and one from the trough of the fold. They found great variation in fineness of fleece and concluded that it was impossible to deduce any definite relationship between body area and fleece fineness, except between widely separated areas.

Duerden (1930), using crimp as an index of fleece fineness, found a range of fineness in Merino fleeces extending over four, or occasionally five commercial qualities or "counts". Adjacent body areas did not vary over one commercial "count" in fleece fineness, a result contradictory to that reported by Reimers and Swart.

Froelich, Spoettel, and Taenzer (1929), in their textbook on wool, recommend the use of samples from three body areas; mid-shoulder, mid-side (over the last true rib) and hip (two inches above the hip joint). They maintain that these areas not only represent the largest portion of the fleece but also will give an average figure of fineness for the entire fleece.

Roberts (1930) reported a comprehensive analysis of mean fineness in individual samples of wool which showed great variability of mean fineness when the sample for measurement was picked at random. He obtained much more uniform results when the samples were zoned prior to measuring them. In one sample of Border Leicester wool from a shoulder area measuring 16 cms. square, on a dried pelt, the variability using samples drawn at random was 25 per cent, and this figure was reduced to 5 per cent by zoning, a striking testimonial to the efficiency of zoning and making up composite samples.

In view of the contradictory results reported in the literature and the need for a definite knowledge of the variations of mean fineness and density between adjacent areas as well as widely removed areas of the fleece, a comprehensive experiment has been planned in which quadruplicate samples have been taken from fourteen body areas of the fleece. Inasmuch as Cheviot and Border Leicester sheep were available at the Institute of Animal Genetics, and a crossbreeding project with these two breeds was under way, ewes from these breeds were selected for the fleece analysis study.

A law of statistics states that a complete analysis of a single population gives more reliable results than a partial analysis of several populations. The fleece may be regarded as a population of individual wool fibres, and accordingly one ewe of each breed was selected to furnish the wool samples for a comprehensive fleece analysis study.

In a comprehensive study of Fleece Analysis of individual sheep and groups of sheep with particular reference to mean fineness, the logical determinations to be made are as follows:

1. The variation of thickness along the length of individual fibres.
2. Variation of average fineness in different groups of fibres according to the number measured.

3. The variation of average fineness in different samples located in proximity to a selected area or point.
4. The variation of average fineness between averages of areas when grouped by regions.
5. The selection of areas for sampling which will accurately represent the entire fleece, keeping in mind the particular nature and utility of each fleece.
6. The variation between similar areas of different fleeces.
7. The variation between individuals, families, and flocks within the same breed.

Roberts (1930) demonstrated the value of zoning to reduce the variability of mean fineness and his results have been accepted and adopted in this experiment.

Objects of Experiment.

Briefly stated, the objects of the work which constitutes Part Two of this thesis are to devise a new system of fleece analysis which can be utilized; firstly in breeding experiments for the investigation of the inheritance of measurable wool characteristics; and secondly, for the determination of the effect of environmental agencies on the fundamental measurable characteristics of the fleece. The results obtained have furnished information upon the variation of the measurable characteristics of wool fibres within small areas, from area to area, and over the body generally in those animals used, and have indicated the relative accuracy of the methods of sampling and analysis which have been employed.

METHODS OF EXPERIMENTATION.

Material Used.

The fleece fineness and density data from Appendix Table No. 6 (Pp. 77 to 93) dealing with the parental and crossbred generations of the Hampshire x Rambouillet Crossbreeding Experiment have been used for a study of the variation of mean fineness and density of fleece in similar areas on different sheep of the same breed.

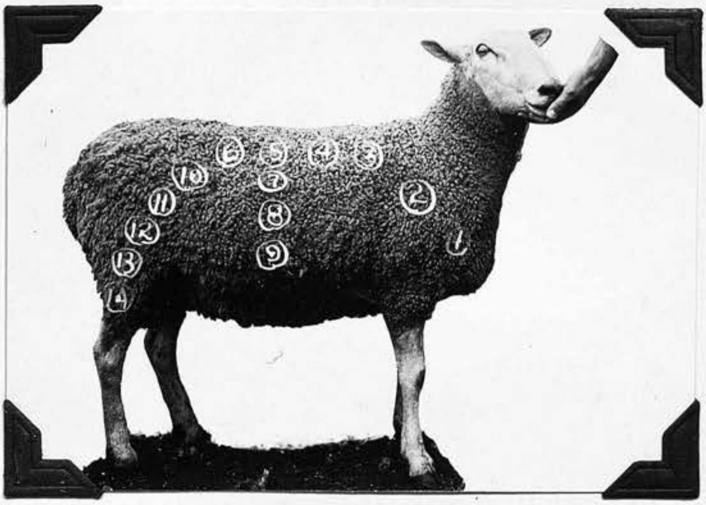
A Border type of Cheviot Ewe (No. 117) and a Border Leicester Ewe (K953) were selected as possessing fairly typical fleeces for their respective breeds. These ewes were in the flock of the Institute of Animal Genetics and had been sheared in June 1930. At the time of sampling (Nov. 7, 1930) these ewes were carrying a fleece of five month's growth.

Method of Sampling.

A scheme of sampling was devised which was designated "Line Sampling". Fourteen body areas were selected for sampling from five different body regions, as shown in Figure No. 18.

Fig. No. 18.

Location of Body Areas.



Area No.	1	Point of Shoulder	Shoulder Region
Area No.	2	Mid Shoulder	
Area No.	3	Top Shoulder	
Area No.	4	Fore Back	Back Region
Area No.	5	Mid Back	
Area No.	6	Rear Back	
Area No.	7	High Side	Side Region
Area No.	8	Mid Side	
Area No.	9	Low Side	
Area No.	10	High Hip	Hip Region
Area No.	11	Low Hip	
Area No.	12	High Britch	Britch Region
Area No.	13	Mid Britch	
Area No.	14	Low Britch	

Anatomical points on the right side of the sheep were selected as base points in mapping out the areas for sampling. The point of the shoulder (lateral tuberosity of the humerus) the top of the shoulder blade at its rear point (posterior angle of the scapula), the last rib near its connection with the spinal column, and the lower limit of wool growth on the rear leg, were determined and formed the basis of locating the other areas. A point midway between the point of the shoulder and the rear of the top of the shoulder blade was selected as the mid-shoulder area. A point on the back midway between the rear edge of the last rib and the rear of the top of the shoulder blade was selected as the mid point of the body, and from this point the wool was parted down the side, and the top of the "part" was selected for the mid-back area. The mid-side area was located half-way along this "part" and the high-side and low-side areas were located at equal distances above and below the mid-side area. With the rear-back and mid-back located, the fore-back area was established at a point near the top-shoulder area so that the back areas were equidistant. The high-hip was located above the hip joint (tuber coxae) and the low-britch near the extremity of wool growth on the lower rear leg. The three intermediate points were then located equidistant from each other.

Quadruplicate samples from each area were
ken with the Wyedina Fleece Caliper shown in
gure Nos. 19 and 20, and described by Burns and
ller. (1931)

Figure No. 19
Wyedina Fleece Caliper.

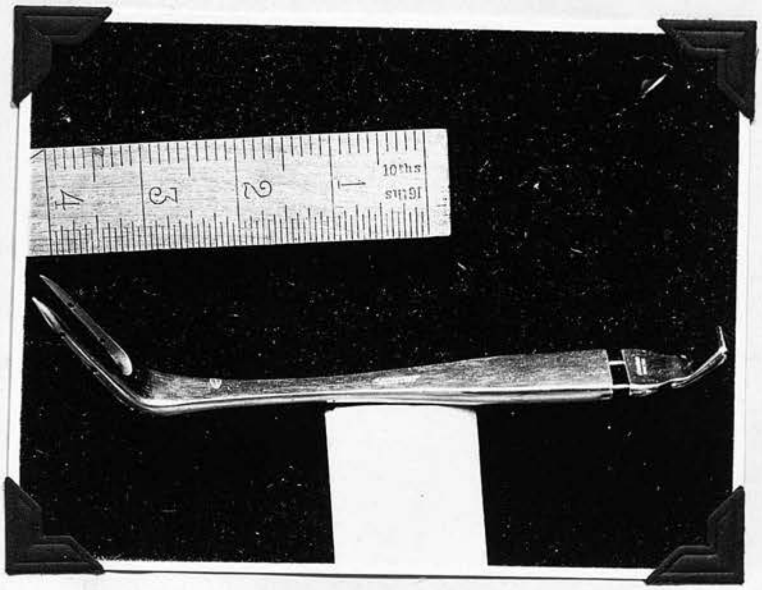
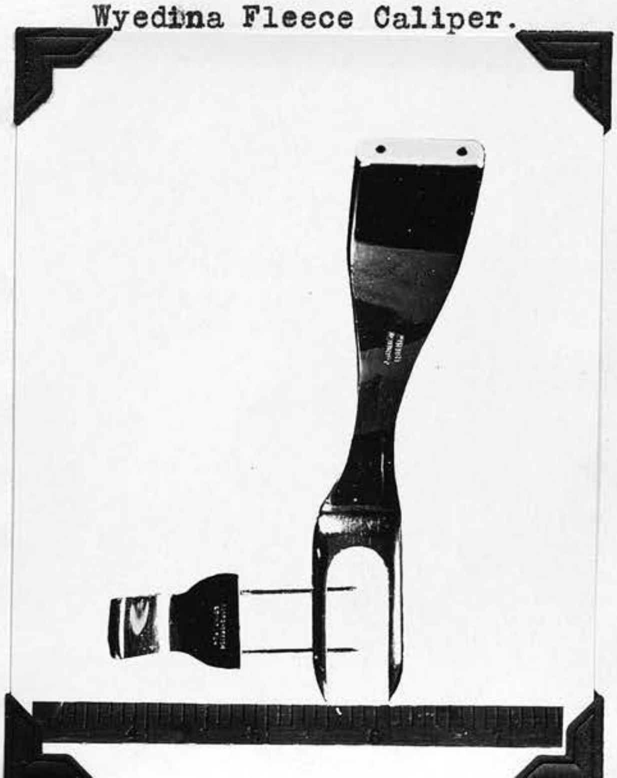


Figure No. 20.
Wyedina Fleece Caliper.



The details of this instrument are plainly shown in the figures. This caliper separates the wool growing on an area of skin surface measuring one-half inch square.

After the area was located an "L-Shaped" part was made in the wool and the caliper was inserted at right angles to one limb of the "L" and parallel to the other. The caliper was carefully held in position so that none of the wool was compressed into its throat, and the cross pins were inserted through the jaws, separating the wool growing on a skin surface one half inch square. The sample was dissected from the surrounding wool and clipped off close to the skin with a pair of surgeon's shears (angled on flat at 45^{0}). The quadruplicate samples were taken from contiguous locations within each area.

Washing of Samples.

The samples were cleansed by soaking them in a soap solution (5 per cent by weight of soap flakes) at a high temperature (about 140 degrees F) and after remaining in the solution for a time they were rinsed out under a hot water jet. To keep the samples from felting they were placed in a pair of hinged wire screens, which held the sample firmly during washing and prevented any tendency for the individual fibres to become entangled. Four samples were handled at a time, so that three samples were soaking while the other sample was being washed and rinsed.

Compositing of Samples.

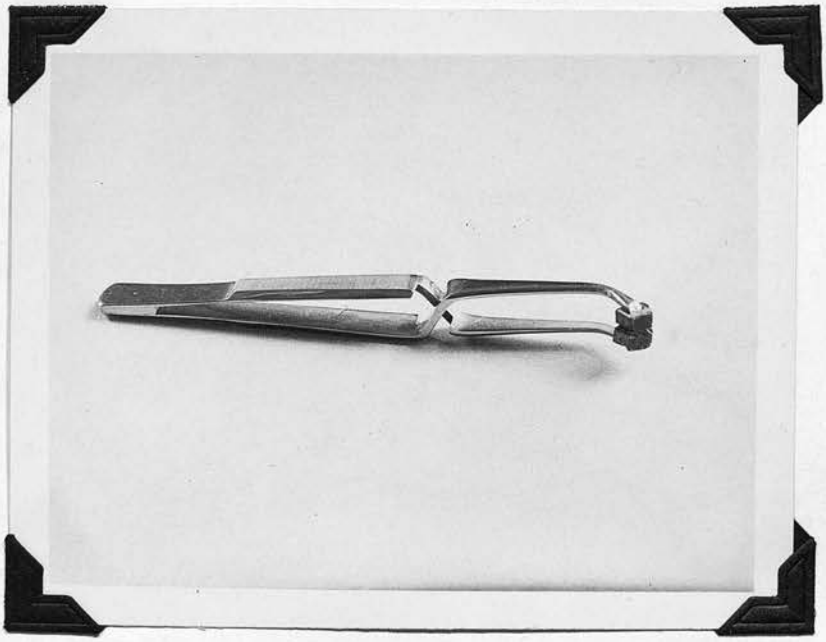
The samples from the first four areas of the Cheviot Ewe No. 117 were measured before and after compositing to study the effectiveness of compositing in the small individual quadruplicate samples. The small individual samples were composited by a continued splitting of the sample until it had been divided into sixteen portions. A small "sheaf" of fibres was drawn from the side of each of the sixteen portions and these "sheaves" made up the composite of the sample. The composite samples of areas and regions were made up in a similar manner, the former from the individual samples and the latter by further splitting the composite samples of areas into eight portions and taking "sheaves" from each of these to form the composite sample of the region.

Laboratory Equipment.

The Micrometer Caliper used for measuring the thickness of the individual fibres in units of ten thousandths of an inch has been described by Burns and Koehler (1925). A new method of measuring stretched fibre length has recently been described by Burns (1931) and this method has been used in this experiment. A pair of cross arm forceps for holding wool fibres have been devised by the writer and Mr. Miller, of the Institute of Animal Genetics. These modified forceps are shown in Figure No. 21. An analytical /

Figure No. 21.

Cross Arm Forceps
for
Stretched Fibre Measurement.



An analytical balance weighing to tenths of a milligram was used for weighing samples over 50 milligrams, and samples weighing under 50 milligrams were weighed on a torsion balance which read to one hundredth of a milligram.

Measurement Technique.

The technique used in micrometer caliper measurement of fineness has already been described in Part One of this thesis (Pp. 26-27). However, one important change in measurement technique has been made in the fleece analysis study. Each fibre of the hundred measured was measured at three places along its length instead of making a single measurement of the mid portion as was used in the Wool Inheritance Study. The statistical effect of taking three measurments along the fibre is to increase the number of measurements from one hundred to three hundred. However, when the measurements were taken, only the average of the three readings was written down, so that the means of the samples are calculated from the average thicknesses of one hundred individual fibres.

The calculated density was determined by proportional weights after one hundred fibres had been measured for the determination of fineness.

The weight-length ratio was determined by measuring the stretched length of a hundred fibres in mm. and then determining their absolute dry weight.

The absolute dry weight was calculated from a standard sample whose absolute dry weight had been determined at the Wool Industries Research Association Laboratory at Torridon, Leeds.

RESULTS OF EXPERIMENT.

The experiment naturally divides itself into two sections, the variation when sampling within a prescribed area and the variation when sampling an entire fleece at a number of selected points.

In comparing the large amount of data it soon became apparent that an ordinary comparison of means was inadequate to show the degree of variation in the experimental results due to the different errors of sampling and determination. The standard error method by which errors of different magnitudes can be separated from the gross error proved ideally suited for the analysis of the data at hand and has been used throughout. The recent publication on Fleece Analysis by Roberts (1930) has served as a guide to the statistical treatment of data herein reported.

The measurement data of the quadruplicate samples from each of the fourteen body areas were used for the calculation of the standard errors. The micrometer measurements were used since these gave a distribution of fibre thicknesses within the sample which was not available when using the weight-length ratio method. The Weight-length ratios were used to check the micrometer mean finenesses.

SAMPLING FROM AN AREA AT A SELECTED POINT ON THE BODY.

Studies of Fleece Fineness.

Cheviot Ewe No. 117

Variation of Fineness Between Quadruplicate Samples Within an Area.

Mean Micrometer Finenesses used as Units.
Per Cent Standard Error of Mean Fineness.

	Micrometer Mean Fineness				Per Cent
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Standard Error.
Area No. 1 Point Shoulder	12.55	12.70	11.82	12.03	1.96
Area No. 2 Mid Shoulder	12.89	12.91	12.70	12.84	0.42
Area No. 3 Top Shoulder	12.27	12.45	12.55	12.65	0.75
Area No. 4 Fore Back	12.03	12.39	12.05	12.02	0.73
Area No. 5 Mid Back	12.65	12.03	12.30	12.36	1.19
Area No. 6 Rear Back	13.29	12.95	13.61	13.32	1.10
Area No. 7 High Side	13.65	13.79	13.50	13.59	0.32
Area No. 8 Mid Side	13.55	13.37	13.21	13.07	0.90
Area No. 9 Low Side	12.89	12.69	13.10	12.35	1.38
Area No. 10 High Hip	14.77	14.57	14.29	14.73	0.86
Area No. 11 Low Hip	14.88	14.85	14.47	14.49	0.78
Area No. 12 High Britch	15.71	16.57	14.78	15.93	2.55
Area No. 13 Mid Britch	16.43	16.66	16.60	16.00	0.98
Area No. 14 Low Britch	16.23	15.17	15.78	16.49	2.07
Average of the Entire Fleece					1.14

Selecting an arbitrary limit of accuracy of a five per cent difference exceeded once in 250 times, the corresponding Percentage Standard Error is 1.737 (Roberts: 1930 Table I.) Only three areas out of the fourteen exceed this figure and the majority are well under the figure, showing that the wool on most of the areas was remarkably uniform, as shown by the correspondence of the mean fineness of quadruplicate samples.

Studies of Fleece Fineness.

Border Leicester Ewe No. K953.

Variation of Fineness Between Quadruplicate Samples Within an Area.

Mean Micrometer Finenesses Used as Units.
Per Cent Standard Error of Mean Fineness.

	Micrometer Mean Fineness				Per Cent Standard Error.
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	
Area No. 1 Point Shoulder	11.27	11.70	11.30	11.24	1.00
Area No. 2 Mid Shoulder	11.02	10.66	10.91	10.87	0.80
Area No. 3 Top Shoulder	12.75	12.52	12.39	11.96	1.55
Area No. 4 Fore Back	12.70	12.74	12.38	12.46	0.81
Area No. 5 Mid Back	12.28	12.33	12.11	12.46	0.68
Area No. 6 Rear Back	13.27	13.80	13.95	13.51	0.39
Area No. 7 High Side	12.36	11.65	12.30	12.28	1.52
Area No. 8 Mid Side	11.65	11.99	12.05	11.70	0.89
Area No. 9 Low Side	11.47	11.54	11.51	11.47	0.47
Area No. 10 High Hip	13.12	13.20	12.54	12.91	1.25
Area No. 11 Low Hip	13.09	13.18	13.09	12.93	0.21
Area No. 12 High Britch	13.12	13.09	12.88	13.11	0.51
Area No. 13 Mid Britch	12.76	12.83	13.12	13.53	1.55
Area No. 14 Low Britch	12.83	14.16	13.67	14.65	3.22
Average of the Entire Fleece					1.06

Using a five per cent accuracy figure one finds in this fleece that with the single exception of the low britch area all the percent standard error figures are considerably lower than the figure of 1.737 for the selected limit of error. The wool of the Border Leicester was even more uniform than in the Cheviot, as shown by the closer correspondence of the mean fineness of quadruplicate samples.

Studies of Fleece Fineness.

Variation Between Individual Fibres Within a Sample.
Averages of Quadruplicate Samples.

Per Cent Standard Error of Mean Fineness.
Micrometer Measurements.

	Cheviot Ewe No. 117	Border Leicester Ewe No. K953
Area No. 1 Point of Shoulder	1.65	1.56
Area No. 2 Mid Shoulder	1.64	1.28
Area No. 3 Top Shoulder	1.71	1.48
Area No. 4 Fore Back	1.73	1.58
Area No. 5 Mid Back	1.53	1.58
Area No. 6 Rear Back	1.77	1.50
Area No. 7 High Side	1.42	1.42
Area No. 8 Mid Side	1.53	1.47
Area No. 9 Low Side	1.54	1.37
Area No. 10 High Hip	1.38	1.59
Area No. 11 Low Hip	1.57	1.42
Area No. 12 High Britch	2.09	1.49
Area No. 13 Mid Britch	2.11	1.52
Area No. 14 Low Britch	2.19	1.83
Average of the Entire Fleece	1.70	1.51

The variation of thickness of fibres within the sample did not vary markedly in the different body areas with the exception of the three areas of the britch region of Cheviot Ewe No. 117. The variation of individual fibre thickness within the sample was remarkably uniform in Border Leicester Ewe No. K953 with no appreciable difference between any of the body areas. However, the variation between fibres was greater than the variation of the mean fineness of different samples within an area (1.51 compared to 1.06 and 1.70 compared to 1.14).

Studies of Fleece Density.

Cheviot Ewe No. 117

Variation of Density Between Quadruplicate Samples within an Area.
Using the calculated density of each Quadruplicate sample as a unit.
Number of fibres from a skin surface measuring one-half inch square.

Per Cent Standard Error of Average Density.

	Calculated Density				Per Cent Standard Error.
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	
Area No. 1 Point Shoulder	2351	2206	2401	2592	3.73
Area No. 2 Mid Shoulder	2461	2119	1970	1820	7.50
Area No. 3 Top Shoulder	1750	2139	1784	2213	7.00
Area No. 4 Fore Back	1963	1720	2047	2082	4.81
Area No. 5 Mid Back	1851	1499	2060	2137	8.69
Area No. 6 Rear Back	1651	2134	1420	1798	9.82
Area No. 7 High Side	1418	1725	1802	1923	7.22
Area No. 8 Mid Side	1567	1531	1771	1424	5.40
Area No. 9 Low Side	1435	1293	1529	1782	7.81
Area No. 10 High Hip	1365	1345	1799	1539	8.00
Area No. 11 Low Hip	1727	1604	1424	1734	5.24
Area No. 12 High Britch	1517	1204	1629	1242	8.58
Area No. 13 Mid Britch	1276	1098	1119	1050	4.84
Area No. 14 Low Britch	1117	1083	1210	992	4.54
Average of the Entire Fleece					6.66

The errors of determination were much larger for density than for fineness since the sampling error was greater and the additional error of calculating the total density of the area by proportional weights was peculiar to density determination. No definite order is observed in the variation of average density in the different body areas. A table of variance was prepared from these data and some interesting information was obtained. The method of preparing a table of variance has been described on pages 30 to 32.

Studies of Fleece Density.

Cheviot Ewe No. 117.

Table of Variance

Calculated Number of Fibres from a Skin Surface Measuring One-half Inch Square.

Body Area No.	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Total
1	2351	2206	2401	2592	9550
2	2461	2119	1970	1820	8370
3	1750	2139	1784	2215	7888
4	1963	1720	2047	2082	7812
5	1851	1499	2060	2137	7547
6	1651	2134	1420	1798	7003
7	1418	1725	1802	1923	6868
8	1567	1531	1771	1424	6293
9	1435	1293	1529	1782	6039
10	1365	1345	1799	1539	6048
11	1727	1604	1424	1734	6489
12	1517	1204	1629	1242	5592
13	1276	1098	1119	1050	4543
14	1117	1083	1210	992	4402
(Σ): Sum	23449	22700	23965	24330	94444
$(\Sigma)^2$: Sum of Squares	41199939	38892660	42634131	44977020	663719642

Table of Variance.

Variation due to:	Degrees of Freedom	Standard Deviation.	Mean Variance.	Gross Variance.
All Causes	55	391	153163	8423944
Sample Trend	3	51	35677	107032
Balance	52	400	159941	8316912
Area Difference	13	358	511547	6650105
Remainder	39	207	42739	1666807
Error of Sampling for density 207 fibres (Wyedina Fleece Caliper)				

The sample trend was much less than the area difference, showing that density tended to follow the same uniformity as already shown for fineness, that is samples within an area did not differ markedly from each other. However, there was a large difference between the different areas, as shown by the much larger figure for the standard deviation (358 as compared with 51).

The Accuracy of the Wyedina Wool Caliper.

Cheviot Ewe No. 117.

All of the quadruplicate samples were taken with the Wyedina Fleece Caliper and a comparison of the standard deviations with different degrees of freedom, show the proportionate error of density due to different causes. The variation due to all causes was 391 fibres, while the sample trend was only 51 fibres. The area difference, 358 fibres, was larger leaving a balance of 207 fibres due to residual errors of determination such as the selection of a prescribed area on the sheep and calculating the number of fibres by means of proportional weights.

Studies of Fleece Density.

Border Leicester Ewe No. K953.

Variation of Density Between Quadruplicate Samples Within an Area.
Using the calculated density of each Quadruplicate Sample as a Unit.
Number of Fibres from a Skin Surface Measuring One-half Inch Square.

	Calculated Density				Per Cent Standard Error.
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	
Area No. 1 Point Shoulder	2515	1969	1614	2755	13.51
Area No. 2 Mid Shoulder	2083	1613	1297	1578	16.65
Area No. 3 Top Shoulder	2115	1690	2248	2074	6.74
Area No. 4 Fore Back	2191	2026	2665	1758	10.19
Area No. 5 Mid Back	1952	1612	2058	1977	5.95
Area No. 6 Rear Back	1914	1698	1757	1819	2.95
Area No. 7 High Side	1763	1877	1464	1813	6.13
Area No. 8 Mid Side	1974	1895	1669	1811	4.19
Area No. 9 Low Side	1714	1765	2051	1782	4.76
Area No. 10 High Hip	2649	1942	1650	1820	12.61
Area No. 11 Low Hip	2400	1949	2043	2388	6.15
Area No. 12 High Britch	2092	2162	2249	1986	3.11
Area No. 13 Mid Britch	2132	1077	1467	1628	15.99
Area No. 14 Low Britch	1439	1144	1489	1491	6.83
Average of the Entire Fleece					8.27

The much greater variation within the area is undoubtedly due to greater difficulty in obtaining an accurate sample from a definite prescribed location. Again there is no definite orderliness in the variation between samples among the various body areas, If this data is made up in the form of a table of variance, the isolation of the different errors involved affords some interesting comparisons.

Studies of Fleece Density.

Border Leicester Ewe No. K953.

Table of Variance.

Calculated Number of Fibres from a Skin Surface Measuring One-half Inch Square.

Body Area No.	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Total
1	2515	1969	1614	2755	8853
2	2083	2513	1297	1578	7471
3	2115	1690	2248	2074	8127
4	2191	2026	2665	1758	8640
5	1952	1612	2058	1977	7599
6	1914	1698	1757	1819	7188
7	1763	1877	1464	1813	6917
8	1974	1895	1669	1811	7349
9	1714	1765	2051	1782	7312
10	2649	1942	1650	1820	8061
11	2400	1949	2043	2388	8780
12	2092	2162	2249	1986	8489
13	2132	1077	1467	1628	6304
14	1439	1144	1489	1491	5563
(Σ) Sum	28933	25319	25721	26680	106653
$(\Sigma)^2$ Sum of Squares.	61123971	47576907	49224365	52264258	825172205

Table of Variance.

Variation due to:	Degrees of Freedom	Standard Deviation.	Mean Variance.	Gross Variance.
All Causes	55	359	128490	7066958
Sample Trend	3	126	186831	560492
Balance	52	354	125124	6506466
Area Difference	13	247	243885	3170508
Remainder	39	292	85537	3335958

Error of Sampling for density 292 fibres.
(Wyedina Fleece Caliper)

The sample trend was much larger in the Border Leicester fleece than in the Cheviot, while the area difference was slightly less. This indicates that there was a tendency for the Cheviot fleece to be more variable in density from area to area. The variation between samples within the area was larger in the Border Leicester fleece, due not so much to the inherent variability of density within the area, as to the difficulty encountered in obtaining an accurate density sample due to the small, tangled locks found in the Border Leicester fleece.

The Accuracy of the Wyedina Fleece Caliper.

Border Leicester Ewe No. K953.

The quadruplicate samples were taken with the Wyedina Fleece Caliper and a comparison of the standard deviations in the table of variance shows the proportionate error in density due to different causes.

The variation due to all causes was 359 fibres, while the sample trend was 126 fibres. The area difference, 247 fibres, was larger leaving a balance of 292 fibres due to residual errors of determination such as the selection of a prescribed area on the sheep and calculating the number of fibres by means of proportional weights.

It is interesting to note that the error of sampling with the original engineer's calipers, 426 fibres (see Page 31) has been reduced to 256 fibres by the use of the Wyedina Fleece Caliper. The latter figure was obtained by combining the data from the Cheviot and Border Leicester fleeces.

Studies in Fleece Density.

Cheviot Ewe No. 117
and
Border Leicester Ewe No. K953.

Table of Variance.

Variation due to:	Degrees of Freedom	Standard Deviation.	Mean Variance.	Gross Variance.
All Causes	111	389	151548	16821792
Sample Trend	3	67	124002	372005
Balance	108	390	152313	16449787
Area Difference	27	321	413019	11151503
Remainder	81	256	65411	5298284
Error of Sampling for Density (Wyedina Fleece Caliper)		256 fibres.		

There was no appreciable difference in the per cent standard errors of mean micrometer fineness between samples within an area in either of the Cheviot or Border Leicester fleeces. There was a difference in density due not so much to the inherent variation of density within each area as to the difficulty encountered in obtaining an accurate density sample. The variation of mean micrometer fineness between quadruplicate samples taken from a total skin surface measuring one inch square was negligible. In each of the body areas duplicate micrometer measurements of fineness from a single sample were more useful than single measurements from each of the quadruplicate samples, for the per cent standard error of mean fineness was larger between individual fibres within the sample than between mean finenesses of quadruplicate samples within the area. However, the standard errors were necessarily lower when comparing the mean finenesses of quadruplicate samples, for the total range of fineness between individual fibres within the sample was much larger than the difference between the mean finenesses of the same samples.

SAMPLING THE ENTIRE FLEECE.

In the preceding section the variation within the sample has proven itself of greater importance than variation between mean finenesses of quadruplicate samples within an area. The next logical step is to compare the variation of mean finenesses of different areas within the fleece to see if there is any definite differential relationship between the various body areas.

Studies in Fleece Fineness. Cheviot Ewe No. 117 and Border Leicester Ewe No. K953. Variation in Fineness between Body Areas. Fineness of quadruplicate Samples of each area used as Units. Per Cent Standard Error of Mean Fineness Micrometer Measurements.	
	Per Cent Standard Error.
Cheviot Ewe No. 117	2.71
Border Leicester Ewe No. K953	1.78

Both fleeces show figures larger than the allowable figure of 1.737 for the selected limit of error, denoting considerable variation from area to area throughout the fleece, for in both cases a five per cent difference would be exceeded by chance more than once in 250 times.

If the average micrometer finenesses of areas are arranged by body regions the following table is obtained:

Studies of Fleece Fineness.

Variation in Fineness Between Areas by Body Regions.

Per Cent Standard Error of Mean Fineness.
Micrometer Measurements.

	Cheviot Ewe No. 117		Border Leicester Ewe No. K953	
	Mean Fineness	Per Cent Standard Error	Mean Fineness	Per Cent Standard Error.
Areas 1-3 Shoulder Region	12.53	2.13	11.55	5.02
Areas 4-6 Back Region	12.55	5.68	12.83	4.12
Areas 7-9 Side Region	13.23	2.34	11.83	2.43
Areas 12-14 Britch Region	16.03	1.54	13.31	2.70
Average for Fleece by Regions		2.92		3.57

The large figures obtained for the per cent standard error of fineness between areas when arranged by regions indicate that in order to attain an accuracy within the selected limit of error it would be necessary to sample these fleeces in at least three areas within each body region. The Cheviot fleece varied considerably more in the back region, while the Border Leicester fleece varied more in the shoulder region.

The average fineness data of the Rambouillets, Hampshires, and their crossbred offspring, (Appendix Table No. 6, Pp. 77-93) furnish a comparison of the variation of fineness of similar areas on different sheep, including both a gross variation between sheep and the variation of fineness within the area.

When "S", the gross variation between similar areas on different sheep, and "s^1" the variation within the sample are known, the figure for "s^2" the variation between sheep, selection of area and other residual errors of determination can be calculated by the formula:

$$s_2 = \text{root of } S - s_1$$

Studies in Fleece Fineness.

Hampshire, Rambouillet and Crossbred Generations.

Variation in Fineness between Similar Areas of Different Sheep.

Per Cent Standard Error of Mean Fineness

	Shoulder.	Side	Back	Belly	Hip	Thigh	Dock	No. Fleeces.
Hampshire Generation								
S	4.84	4.24	3.43	5.12	3.82	4.06	4.10	13
s_1	1.87	2.18	1.94	1.70	1.94	2.35	1.73	3
s_2	4.46	3.64	2.83	4.73	3.29	3.31	3.62	-
Rambouillet Generation								
S	4.14	4.07	3.92	3.79	3.85	4.33	3.43	17
s_1	1.99	1.96	2.18	1.57	2.17	2.22	2.43	7
s_2	3.63	3.57	3.26	3.45	3.18	3.72	2.42	-
F_1 Generation								
S	2.20	2.40	2.54	1.68	2.30	2.19	1.87	31
s_1	2.06	1.99	2.27	1.48	2.16	2.27	2.48	23
s_2	0.77	1.34	1.14	0.80	0.79	--	--	--
F_2 Generation								
S	2.83	3.13	2.89	2.67	3.01	3.11	2.45	18
s_1	2.16	2.22	2.57	1.85	2.44	2.36	2.45	18
s_2	1.83	2.21	1.32	1.93	1.76	2.03	--	--
Averages of all Fleeces.								
S	3.50	3.46	3.20	3.32	3.25	3.42	2.96	79
s_1	2.07	2.09	2.34	1.62	2.25	2.29	2.41	51
s_2	2.82	2.76	2.18	2.90	2.35	2.54	1.72	--

Considering all of the fleeces as one population, there was no appreciable difference between the variation within the sample and the variation between similar areas on different sheep, for the per cent standard errors correspond closely. This result confirms the results obtained with the Cheviot and Border Leicester fleeces, in that there was surprising uniformity within body areas. The gross variation (S) of mean micrometer fineness between similar areas on different sheep was much larger in the purebred generations than in the crossbred generations.

Studies in Fleece Density

Cheviot Ewe No. 117
and
Border Leicester Ewe No. K953.

Variation of Density between Body Areas.
The Average density of the Quadruplicate Samples of Each Area were Used as Units.
Number of Fibres from a Skin Surface Measuring One-half Inch Square.

Per Cent Standard Error of Average Density.

	Per Cent Standard Error
Cheviot Ewe No. 117	20.19
Border Leicester Ewe No. K953	3.34

Both of these figures exceed 1.737, the selected limit of error and indicate that there was considerable variation in density between different body areas. The striking variation of the Cheviot fleece is shown by the high per cent standard error. This variation was due to a larger inherent variability of density in the Cheviot fleece, which was particularly low in density in the britch region.

If the average density figures of each area are arranged by body regions the following table is obtained:

Studies of Fleece Density.

Cheviot Ewe No. 117
and
Border Leicester Ewe No. K953.

Variation of Density Between Areas by Body Regions.
Number of Fibres from a Skin Surface Measuring One-half Inch Square.

Per Cent Standard Error of Average Density.

	Cheviot Ewe No.117		Border Leicester Ewe No. K953	
	Average Density	Per Cent Standard Error.	Average Density	Per Cent Standard Error.
Areas 1-3 Shoulder Region	2151	7.02	2038	3.19
Areas 4-6 Back Region	1865	2.41	1952	6.86
Areas 7-9 Side Region	1600	4.69	1798	2.34
Areas 12-14 Britch Region	1212	9.32	1696	15.86
Average of entire Fleece by Regions		5.86		7.06

The large figures obtained for the per cent standard error of density between areas when arranged by regions indicate a variation larger than the selected limit of error of 1.737, and in order to attain this accuracy it would be necessary to take samples in at least three places within each region. The britch regions as might be expected, were more variable in average density than the other body regions.

The average density data of the Rambouillets, Hampshires and their crossbred offspring (Appendix Table No. 6, Pp. 77-93) furnish a comparison of the variation of density in similar areas on different sheep.

Studies of Fleece Density.

Hampshire, Rambouillet and Crossbred Generations.

Variation of Density between Similar Areas of Different Sheep.

Per Cent Standard Error of Average Density

	Shoulder	Side	Back	Belly	Hip	Thigh	Dock	No. Fleeces
Hampshire Generation S	9.63	8.48	6.71	11.89	7.77	9.24	8.27	13
Rambouillet Generation S	11.09	8.14	7.76	9.19	6.47	8.79	9.86	17
F_1 Generation S	5.31	4.16	5.18	5.76	4.52	6.30	5.30	31
F_2 Generation S	5.09	6.50	6.75	7.27	7.40	5.80	7.49	18
Averages of All Fleeces S	7.78	6.82	6.60	8.53	6.54	7.53	7.73	79

In a study of density it was impossible to isolate the variation within the sample from the gross error. The only possible grouping was a comparison of the gross per cent standard error of density between similar areas of different sheep of the same breed. There was a significant difference between the body areas, due largely to errors of sampling. The table of variance given on Page 30 testifies that the error of sampling is greater than the variation between the samples of a body area (426 fibres compared to 118 fibres.)

THE ACCURACY OF COMPOSITE SAMPLES OF BODY AREAS AND REGIONS.

The sampling of the fleece on the sheep takes comparatively little time when compared with the time required for laboratory analysis, and a system of zoning and making up composite samples of body areas and regions would markedly reduce the number of laboratory measurements. Composite samples of each body area were made up by zoning and the micrometer mean fineness and weight-length ratios were determined. Later composite samples of the body regions were made up by zoning the composite samples of areas. Mathematically considered, these composite samples should give results identical to the average of the separate determinations made on each of the quadruplicate samples of each body area. However, certain errors occur in making up composite samples, particularly the tendency for the fingers to pick out subconsciously the coarsest fibres from a sample. The results of the measurements of the composite samples are shown in the following table:

STUDIES OF FLEECE FINENESS.

Cheviot Ewe No. 117

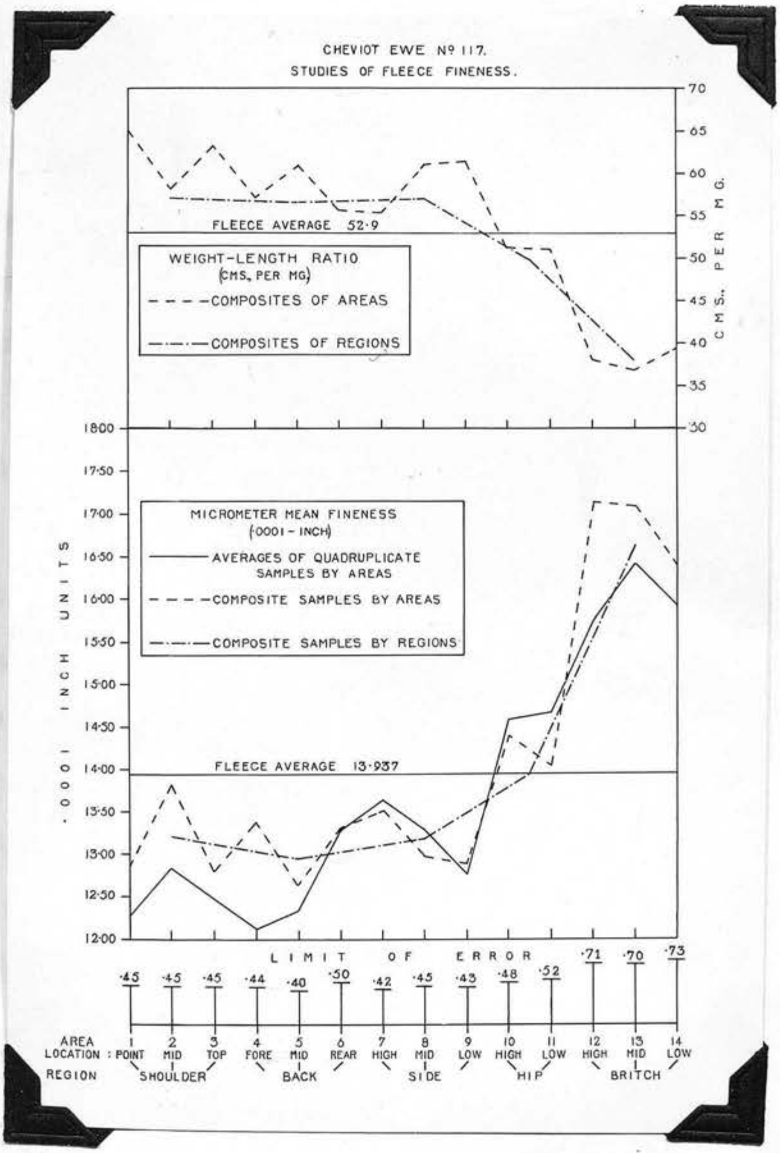
The Accuracy of Composite Samples of Areas and Regions.

	Micrometer Caliper Measurements			Weight-Length Ratio.	
	Mean Fineness in .0001 Inch Units			Cms. per Mg.	
	Average of Quadruplicates	Composite of area	Composite of Region	Composite of Area	Composite of Region
Area No. 1 Point Shoulder	12.27	12.86		65.0	
Area No. 2 Mid Shoulder	12.84	13.82	13.22	58.2	57.1
Area No. 3 Top Shoulder	12.48	12.78		63.3	
Area No. 4 Fore Back	12.12	13.39		57.2	
Area No. 5 Mid Back	12.34	12.63	12.95	60.9	56.6
Area No. 6 Rear Back	13.29	13.31		55.6	
Area No. 7 High Side	13.63	13.53		55.4	
Area No. 8 Mid Side	13.30	12.99	13.19	60.9	57.1
Area No. 9 Low Side	12.76	12.90		61.3	
Area No. 10 High Hip	14.59	14.40		51.2	
Area No. 11 Low Hip	14.67	14.05	13.94	51.0	50.0
Area No. 12 High Britch	15.75	17.13		38.0	
Area No. 13 Mid Britch	16.42	17.09	16.62	36.8	38.0
Area No. 14 Low Britch	15.92	16.40		39.5	
Average of Entire Fleece (14 Body Areas)	13.74	14.09	13.98	53.9	51.8

Variation between Mean Micrometer Fineness of Entire Fleece Per Cent Standard Error 0.80

These data are more clearly presented in graphic form and are shown in Figure No. 22.

Figure No. 22.



The weight-length ratio has been plotted above the micrometer fineness so that the relative relationships in the different body areas can be seen at a glance. At the bottom of the chart are a series of columns entitled "limit of error". The figures at the top of these columns represent the maximum allowable error, which is three times the largest of the probable errors of the mean micrometer finenesses in the quadruplicate samples. These limits of error serve as indices of the significance of the differences between the mean finenesses determined from the composite samples of body areas and regions, and the average of the quadruplicate samples of areas.

The variation between the fleece averages in mean micrometer fineness shows a remarkably close correspondence between the composites of areas and regions and the average of the quadruplicates of areas. The per cent standard error 0.80 is less than one half the prescribed limit of error. This low per cent of standard error indicates that the accuracy of zoning, in making up the composite samples of areas and regions, was remarkably high in the Cheviot fleece. The same accuracy is confirmed by an inspection of Figure No. 22. In only four areas out of the fourteen is the difference between the composites of areas and the average of the quadruplicates of areas larger than the limit of error. In the remaining ten areas the composite sample closely corresponds to the average of the quadruplicates. The side region gave the most uniform results. The inverse relationship between micrometer means and weight-length ratios is clearly demonstrated. Body areas from the shoulder to the low hip were finer than the average of the fleece, while the britch areas were particularly coarse. The fleece was uniformly fine in the shoulder, back, and side regions and was very coarse in the britch region.

A comparison of fibre thickness variability within the sample of zoned and non-zoned samples was made on seventeen samples from Cheviot Ewe No. 117. In measuring the fibre thickness of the non-zoned samples fifty fibres were drawn from each side of the sample. The average percentage figures for the coefficients of variability of fibre thickness are as follows:

Zoned samples	16.66
Non-zoned samples	16.81

The difference between these figures is negligible, indicating that zoning was not effective in reducing fibre thickness variability within the small samples whose air dry weight was from three to four tenths of a gram. A similar study of the effect of zoning in the body areas and regions gave the following results, which are the average figures for the entire fleece (14 body areas):

Coefficient of Variability of Fibre Thickness within the Sample.

Per Cent.

	Cheviot Ewe No. 117	Border Leicester Ewe No.K953
Average of Quadruplicate Samples	17.07	14.88
Average of Composites of Areas	16.18	15.31
Composites of Regions	17.10	16.59
Per Cent Standard Error of Average Variability	4.49	4.05

The large per cent standard error indicates that there is a significant difference in the variability of fibre thickness between composite and individual quadruplicate samples. Theoretically the variability of fibre thickness should be less in the composite samples because all portions of the sample are equally represented in the composite sample. However, the tendency of the fingers to pick out the coarser fibres has already been pointed out and this is undoubtedly the factor which was responsible for the larger part of the variation.

STUDIES OF FLEECE FINENESS.

Border Leicester Ewe No. K953.

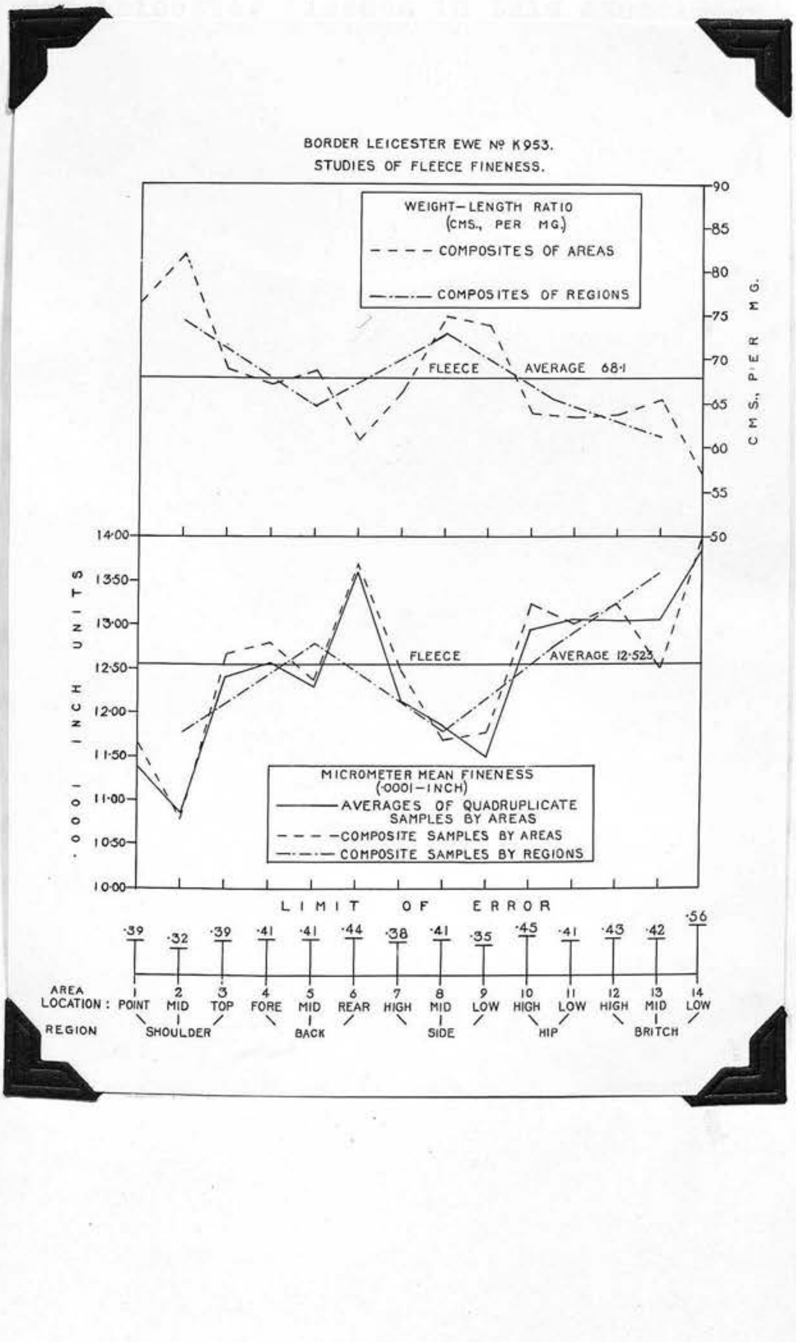
The Accuracy of Composite Samples of Areas and Regions.

	Micrometer Caliper Measurements — Mean Fineness in .0001 Inch Units			Weight-Length Ratio. Cms. per Mg.	
	Average of Quadruplicates	Composite of area	Composite of region	Composite of area	Composite of Region.
Area No. 1 Point Shoulder	11.38	11.67		76.4	
Area No. 2 Mid Shoulder	10.87	10.78	11.77	81.8	74.4
Area No. 3 Top Shoulder	12.41	12.67		69.0	
Area No. 4 Fore Back	12.57	12.80		67.3	
Area No. 5 Mid Back	12.30	12.37	12.78	68.8	64.8
Area No. 6 Rear Back	13.63	13.69		60.9	
Area No. 7 High Side	12.15	12.50		66.7	
Area No. 8 Mid Side	11.85	11.69	11.79	75.0	73.1
Area No. 9 Low Side	11.50	11.79		74.0	
Area No. 10 High Hip	12.94	13.25		64.0	
Area No. 11 Low Hip	13.07	13.01	12.73	63.6	65.7
Area No. 12 High Britch	13.05	13.23		63.8	
Area No. 13 Mid Britch	13.06	12.50	13.60	65.6	61.3
Area No. 14 Low Britch	13.83	13.99		57.2	
Average of Entire Fleece (14 body areas)	12.47	12.57	12.53	68.2	67.9

Variation between mean micrometer finenesses of entire fleece.
Per Cent Standard Error 0.53

The variation in the fleece averages of mean micrometer fineness shows a remarkably close correspondence between the composites of areas and regions and the average of the quadruplicates of areas. The per cent standard error 0.53 is less than one third of the prescribed limit of error 1.737. This very low per cent of standard error between composites and averages of the quadruplicates of areas indicates that in the Border Leicester fleece the accuracy of zoning in making up composite samples of either areas or regions, was remarkably high and composite samples of body areas or regions could be made up with confidence that they would accurately represent the mean fineness of the entire fleece. The accuracy of zoning in this fleece is confirmed by an inspection of Figure No. 23 showing the results obtained with the Border Leicester fleece. In only two areas out of the fourteen was the difference between the composite of the area and the average of the quadruplicates of the area, larger than the limit of error. In the other twelve body areas the composite sample gave practically the same result in fineness as the average of the quadruplicates of the area. The composites of areas and regions and the average of the quadruplicates of areas corresponded more closely in the side region indicating that this region had the most uniform wool. The inverse relationship between micrometer mean fineness and weight-length ratio is clearly demonstrated. It is interesting to compare the mean fineness of the

Figure No. 23.


BORDER LEICESTER EWE Nº K953.
STUDIES OF FLEECE FINENESS.
WEIGHT-LENGTH RATIO (CMS., PER MG.)
COMPOSITES OF AREAS
COMPOSITES OF REGIONS
FLEECE AVERAGE 68·1
CMS., PER MG.
90
85
80
75
70
65
60
55
50
14·00
13·50
13·00
12·50
12·00
11·50
11·00
10·50
10·00
·0001 INCH UNITS
FLEECE AVERAGE 12·523
MICROMETER MEAN FINENESS (·0001-INCH)
AVERAGES OF QUADRUPLICATE SAMPLES BY AREAS
COMPOSITE SAMPLES BY AREAS
COMPOSITE SAMPLES BY REGIONS
LIMIT OF ERROR
·39 ·32 ·39 ·41 ·41 ·44 ·38 ·41 ·35 ·45 ·41 ·43 ·42 ·56
AREA LOCATION: 1 POINT 2 MID 3 TOP 4 FORE 5 MID 6 REAR 7 HIGH 8 MID 9 LOW 10 HIGH 11 LOW 12 HIGH 13 MID 14 LOW
REGION SHOULDER BACK SIDE HIP BRITCH

different body areas with the average fineness of the entire fleece as indicated by the fourteen body areas. The shoulder and side areas were finer while the back, hip, and britch areas were coarser. Figure Nos. 22 and 23 show different types of curves for the Cheviot and Border Leicester fleeces in this experiment. The Cheviot fleece runs sub-normal from the shoulder to the hip and then becomes very coarse in the britch while the graph of the Border Leicester fleece is more irregular crossing and recrossing the average line in the areas from the shoulder to the hip, but the britch region is not so coarse in relation to the other body areas as in the Cheviot. The average fineness of the entire fleece corresponds closely in the Cheviot and Border Leicester fleeces used in this experiment, and if these fleeces were typical of the two breeds, the uniform fleece fineness of the Half-breed sheep is not such a remarkable occurence as had been generally supposed in spite of the visual fleece differences between the two parental breeds. These visual differences are mainly dependent upon differences of length of fibre and staple formation rather than upon fibre thickness.

STUDIES OF FLEECE DENSITY.

Cheviot Ewe No. 117.

The Accuracy of Composite Samples of Areas and Regions.

Number of fibres from a skin surface measuring One-half Inch Square.

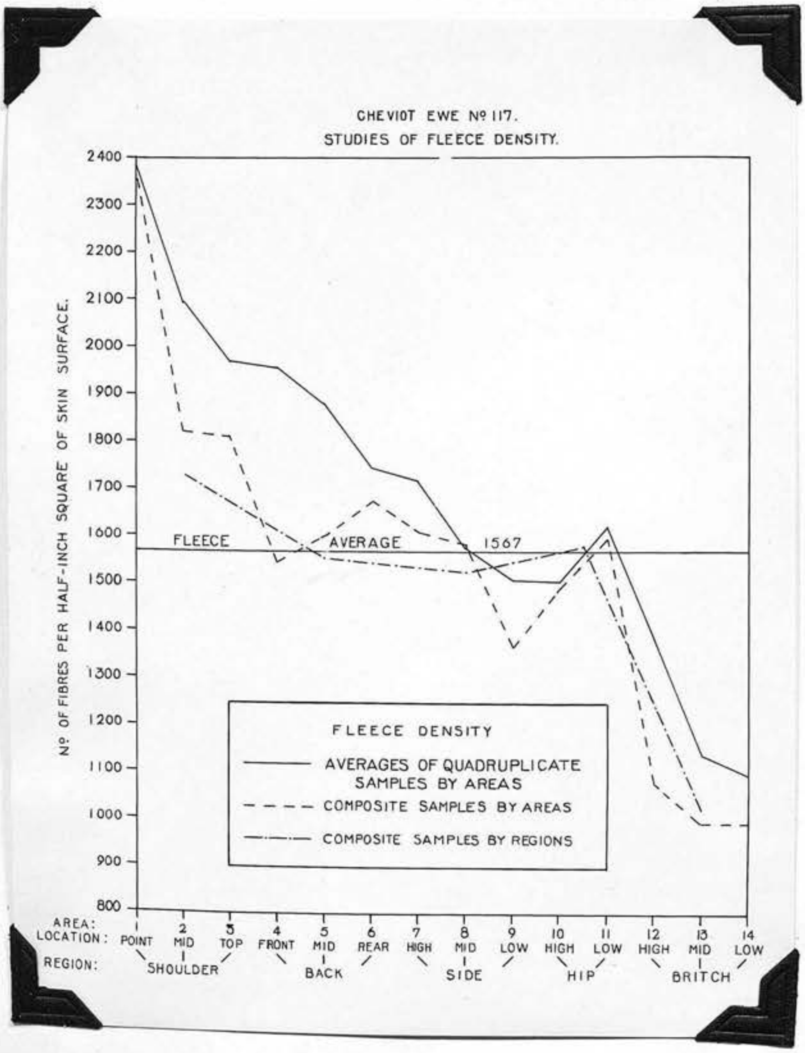
	Average of Quadruplicates	Composite of area.	Composite of Region.
Area Nol 1 Point Shoulder	2387	2356	
Area No. 2 Mid Shoulder	2095	1821	1727
Area No. 3 Top Shoulder	1971	1812	
Area No. 4 Fore Back	1953	1546	
Area No. 5 Mid Back	1881	1603	1557
Area No. 6 Rear Back	1743	1674	
Area No. 7 High Side	1718	1606	
Area No. 8 Mid Side	1573	1584	1526
Area No. 9 Low Side	1510	1368	
Area No. 10 High Hip	1505	1491	
Area No. 11 Low Hip	1622	1598	1581
Area No. 12 High Britch	1384	1077	
Area No. 13 Mid Britch	1138	994	1022
Area No. 14 Low Britch	1097	994	
Entire Fleece (14 body areas)	1629	1549	1523

Variation between Average Densities of Entire Fleece
Per Cent Standard Error 2.49

The variation between the fleece averages in fleece density shows a per cent standard error higher than the prescribed limit of error 1.737, but as already pointed out, the errors of determination are much larger for density than for fineness. The per cent standard error of density 2.49, indicates that a five per cent difference would be exceeded by chance once in 25 times. The differences are not significant when compared with the sampling error of density for the Cheviot fleece (207 fibres).

These data are shown in graphical form in Figure No. 24.

Figure No. 24.

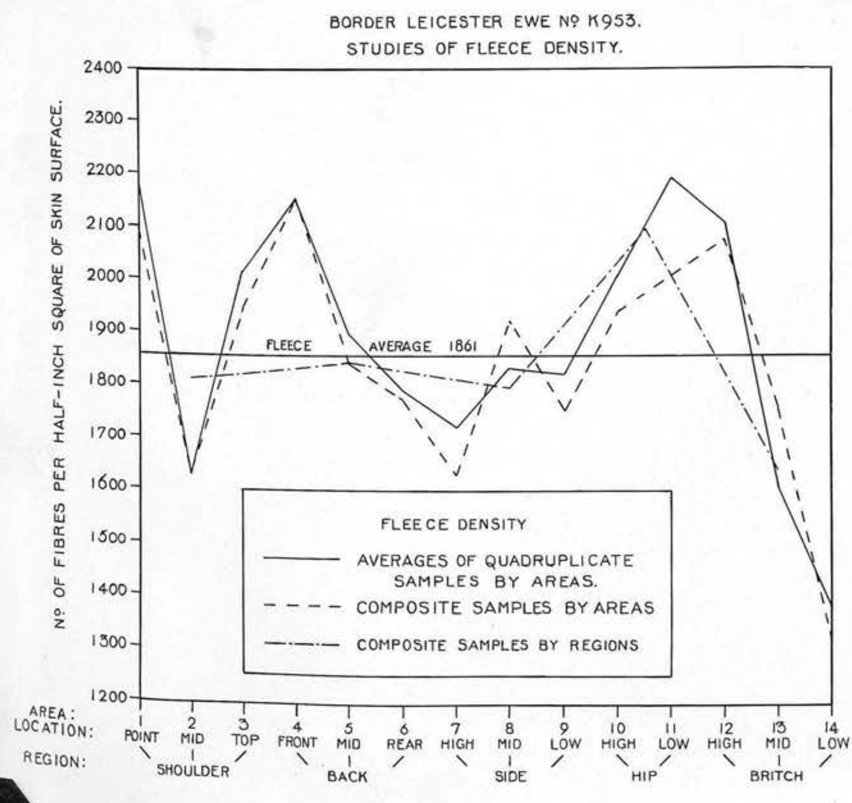


Fleece density was more uniform in the side, ip, and britch regions and less uniform in the shoul- er and back regions. In other words, the density f fleece in the side, hip and britch regions of the heviot fleece correspond more closely than in the houlder and back regions. As pointed out above, the ifferences are not significant when compared with the ampling error of density.

The variation between the fleece averages of density shows a figure which is smaller than the prescribed limit of error and this denotes that in the Border Leicester fleece the variation of density was unaffected by zoning, confirming the results already obtained with fleece fineness.

Figure No. 25 shows the Border Leicester fleece to be more uniform in density in the different body areas than was the case in the Cheviot fleece. The differences between the composite samples of areas and regions and the average of the quadruplicate samples of areas is negligible as it is less than the sampling error for density.

Figure No. 25.



The very low density in the mid shoulder area and the very high density in the low hip area did not seem logical, so new samples were taken from these areas in May 1931, for the purpose of checking the original samples taken in November 1930. The figures obtained were as follows:

Border Leicester Ewe No. K953.

Average Density.

Number of fibres from a skin surface measuring one-half inch square.

	Composite Samples of Areas.	
	Sampled Nov. 1930	Sampled May 1931.
Area No. 2 Mid Shoulder	1642	3319
Area No. 3 Low Hip	2246	2574

In both areas, and particularly in the mid shoulder, there was a large increase in the number of fibres per unit area. This would indicate that there is a strong possibility of seasonal variation of density in the same individual, certain of the follicles having a resting stage in the summer and autumn months, and becoming active in late autumn and early winter months, producing extra fibres to make up the winter coat. The results of the density determination indicate that the dormant follicles became active shortly after the ewe was sampled in November.

If fleece analysis is to be applied to sufficient numbers of fleeces to obtain results which will be of use in breeding and nutrition experiments, then the value of zoning in curtailing the time used in laboratory measurement is a particularly valuable feature.

The accurate results obtained by zoning in this experiment would indicate that the procedure of zoning samples or groups of samples to make up composite samples of body areas or regions can be followed with assurance that a true picture of the fleece will be obtained.

A COMPARISON OF MICROMETER MEAN FINENESS WITH THE WEIGHT-LENGTH RATIO.

Throughout the course of this experiment with fleece analysis weight-length ratio determinations were used as a check on the micrometer measurements. These check measurements were made on the same hundred fibres measured by the micrometer, from the composite samples of the fourteen body areas. The results obtained are shown in the following table:

STUDIES OF FLEECE FINENESS

Cheviot Ewe No. 117
and
Border Leicester Ewe No. K953.

A comparison of the micrometer mean fineness with the root of the weight-length ratio for the same hundred fibres.

Composite samples of Body Areas. Arranged by micrometer means from the coarsest to the finest.

Sample	Micrometer Mean .0001 inch	Root of Weight-Length Ratio. Cms. per Mg.
1	17.13	6.16
2	17.09	6.07
3	16.40	6.28
4	14.40	7.16
5	14.05	7.14
6	13.99	7.56
7	13.82	7.63
8	13.69	7.80
9	13.53	7.44
10	13.39	7.56
11	13.31	7.46
12.	13.25	8.00
13	13.23	7.99
14	13.01	7.97
15	12.99	7.80
16	12.90	7.83
17	12.86	8.06
18	12.80	8.20
19	12.78	7.96
20	12.67	8.31
21	12.63	7.80
22	12.50	8.10
23	12.50	8.17
24	12.37	8.29
25	11.79	8.60
26	11.69	8.66
27	11.67	8.74
28	10.78	9.44
Mean	13.34	7.80

A correlation table has been arranged from these data by grouping the Micrometer mean finenesses by half units and the root of the Weight-Length ratio finenesses by quarter units. The figures used as ordinates are the averages of the selected class intervals.

The Relationship of Micrometer Caliper Fineness and Weight-Length Ratio.

Correlation Table.

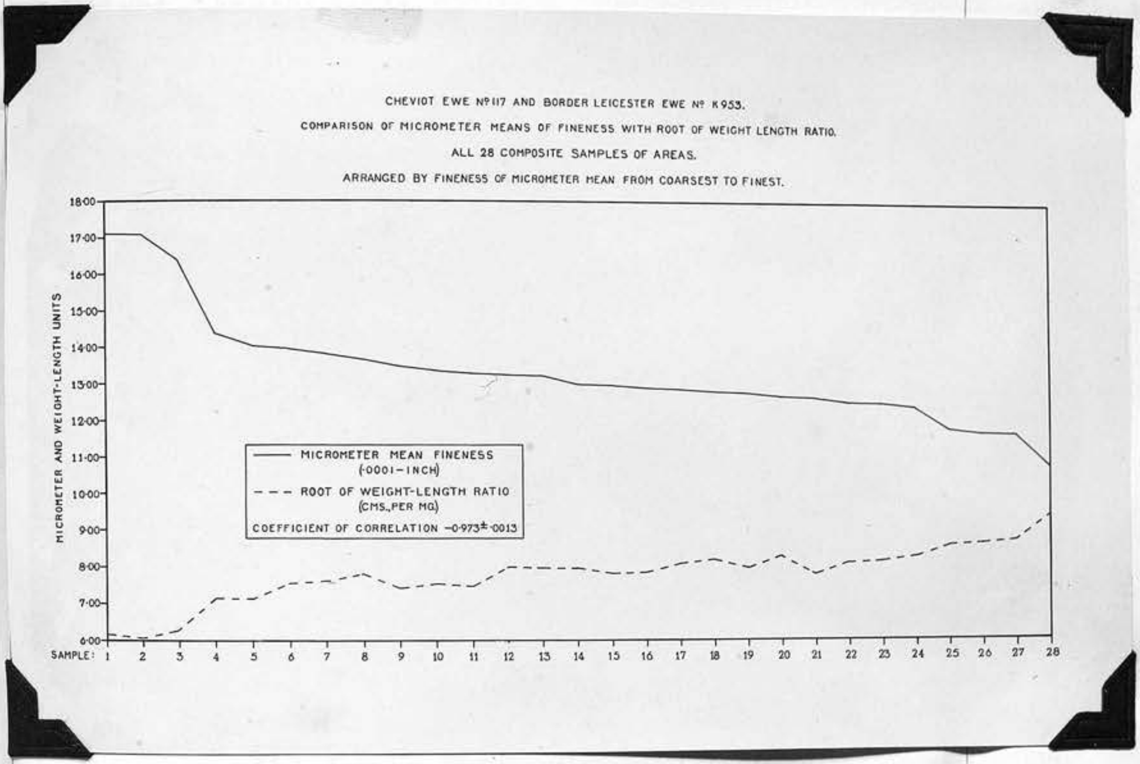
Micrometer Fineness .0001 inch.	Root of Weight-Length Ratio. Cms. per Mg.									
	6.13	6.38	7.13	7.38	7.63	7.88	8.13	8.38	8.63	9.38	Total
17.25	2										2
16.75											0
16.25		1									1
15.75											0
15.25											0
14.75											0
14.25			2								2
13.75				1	2	1					4
13.25				1	1	2	1				5
12.75						4	4	1			9
15.25								1			1
11.75									3		3
11.25											0
10.75										1	1
Totals	2	1	2	2	3	7	5	2	3	1	28

Coefficient of Correlation = $-0.973 \pm .0013$

The distribution of these data in the form of a "swarm" along a line from the upper left hand corner to the lower right hand corner, is typical of a high negative correlation; that is, the root of the weight-length ratio increases as the micrometer mean fineness decreases.

The micrometer means and roots of weight-length ratios are shown graphically in Figure No. 26.

Figure No. 26.



There was a close correspondence between the two systems of measurement which was confirmed by the high correlation coefficient. There were only eight reversals out of the twenty eight samples and of these reversals only two were of great magnitude. Although there was a high correlation there was no definite differential ratio between units, for the units of determination were far too dissimilar to expect such a relationship. The general relationship was definitely asserted and one can proceed with micrometer measurements with assurance that the mean fineness obtained will be in direct relationship, though not necessarily corresponding to a figure obtained when the weight-length ratio is used. According to a table of Wallace and Snedecor (1925) a correlation coefficient of 0.973 would indicate that the standard deviation of fineness differences due to these two systems of measurement could be reduced by 78 per cent, which is a very striking illustration of the close relationship existing between the two systems of measurement.

Some of the factors which probably enter in to make the determination of a differential ratio of units, between micrometer mean fineness and weight-length ratio, very difficult, are as follows:

1. The micrometer measurement is of fibre thickness while the weight-length ratio is an index of cylindrical volume.
2. There is a slight crushing action in micrometer measurement which is absent in the weight-length ratio.
3. The weight-length ratio is a very accurate measure of the mean fineness of a sample, for each portion of the fibre throughout its entire length contributes equally to the resultant weighted mean of fineness.
4. In micrometer measurement only a relatively small portion of the total length of the fibre contributes to the measure of fineness.

5. In a weight-length ratio each fibre contributes twice; once in respect to length and again in respect to its weight.
6. In thickness measurements each fibre contributes only once in respect to its diameter.

The mean fineness of a sample as determined by weight-length ratio and by thickness measurement corresponds only in those cases where the weight of the long coarse fibres is counterbalanced by the weight of the short fine ones. This condition evidently existed in the wool samples from the Cheviot and Border Leicester fleeces which were used in this experiment.

The Time Required for Fineness Measurement.

A record was kept of the time required to measure thickness and fibre length and the averages for 37 samples were as follows:

	Time used in measuring.
Thickness of 100 fibres with the Micrometer	26 minutes
Stretched fibre length of the same 100 fibres	39 minutes

The measurement of thickness at three places along the length of each fibre took slightly less time than the measurement of stretched fibre length. Additional time was required for weighing before the weight-length ratio was calculated.

The Necessary Number of Fibres to Measure

The coefficients of variability of mean micrometer fineness and stretched fibre length were calculated and have been incorporated into the following table of the necessary number of fibres to measure in order to conform with the limit of error selected for this experiment.

The following formula was used in these calculations:

$$n = (C/s_1)^2$$

n = necessary number of fibres to measure.

C = Coefficient of Variability of fineness or stretched fibre length.

s_1 = Per cent standard error corresponding to the selected limit of error. In this experiment the figure is 1.737.

	Micrometer Measurement and stretched Fibre Length. Necessary number of Fibres to Measure		
	Maximum	Minimum	Average
Cheviot Ewe No.117			
Micrometer Measurement.	182	56	89
Stretched Fibre length.	187	10	68
Border Leicester Ewe No. K953			
Micrometer Measurement.	110	58	81
Stretched Fibre length.	71	23	43

The dispersion of stretched fibre length was smaller than the dispersion of fibre thickness and consequently the necessary number of fibres to be measured is smaller.

The weight-length ratio and micrometer methods of determining fleece fineness work very well together, since the micrometer measurements furnish distribution data of the thicknesses of the individual fibres, while the weight-length ratio furnishes an accurate weighted mean of fineness for the sample, as well as distribution data on stretched fibre length which is very useful not only in a study of fibre length but also for indices of density other than the number of fibres per unit area.

A large number of micrometer measurements were made in obtaining the mean fineness of the individual quadruplicate samples which form the basic data of this experiment. The following table of the necessary number of fibres to measure to conform to different limits of error has been calculated from the coefficients of variability of fineness for the micrometer finenesses of the quadruplicate samples:

STUDIES OF FLEECE FINENESS.

Necessary Number of Fibres to Measure.

Micrometer Measurement.

	Cheviot Ewe No. 117			Border Leicester Ewe No. K953		
	Max.	Min.	Av.	Max.	Min.	Av.
5% difference exceeded once in 25 times	95	26	49	63	19	37
once in 50 times	122	33	63	80	24	48
once in 100 times	149	46	77	99	30	59
once in 250 times	187	50	97	123	37	73
10% difference exceeded once in 25 times	24	6	12	16	5	9
once in 50 times	30	8	16	20	6	12
once in 100 times	37	10	19	25	7	15
once in 250 times	47	13	24	31	9	18

In all cases the measurement of 100 fibres was more than sufficient to ensure a limit of error of a 5 per cent difference exceeded by chance once in 250 times. The measurement of 100 fibres gave data which adapted itself particularly well to statistical treatment for in the formulas requiring a division by the square root of n, the quotient was merely the dividend pointed off to the first place.

DISCUSSION.

Certain factors to be considered in the determination of fleece fineness which covered the different phases of variation in mean fineness from the individual fibre on up through the variation in samples, areas, fleeces and breeds of sheep were outlined in the introduction.

The accuracy of the measurement of the average thickness of each individual fibre has been tested by a number of investigators who have reported a great variability of thickness from base to tip. Insofar as the writer is aware, no definite measure has been made of the contribution of each fibre to the mean fineness of the sample. This would be a very tedious task involving thousands of measurements. However, the fleece analysis experiment just completed by the writer gives indirect information which can be applied to this problem. In the weight-length ratio method each portion of the fibre throughout its entire length contributes equally to the resultant weighted mean of fineness. As the same fibres were used in the determination of average fineness by the micrometer and weight-length ratio methods, the results obtained are directly comparable. The close correspondence of the fineness figures obtained by the two methods and the exceptionally high coefficient of correlation indicate that even though the fibre was variable along its length still the measurement of thickness at three places along its length gave results for average fineness which corresponded very closely with those obtained by the weight-length ratio. The variation in thickness along individual fibres was compensated for, insofar as mean fineness of samples was concerned, by taking measurements of thickness at three different portions of their length. (The width of the micrometer jaws is three sixteenths of an inch.)

The second phase of fineness variation to be considered is the variation of average thickness among different individual samples and the effect of measuring different numbers of fibres on the accuracy of the figure for average fineness. Roberts (1930) in his work with the analysis of the sample, stated that in zoned samples the number of fibres measured was independent of the size of the sample. This experiment has shown that the measurement of one hundred fibres gawe a result which was within a five per cent difference exceeded by chance once in 250 times. This is rather a narrow limit of error and it is quite likely that in the majority of wool samples the measurement of a hundred fibres from a composite sample would give satisfactory results.

The third phase of fineness variation to be considered is the variation of average thickness among different samples within a body area. In this experiment the variation among the quadruplicate samples within an area was very small, in fact it was smaller than the variation within each individual sample. This indicates that there was no great variation in mean fineness between adjacent samples of wool in a selected area. Single samples from each body area would have been sufficient in this experiment, but duplicate samples are preferable as the results from one sample may be used as a check on the other one. The small size (two to seven tenths of a gram), of these samples must be remembered when comparing these results with results obtained with much larger samples, which should be compared with the results obtained between body areas in this experiment.

The small samples taken at a number of points over the body tend to give a better picture of the entire fleece than a single large area, which would represent only the one particular body region. In cooperative projects with sheep breeders, small samples can be taken from stud animals without damaging the appearance of the sheep--a practical point which is of considerable importance.

The fourth phase of fineness variation to be considered is the variation of average fineness among different areas of the fleece. The variation in mean fineness between the body regions exceeded the prescribed limit of error. The following outline diagrams show the location of the body areas and the average of the mean finenesses of the quadruplicate samples of each area. The area number is within the circle and underneath is the micrometer mean fineness in ten thousandths of an inch.

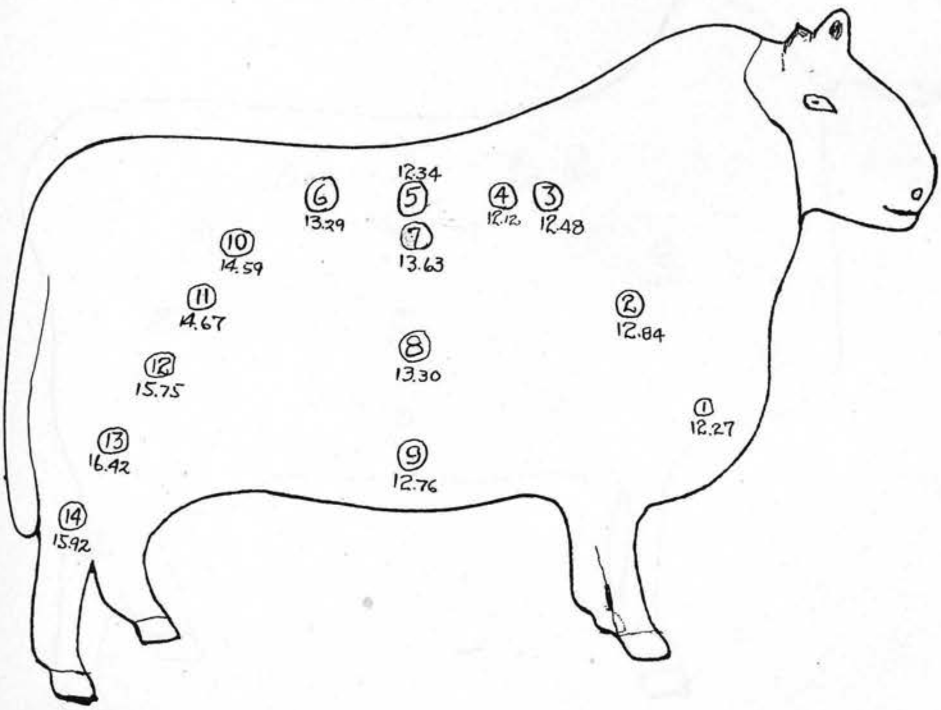
Cheviot Ewe No. 117. *

Mean Micrometer Fineness.

.0001 Inch Units.

Average of Quadruplicate Samples.

Figure No. 27.



* Drawing taken from a photograph of a prize-winning Cheviot Ram.

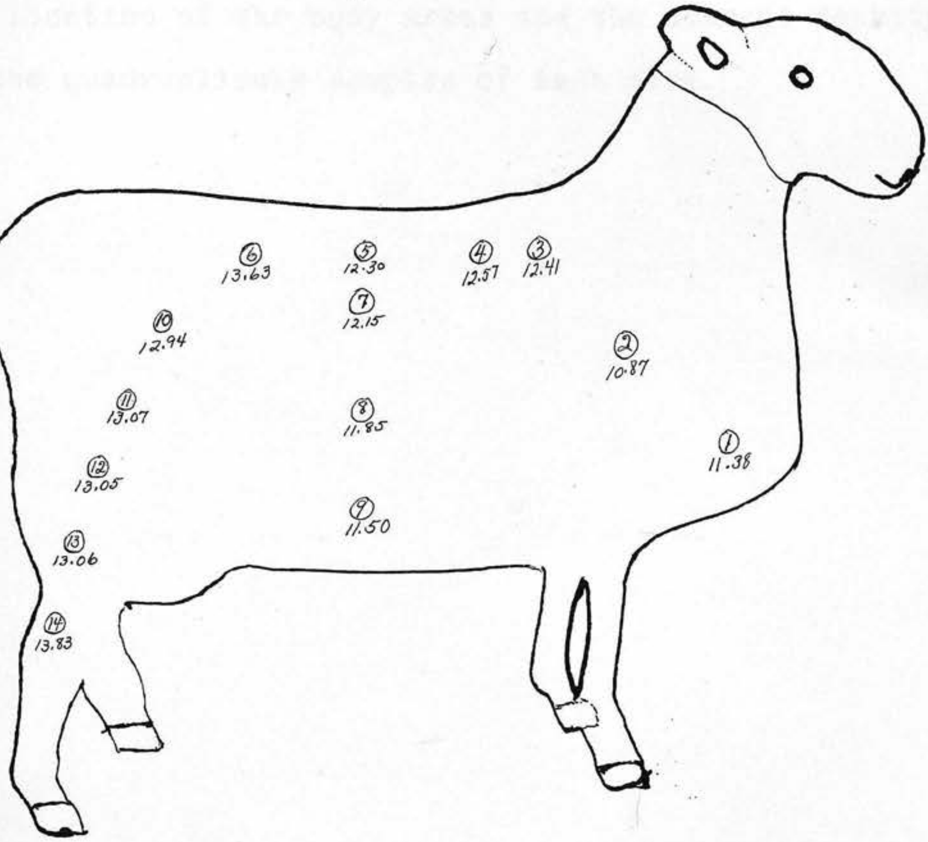
Border Leicester Ewe No. K953. *

Mean Micrometer Fineness.

.0001 Inch Units.

Average of Quadruplicate Samples.

Figure No. 28.



* Drawing taken from a photograph of a prize-winning Border Leicester Ram.

The variation of mean finenesses indicate that in order to obtain results within the selected limit of error, it would be necessary to sample in at least three areas within each body region. The Cheviot fleece is much coarser in the britch region than the Border Leicester.

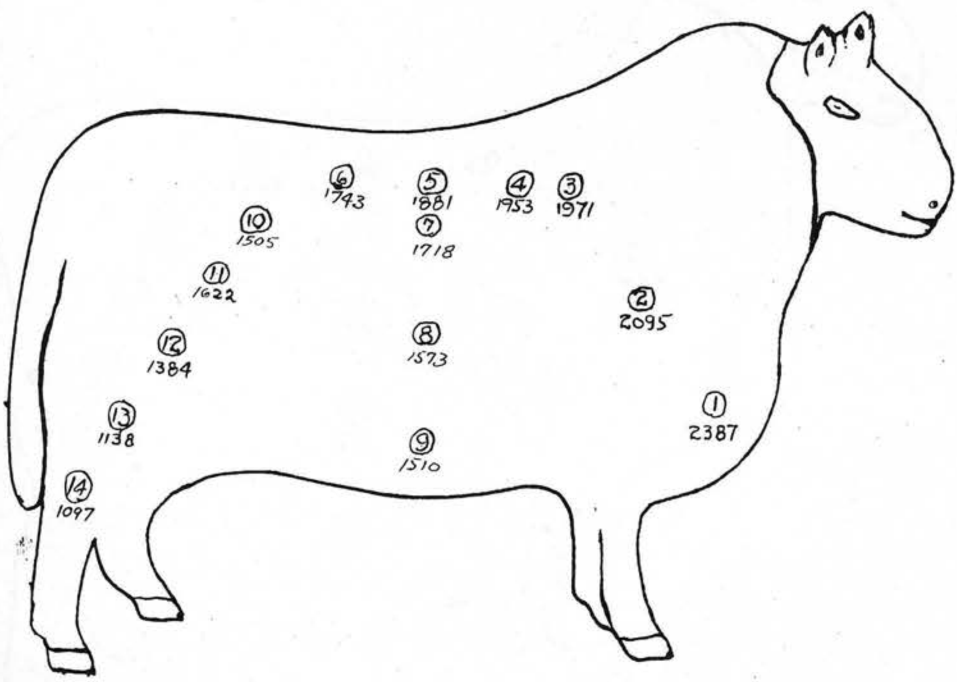
The variation of average density between the different body regions exceeded the selected limit of error. The following outline diagrams show the location of the body areas and the average density of the quadruplicate samples of each area.

Cheviot Ewe No. 117.*

Average Density.

Calculated Number of Fibres from a Skin Surface Measuring One-half Inch Square.

Figure No. 29.



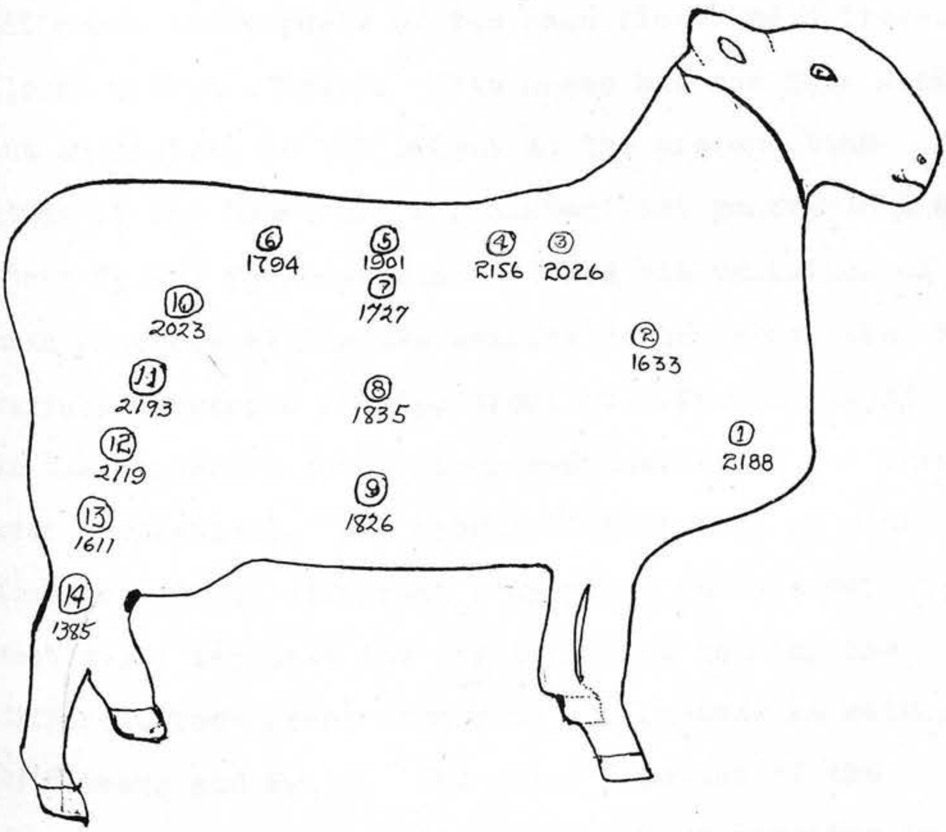
* Drawing taken from a photograph of a prize-winning Cheviot Ram.

Border Leicester Ewe No. K953.*

Average Density.

Calculated Number of Fibres from a Skin Surface Measuring One-half Inch Square.

Figure No. 30.



* Drawing taken from a photograph of a prize-winning Border Leicester Ram.

The results obtained with density confirm the results obtained with mean fineness. In order to obtain accuracy within the selected limit of error, at least three areas from each body region should be sampled. There was an indication that there is a seasonal variation of density for in the Border Leicester samples taken in May 1931 there were more fibres per unit area than in the samples taken in November 1930 from the same areas on the same sheep.

The fifth phase of fineness variation to be considered is the variation of average fineness among different individuals of the same flock and different flocks within a breed. This phase has not been worked out accurately to any extent at the present time. A study of the Hampshire and Rambouillet generations and their F_1 and F_2 generations showed the variation of mean fineness within the samples to be larger than the variation between similar areas on different sheep in the crossbred generations and smaller in the purebred generations. The random distribution of mean fineness of the different body areas in this experiment would indicate the difficulty of ranking the different body areas according to fineness as attempted by Reimers and Swart. The major portions of the fleece in this experiment were so close together in fineness that slight environmental changes could alter the fineness ranking in a subsequent analysis of the same fleece sampled at a later date.

The number and location of the samples taken will depend on the nature of the material under study and the objects of the experiment. The study of the measurable fleece characters of the same individual sheep at different times as influenced by nutrition requires a sample which will give a good average figure. The side region would be the most representative region from which to select samples. Samples from the side region would be sufficient in the British Coarse Woolled Mountain breeds in which the coarseness of the britch is not important. In fleece analysis studies of commercial flocks of fine-wool and crossbred type samples from the side region should be sufficient to give average figures of fineness. In fleece analysis of pedigree flocks samples should be taken from at least three body regions; the side, hip, and britch, so as to get an index of the variation within the fleece. In detailed fleece analysis studies of the individual sheep, for instance in stud rams and ewes, samples should be taken from fourteen body areas. A composite sample of the side region should suffice for fleece analysis in crossbreeding experiments where the parental breeds differ greatly in fineness, such as the Lincoln-Merino cross.

It is hard to lay down definite rules to cover all cases of fleece analysis as so much depends upon the specific nature of the experiment as well as upon the breed of sheep employed.

Laboratory analysis of the fleece is useful in the study of the individual fleece, for at the present time we know very little concerning the balance which exists between heredity and environment as manifested in the measurable characters of the fleece. The wool measurements which have been made by different investigators have often given contradictory results due to different methods of analysis, in the selection of body areas for sampling, the selection of individual sheep, and the technique of making up and measuring the samples. At the present time we do not have any measurement of the relative importance of each of these factors in such differences. The errors of determination in any of the factors are large and these errors must be known for each type and breed of sheep before any accurate results can be obtained in breeding or nutritional projects which involve measurable fleece characters. The environment of the fleece can be controlled only within certain limits, which may be designated as normal conditions of health and management. Outside of these limits there are the effects due to sex, season and age, and finally the effects due to heredity. With such a great number of sources of error it is not surprising that contradictory results have been obtained in the study of measurable fleece characters.

In this experiment certain of these errors of sampling and the technique of making up and measuring the samples have been determined individually and collectively. The variation of fleece fineness and density on the individual sheep has been studied and supplementary data has shown the variation between similar body areas on different fleeces of the same breed. There remains the question of the variation between body areas of different sheep of the same breed and different breeds.

In such a complex problem, with such a variety of errors, any one of which may seriously affect the results obtained, it is necessary to do a large amount of carefully planned measurement work to determine the normal variation in fleece characters of the different breeds of sheep. It is absolutely necessary to know the range of variation of measurable fleece characters due to environment before any accurate study can be made of hereditary factors. It is much too large a problem for any one experiment station and it is hoped that the various stations throughout the world which are working with wool research, will cooperate and coordinate their work, for without coordination of results and isolation and control of the different errors of determination, the results obtained by laboratory fleece analysis will be of little use.

SUMMARY.*

1. Three micrometer measurements of thickness at three portions of one hundred fibres gave a mean fineness closely corresponding to the weight-length ratio.

2. The measurement of one hundred fibres from each sample gave a mean fineness well within the selected limit of error; a five per cent difference exceeded by chance once in 250 times.

3. The variation between mean finenesses of quadruplicate samples around a selected point on the body was negligible.

4. The variation between average density of quadruplicate samples around a selected point on the body was significant. This was due to the errors of sampling and determination by proportionate weights.

5. The Wyedina Fleece Caliper proved a more accurate instrument for taking density samples than the ordinary engineer's caliper.

6. The variation between the average mean finenesses of different areas of the body was significant.

7. The variation between averages of density of different areas of the body was significant in the Cheviot, Border Leicester, Hampshire,

*All statements refer to the detailed fleece analysis of the Cheviot and Border Leicester fleeces unless stated otherwise.

7. Contd.

Rambouillet, and crossbred Hampshire x Rambouillet fleeces.

8. There was a significant variation in mean fineness between similar body areas of different sheep of the same breed. The variation within the samples was much less than the gross variation between similar areas in the Hampshire and Rambouillet generations, but of the same size in the F_1 and F_2 generations.

9. Composite samples of body areas and regions, made up by zoning the quadruplicate samples gave fineness and density figures which corresponded closely with the results obtained by averaging the determinations from each quadruplicate within the area or region.

10. Micrometer means of fineness corresponded closely with Weight-Length Ratios of the same fibres. The Coefficient of Correlation was 0.973 ± 0.0013.

11. The system of sampling adopted for any particular experiment would depend on the nature of the fleeces of the sheep under study and the objects of the experiment.

    A. In crossbreeding experiments where the parental breeds show great differences

11. Cont'd.

of fleece type as in the Lincoln and Merino, a composite sample of the side region would give satisfactory results.

B. In crossbreeding experiments where the parental breeds are similar in fleece type composite samples of at least three body regions (side, hip, and britch) should be taken, and if possible the back and shoulder regions should also be sampled.

C. In wool inheritance studies within a breed in which wool is a major consideration, particularly in the study of individual fleeces of stud rams and ewes, duplicate samples should be taken from the fourteen body areas designated in this experiment.

D. In wool inheritance, particularly kemp studies, in British Coarsewoolled Mountain breeds, composite samples from the appropriate dorsal region should be sufficient.

E. In studies of the effect of environment on measurable fleece characters, samples from a tattooed area in the side region would give satisfactory results.

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Fleece Analysis for Biological and Agricultural Purposes.
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Correlation and Machine Calculation.
Iowa State College of Agri. and Mechanic Arts. Official Publication. Vol. 23 No. 35 Pp. 47.

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The writer wishes to thank the following people for their assistance in the Hampshire x Rambouillet Crossbreeding Experiment:

Mr. J. A. Hill of the Wyoming Experiment Station, who planned the experiment and developed the density determination method.

Mr. F. A. Hays, of the Massachusetts Experiment Station, formerly of the Wyoming Experiment Station, who had charge of the mating and management of the sheep during the first two years of the experiment and who planned the experiment in cooperation with Mr. J. A. Hill.

Mr. F. S. Hultz, of the Wyoming Experiment Station, who had charge of the mating and management of the sheep during the latter part of the experiment.

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APPENDIX.

Table No. 1.

F L E E C E   A N A L Y S I S.

MICROMETER MEASUREMENT

Frequency Distribution Data.

Cheviot Ewe No. 117.	Size in .0001 Inch.												Mean Fine-ness
	7	8	9	10	11	12	13	14	15	16	17	18	
Area No. 1. Pt. of Shoulder.													
Sample No. 1. Not Composite	1	3	5	9	13	9	25	16	13	4	1	1	12.60
Composite	1	5	3	12	6	15	19	21	14	4			12.55
Sample No. 2. Not Composite		3	3	11	12	18	29	6	16	1	1	1	12.49
Composite		1	1	12	13	16	22	17	15	2	1		12.70
Sample No. 3. Not Composite	1	4	7	12	14	16	18	14	10	5			12.16
Composite	2	6	10	11	14	17	18	8	12	3			11.82
Sample No. 4. Not Composite	2	2	9	13	12	18	21	9	11	3			12.01
Composite	2	1	3	17	23	10	21	9	12	2			12.03
Composite Sample of Area No. 1.		4	1	8	11	19	19	10	19	9			12.86
Area No. 2. Mid Shoulder													
Sample No. 1. Not Composite		3	7	5	11	10	22	17	8	7	8	2	13.06
Composite		2	4	6	11	21	21	11	14	4	5	1	12.89
Sample No. 2. Not Composite		2	4	2	9	15	15	18	25	5	2	4	13.46
Composite			3	9	17	13	23	13	11	7	4	1	12.91
Sample No. 3. Not Composite		1	6	9	15	13	21	19	12	3	2		12.61
Composite		3	3	12	8	18	16	21	12	6	1		12.70
Sample No. 4. Not Composite		5	6	6	13	8	25	18	15	2	2	1	12.66
Composite		1	8	5	18	14	11	17	13	10	2	1	12.84
Composite Sample of Area No. 2.			1	7	8	13	9	20	19	16	5	2	13.82

APPENDIX.

Table No. 1. Cont'd.

Cheviot Ewe No. 117.	Size in .0001 Inch.												Mean Fine-ness
	7	8	9	10	11	12	13	14	15	16	17	18	
Area No. 3. Top Shoulder													
Sample No. 1.													
Not Composite			8	15	20	15	19	9	15	2			12.16
Composite		3	5	18	15	14	16	9	11	7	2		12.27
Sample No. 2.													
Not Composite	1	2	10	15	13	11	20	16	8	4	1		12.11
Composite		1	7	14	8	23	17	13	10	3	3	1	12.45
Sample No. 3													
Not Composite		2	8	15	19	10	16	14	11	3	3		12.23
Composite		4	4	9	12	21	13	18	13	5	1		12.55
Sample No. 4													
Not Composite		1	0	13	18	17	11	13	17	8	3		12.86
Composite		1	5	14	12	16	17	10	13	8	3		12.65
Composite Sample of Area No. 3			4	12	15	14	13	14	25	2	1		12.78
Composite Sample of Shoulder Region (Areas 1-3)			2	9	10	12	17	19	25	4	2		13.22
Area No. 4. Fore Back.													
Sample No. 1.													
Not Composite		1	7	14	17	15	14	12	9	6	4	1	12.45
Composite		2	7	19	20	11	18	9	7	3	3	1	12.03
Sample No. 2.													
Not Composite		0	12	14	17	21	16	6	6	6	2	0	11.99
Composite		1	5	14	17	16	17	15	7	6	1	1	12.39
Sample No. 3.													
Not Composite		0	15	11	18	7	14	15	10	5	3	1	12.30
Composite		1	12	15	12	20	12	15	9	2	2	0	12.05
Sample No. 4.													
Not Composite		3	6	17	21	11	18	13	5	4	2	0	12.00
Composite	1	2	10	16	11	20	14	13	8	2	2	1	12.02
Composite Sample of Area No. 4.		1	4	10	9	15	8	13	19	14	5	2	13.39

APPENDIX.

Table No. 1. Cont'd.

Cheviot Ewe No. 117.	Size in .0001 Inch.												Mean Fine-ness.
	8	9	10	11	12	13	14	15	16	17	18	19	
Area No. 5. Mid Back.													
Sample No. 1. Not Composite	0	4	20	9	13	14	21	14	5	1			12.61
Composite	0	6	8	9	22	24	15	12	3	0	1		12.65
Sample No. 2. Composite	1	9	14	14	18	22	14	6	2				12.03
Sample No. 3. Composite		6	15	17	21	14	13	7	6	2			12.30
Sample No. 4		8	17	10	11	19	19	13	2	0			12.36
Composite Sample of Area No. 5.	4	1	14	11	14	16	22	11	7				12.63
Area No. 6. Rear Back.													
Sample No. 1. Composite		3	16	8	9	15	17	11	13	5	2	1	13.29
Sample No. 2. Composite		6	14	13	8	14	14	17	10	3	1		12.95
Sample No. 3. Composite		6	9	10	6	12	14	18	16	6	2	1	13.61
Sample No. 4. Composite		3	10	14	10	15	13	16	11	6	2		13.32
Composite Sample of Area No. 6.	1	6	7	7	14	13	15	22	10	5			13.31
Composite Sample of Back Region (Areas 4-6)	4	4	9	8	17	15	11	18	12	2			12.95
Area No. 7. High Side.													
Sample No. 1. Composite		3	3	12	15	9	17	25	11	5	0	1	13.65
Sample No. 2. Composite			9	8	9	16	13	27	11	4	3		13.79
Sample No. 3. Composite		2	6	11	15	17	12	21	9	4	2	1	13.50
Sample No. 4. Composite			4	8	19	16	18	21	10	4			13.59
Composite Sample of Area No. 7.		2	4	8	12	22	17	26	4	5			13.53

APPENDIX.

Table No. 1. Cont'd.

Cheviot Ewe No. 117.	Size in .0001 Inch 8	9	10	11	12	13	14	15	16	17	18	19	20	Mean Fineness.
Area No. 8. Mid Side														
Sample No. 1. Composite		1	7	8	11	20	23	14	9	6	1			13.55
Sample No. 2. Composite		2	8	11	10	16	23	19	6	3	2			13.37
Sample No. 3. Composite		5	10	7	13	20	19	10	9	4	2	1		13.21
Sample No. 4. Composite	2	1	8	11	18	17	17	14	8	4				13.07
Composite Sample of Area No. 8.			18	8	14	16	15	21	7	0	1			12.99
Area No. 9. Low Side														
Sample No. 1. Composite		3	4	17	13	28	19	11	5	1				12.89
Sample No. 2. Composite	1	5	16	3	14	22	18	19	2					12.69
Sample No. 3. Composite	2	4	8	10	12	18	21	13	11	3				13.10
Sample No. 4. Composite	3	9	11	11	15	19	21	5	4	3				12.35
Composite Sample of Area 9.		1	13	11	11	21	24	15	4					12.90
Composite Sample of Side Region (Areas 7-9)	1	0	6	12	14	23	19	15	9	1				13.19
Area No. 10. Hip.														
Sample No. 1 Composite			3	3	5	13	14	25	19	15	2	1		14.77
Sample No. 2. Composite		1	2	3	3	17	15	33	15	7	3	0	1	14.57
Sample No. 3. Composite			7	6	13	13	15	13	10	13	8	2		14.29
Sample No. 4. Composite		1	4	3	3	12	21	17	18	17	3	1		14.73
Composite Sample of Area No. 10.			1	7	9	19	13	22	18	12	1	1		14.40

APPENDIX.

Table No. 1. Cont'd.

Cheviot Ewe No. 117.	Size in .0001 Inch																	Mean Fineness.
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Area No. 11. Low Hip.																		
Sample No. 1. Composite		3	10	9	5	8	19	18	16	10	2							14.88
Sample No. 2. Composite	1	7	6	4	10	10	19	19	8	10	3	3						14.85
Sample No. 3. Composite	1	2	7	12	13	13	16	16	12	6	2							14.47
Sample No. 4. Composite	2	4	6	5	12	11	23	22	12	3								14.49
Composite Sample of Area No.11.	2	3	8	11	17	13	20	13	8	5								14.05
Composite Sample of Hip Region (Areas 10,11)	3	8	7	9	14	13	18	14	9	4	1							13.94
Area No. 12. High Britch.																		
Sample No.1. Composite	2	8	6	7	7	3	12	11	9	10	7	8	7	1	1	0		15.71
Sample No.2. Composite	1	2	2	4	8	13	16	4	10	10	6	8	9	6	1	0		16.57
Sample No.3. Composite	3	8	6	7	14	10	9	16	7	5	8	4	1	0	2	0		14.78
Sample No.4. Composite	3	1	5	4	14	8	11	7	12	14	6	7	6	1	0	1		15.93
Composite Sample of Area No.12.		3	2	3	4	4	11	12	12	12	13	12	11	1				17.13
Area No. 13. Mid Britch																		
Sample No.1. Composite	1	5	6	5	8	8	4	15	9	9	5	11	9	2	2	1	1	16.43
Sample No.2. Composite		3	8	4	3	7	10	17	10	10	6	4	8	2	7	1		16.66
Sample No.3. Composite	2	1	5	3	7	8	12	15	9	7	10	4	8	6	3			16.60

APPENDIX.

Table No. 1. Cont'd.

Cheviot Ewe No. 117.	Size in .0001 Inch																		Mean Fine-ness
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Area No. 13. Mid Britch.																			
Sample No.4 Composite		1	6	4	6	8	8	11	11	14	8	6	8	3	2	2	1	1	16.00
Composite Sample of Mid Britch. (Area No. 13)			9	1	2	3	4	12	12	5	12	8	17	10	3	0	2		17.09
Area No. 14 Low Britch.																			
Sample No.1. Composite	1	0	4	3	8	12	5	10	12	10	5	7	11	8	3	1	1	0	16.23
Sample No.2. Composite	0	1	5	12	11	11	9	6	12	8	4	2	9	6	1	3	0	0	15.17
Sample No.3 Composite	0	1	5	7	3	15	5	12	13	9	7	6	8	2	5	1	0	1	15.78
Sample No 4 Composite	1	0	3	4	7	2	11	14	12	12	3	2	13	10	4	1	1	0	16.49
Composite Sample of Area No.14		2	6	4	5	8	4	14	10	9	7	5	9	10	5	2	1		16.40
Composite Sample of Britch Region (Areas 12-14)	1	2	3	8	4	6	6	11	4	11	8	7	9	11	6	1	1	1	16.62

APPENDIX.

Table No. 1. Cont'd.

Sampled Nov. 7, 1930.

Border Leicester Ewe No. K953	Size in .0001 Inch. 7	8	9	10	11	12	13	14	15	16	17	18	19	Mean Fineness.
Area No. 1. Pt. of Shoulder														
Sample No. 1. Composite		7	11	19	21	14	14	9	5					11.27
Sample No. 2. Composite		2	2	23	20	18	22	11	2					11.70
Sample No. 3. Composite		2	10	30	18	13	12	12	2	1				11.30
Sample No. 4. Composite	1	8	8	23	19	9	17	12	3					11.24
Composite Sample of Area No. 1.		2	4	20	24	16	19	13	2					11.67
Area No. 2. Mid Shoulder														
Sample No. 1. Composite	0	3	4	29	36	14	9	4	1					11.02
Sample No. 2. Composite	1	2	14	30	31	13	7	1	1					10.66
Sample No. 3. Composite		3	9	32	23	20	10	2	1					10.91
Sample No. 4. Composite	1	3	17	17	32	17	8	3	1	1				10.87
Composite Sample of Area No. 2.		7	7	33	27	11	10	5						10.78
Area No. 3. Top Shoulder														
Sample No. 1. Composite			2	10	22	11	18	14	16	6	1			12.75
Sample No. 2. Composite			3	12	17	20	15	15	15	3				12.52
Sample No. 3. Composite				17	19	16	22	13	8	5				12.39
Sample No. 4. Composite			7	19	17	24	12	10	4	7				11.96
Composite Sample of Area. No. 3			2	11	15	23	12	17	16	4				12.67
Composite Sample of Shoulder Region (Areas 1-3)	1	4	3	14	22	23	18	8	5	2				11.77

APPENDIX.

Table No. 1. Cont'd.

Border Leicester Ewe No. K953	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean Fineness.
Area No. 4. Fore Back														
Sample No. 1. Composite			4	14	14	14	15	19	15	3	3			12.70
Sample No. 2. Composite			3	16	12	14	16	16	15	7	0	1		12.74
Sample No. 3. Composite			5	17	19	16	9	11	17	6				12.38
Sample No. 4. Composite			2	17	20	12	17	13	17	3				12.46
Composite Sample of Area No. 4.			2	16	12	12	19	14	18	6	1			12.80
Area No. 5. Mid Back														
Sample No. 1 Composite			3	20	15	16	20	10	12	4				12.28
Sample No. 2 Composite			7	15	17	13	16	15	13	4				12.33
Sample No. 3 Composite			6	26	10	19	9	13	13	3	1			12.11
Sample No. 4 Composite			3	15	18	13	22	12	12	4	1			12.46
Composite Sample of Area. No. 5														
Area No. 6. Rear Back.														
Sample No. 1 Composite				14	14	11	11	12	23	11	3	1		13.27
Sample No. 2 Composite				5	14	13	10	15	19	15	7	2		13.80
Sample No. 3 Composite				4	10	9	17	12	27	15	5	1		13.95
Sample No. 4 Composite			2	5	15	13	9	14	28	10	3	1		13.51
Composite Sample of Area No. 6.				10	11	7	14	15	27	7	8	0	1	13.69
Composite Sample of Back Region. (Areas 4-6)			1	19	9	13	24	11	14	6	2	1		12.78

APPENDIX.

Table No. 1. Cont'd.

Border Leicester Ewe No. K953	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean Fineness
Area No. 7. High Side														
Sample No. 1. Composite		1	5	13	13	22	16	16	10	4				12.36
Sample No. 2. Composite		1	8	21	22	18	11	12	6	1				11.65
Sample No. 3. Composite			2	12	17	23	23	16	6	1				12.30
Sample No. 4. Composite		1	0	16	21	21	15	14	8	3	0	1		12.28
Composite Sample of Area No. 7		1	3	13	18	11	21	15	16	2				12.50
Area No. 8. Mid Side														
Sample No. 1. Composite		2	5	26	11	24	20	6	5	1				11.65
Sample No. 2. Composite			3	17	21	21	21	11	4	2				11.99
Sample No. 3. Composite			1	22	22	14	19	13	7	2				12.05
Sample No. 4. Composite	1	3	9	17	19	18	12	11	7	3				11.70
Composite Sample of Area No. 8		6	9	18	19	13	11	11	10	3				11.69
Area No. 9. Low Side.														
Sample No. 1 Composite		2	4	20	25	26	17	4	1	1				11.47
Sample No. 2. Composite			7	17	27	25	15	7	1	1				11.54
Sample No. 3. Composite		4	9	17	19	21	16	11	3					11.51
Sample No. 4. Composite		2	12	18	22	15	18	10	1	2				11.47
Composite Sample of Area No. 9		2	4	16	21	23	20	10	4					11.79
Composite Sample of Side Region Areas (7-9)	1	4	8	20	16	12	16	10	8	5				11.79

APPENDIX.

Table No. 1. Cont'd.

Border Leicester Ewe No. K-953.	Size in .0001 Inch. 8	9	10	11	12	13	14	15	16	17	18	19	20	Mean Fineness.
<u>Area No. 10.</u> Hip.														
Sample No. 1. Composite			13	12	15	14	18	16	8	4				13.12
Sample No. 2. Composite		2	13	12	10	12	16	23	9	3				13.20
Sample No. 3. Composite		2	17	13	22	11	13	18	4					12.54
Sample No. 4. Composite	1	5	12	13	14	10	13	18	13	1				12.91
Composite Sample of Area No. 10		1	15	10	13	13	7	27	10	4				13.25
<u>Area No. 11.</u> Low Hip														
Sample No. 1. Composite		3	11	10	13	20	17	12	11	2	1			13.09
Sample No. 2. Composite		1	5	11	22	17	14	23	7					13.18
Sample No. 3. Composite		3	7	9	19	20	17	15	9	0	1			13.09
Sample No. 4. Composite		1	9	17	14	20	16	14	8	1				12.93
Composite Sample of Area No. 11.	1	4	7	15	17	11	13	20	11	1				13.01
Composite Sample of Hip Region (Areas 10-11)	1	3	20	8	12	19	9	18	7	3				12.73

Appendix.

Table No. 1. Cont'd.

Border Leicester Ewe No. K-953	Size in .0001 Inch. 8	9	10	11	12	13	14	15	16	17	18	19	20	21	Mean Fineness.
<u>Area No. 12.</u> High Britch.															
Sample No. 1. Composite	1	2	10	11	15	21	7	19	10	3	1				13.12
Sample No. 2. Composite	3	2	5	10	18	23	10	16	9	4					13.09
Sample No. 3. Composite	1	1	6	10	26	22	14	13	7						12.88
Sample No. 4. Composite	3	0	7	7	19	24	12	16	12						13.11
Composite Sample of Area No.12	1	0	6	14	17	21	12	14	10	4	1				13.23
<u>Area.No. 13.</u> Mid Britch.															
Sample No. 1. Composite	1	4	8	15	20	16	12	14	9	1					12.76
Sample No. 2. Composite	3	4	6	13	16	18	15	17	7	1					12.83
Sample No. 3. Composite		4	5	8	17	23	21	14	6	1	1				13.12
Sample No. 4. Composite		3	7	7	9	25	14	21	8	3	2	0	1		13.53
Composite Sample of Area No.13.	4	4	7	16	20	19	10	13	5	2					12.50
<u>Area No. 14.</u> Low Britch.															
Sample No. 1. Composite		8	9	17	13	13	16	9	7	6	2				12.83
Sample No. 2. Composite	1	2	4	11	13	15	8	13	13	6	8	4	1	1	14.16
Sample No. 3. Composite			8	14	10	18	11	17	9	10	2	0	1		13.67
Sample No. 4. Composite	1	3	1	6	10	13	18	15	8	8	7	4	4	2	14.65
Composite Sample of Area No.14		1	8	6	15	16	12	17	10	5	5	2	3		13.99
Composite Sample of Britch Region (Areas 12-14)	1	2	6	6	13	26	11	18	8	5	1	1	2		13.60

APPENDIX.

Table No. 2. Cont'd.

F L E E C E A N A L Y S I S.

WEIGHT-LENGTH RATIO.

Cheviot Ewe No. 117 Sampled Nov. 7, 1930	Total Length in cms.	Absolute dry weight in mgs.	Weight-Length Ratio.
Composite of Area No.12 High Britch	998.8	26.29	38.0
Composite of Area No.13 Mid Britch	988.1	26.82	36.8
Composite of Area No.14 Low Britch	951.2	24.06	39.5
Composite of Areas 12-14 Britch Region	962.5	25.30	38.0

APPENDIX.

Table No. 2. Cont'd.

F L E E C E   A N A L Y S I S.

WEIGHT-LENGTH RATIO.

Border Leicester Ewe No. K953 Sampled Nov.7,1930.	Total Length in cms.	Absolute dry weight in mgs.	Weight-Length Ratio.
Composite of Area No.1 Point of Shoulder	1620.4	21.21	76.4
Composite of Area No.2 Mid Shoulder	1505.7	18.40	81.8
Composite of Area No.3 Top Shoulder	1669.0	24.20	69.0
Composite of Shoulder Region (Areas 1-3)	1637.1	22.00	74.4
Composite of Area No.4 Fore Back	1683.7	25.01	67.3
Composite of Area No.5 Mid Back	1739.5	25.29	68.8
Composite of Area No.6 Rear Back	1712.5	28.10	60.9
Composite of Back Region (Areas 4-6)	1710.8	26.40	64.8
Composite of Area No.7 High Side	1703.7	25.56	66.7
Composite of Area No.8 Mid Side	1603.7	21.39	75.0
Composite of Area No.9 Low Side	1583.0	21.39	74.0
Composite of Side Region (Areas 7-9)	1595.8	21.82	73.1
Composite of Area No.10. Hip	1674.9	26.19	64.0
Composite of Area No.11. Low Hip	1614.3	25.38	63.6
Composite of Hip Region (Areas 10,11)	1631.1	24.81	65.7

APPENDIX.

Table No. 2. Cont'd.

FLEECE ANALYSIS.

WEIGHT-LENGTH RATIO.

Border Leicester Ewe No. K953 Sampled Nov.7,1930.	Total Length in cms.	Absolute dry weight in mgs.	Weight-Length Ratio.
Composite of Area No.12 High Britch	1619.5	25.38	63.8
Composite of Area No.13 Mid Britch	1445.2	22.02	65.6
Composite of Area No.14 Low Britch	1357.6	23.75	57.2
Composite of Britch Region.(Areas 12-14)	1489.8	24.29	61.3

APPENDIX.

Table No. 3.

F L E E C E   A N A L Y S I S.

FLEECE DENSITY.

Unit Area - Half Inch Square Surface on Skin.

Cheviot Ewe No. 117. Sampled Nov.7, 1930.	Air Dry Weights in Grams.				Calculated Density. No. fibres per half inch sq. surface on ski
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas	Weight	No. Fibres	
Area No.1 Pt. Shoulder.					
Sample No.1					
Not Composite	.3080	1	.0135	100	2282
Composite	.3080	1	.0131	100	2351
Sample No.2					
Not Composite	.3066	1	.0127	101	2438
Composite	.3066	1	.0139	100	2206
Sample No.3					
Not Composite	.3091	1	.0125	101	2498
Composite	.3091	1	.0130	101	2401
Sample No.4					
Not Composite	.3499	1	.0127	100	2755
Composite	.3499	1	.0135	100	2592
Composite of Area No.1	1.3002	4	.0138	100	2356
Area No. 2 Mid Shoulder.					
Sample No.1					
Not Composite	.3986	1	.0160	100	2491
Composite	.3986	1	.0162	100	2461
Sample No.2					
Not Composite	.3399	1	.0167	101	2056
Composite	.3399	1	.0162	101	2119
Sample No.3					
Not Composite	.3034	1	.0154	101	1990
Composite	.3034	1	.0154	100	1970
Sample No.4					
Not Composite	.2894	1	.0156	101	1874
Composite	.2894	1	.0159	100	1820
Composite of Area No.2	1.3545	4	.0186	100	1821
Area No. 3 Top Shoulder.					
Sample No.1					
Not Composite	.3010	1	.0178	103	1742
Composite	.3010	1	.0172	100	1750

APPENDIX.

TABLE No. 3. Cont'd.

F L E E C E A N A L Y S I S.

FLEECE DENSITY.

Cheviot Ewe No. 117. Sampled Nov.7, 1930.	Air Dry Weights in Grams.				Calculated Density. No.Fibres per half inch sq. surface on ski
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas	Weight	No.Fibres	
Area No. 3 Top Shoulder.					
Sample No.2					
Not Composite	.3679	1	.0166	101	2238
Composite	.3679	1	.0172	100	2139
Sample No.3					
Not Composite	.2748	1	.0169	101	1642
Composite	.2748	1	.0154	100	1784
Sample No.4					
Not Composite	.3464	1	.0179	101	1955
Composite	.3464	1	.0155	99	2213
Composite of Area No.3	1.3042	4	.0180	100	1812
Composite of Shoulder Region (Areas 1-3)	3.9589	12	.0191	100	1727
Area No. 4. Fore Back.					
Sample No.1					
Not Composite	.3199	1	.0164	100	1951
Composite	.3199	1	.0163	100	1963
Sample No.2					
Not Composite	.2855	1	.0157	100	1819
Composite	.2855	1	.0166	100	1720
Sample No.3					
Not Composite	.3460	1	.0161	99	2128
Composite	.3460	1	.0169	100	2047
Sample No.4					
Not Composite	.3394	1	.0161	100	2108
Composite	.3394	1	.0163	100	2082
Composite of Area No.4	1.3051	4	.0211	100	1546
Area No. 5. Mid Back					
Sample No.1.					
Not Composite	.2850	1	.0160	101	1799
Composite	.2850	1	.0154	100	1851

APPENDIX.

Table No. 3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Cheviot Ewe No. 117. Sampled Nov.7, 1930.	Air Dry Weights in Grams				Calculated Density No. fibres per half inch sq. surface on skin
	Entire Sample		Fractional Portion		
	Weight	No. Unit Areas	Weight	No. Fibres	
Area No. 5. Mid Back					
Sample No.2 Composite	.2218	1	.0148	100	1499
Sample No.3 Composite	.3100	1	.0152	101	2060
Sample No.4 Composite	.2892	1	.0134	99	2137
Composite of Area No.5	1.1221	4	.0175	100	1603
Area No. 6. Rear Back.					
Sample No.1 Composite	.2856	1	.0173	100	1651
Sample No.2 Composite	.3607	1	.0169	100	2134
Sample No.3 Composite	.2655	1	.0187	100	1420
Sample No.4 Composite	.3398	1	.0189	100	1798
Composite of Area No.6	1.2719	4	.0190	100	1674
Composite of Back Region (Areas 4-6)	3.6991	12	.0198	100	1557
Area No. 7. High Side.					
Sample No.1 Composite	.2681	1	.0191	101	1418
Sample No.2 Composite	.3570	1	.0207	100	1725
Sample No.3 Composite	.3406	1	.0189	100	1802
Sample No.4 Composite	.3731	1	.0194	100	1923
Composite of Area No.7	1.3551	4	.0211	100	1606

APPENDIX.

Table No. 3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Cheviot Ewe No. 117. Sampled Nov.7, 1930.	Air Dry Weights in Grams				Calculated Density. No.Fibres per half inch sq. surface on ski
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas	Weight	No.Fibres.	
Area No. 8 Mid Side					
Sample No.1 Composite	.2884	1	.0184	100	1567
Sample No.2 Composite	.2634	1	.0172	100	1531
Sample No.3 Composite	.2922	1	.0165	100	1771
Sample No.4 Composite	.2336	1	.0164	100	1424
Composite of Area No.8	1.0894	4	.0172	100	1584
Area No. 9 Low Side					
Sample No.1 Composite	.1989	1	.0140	101	1435
Sample No.2 Composite	.1849	1	.0143	100	1293
Sample No.3 Composite	.2293	1	.0153	102	1529
Sample No.4 Composite	.2541	1	.0144	101	1782
Composite of Area No. 9	.8700	4	.0159	100	1368
Composite of Side Region (Areas 7-9)	3.3145	12	.0181	100	1526
Area No. 10 Hip.					
Sample No.1 Composite	.2893	1	.0212	100	1365
Sample No.2 Composite	.2811	1	.0209	100	1345
Sample No.3 Composite	.3454	1	.0192	100	1799
Sample No.4 Composite	.3170	1	.0206	100	1539
Composite of Area No. 10	1.2319	4	.0214	103	1491

APPENDIX.

Table No. 3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Cheviot Ewe No. 117. Sampled Nov.7, 1930.	Air Dry Weights in Grams.				Calculated Density. No.fibres per half inch sq. surface on skin
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas	Weight	No. Fibres	
Area No.11 Low Hip.					
Sample No.1 Composite	.3437	1	.0199	100	1727
Sample No.2 Composite	.3289	1	.0215	100	1604
Sample No.3 Composite	.2792	1	.0196	100	1424
Sample No.4 Composite	.3278	1	.0189	100	1734
Composite of Area No.11	1.2911	4	.0202	100	1598
Composite of Hip Region (Areas 10,11)	2.5297	8	.0200	100	1581
Area No.12 High Britch.					
Sample No.1 Composite	.3508	1	.0229	99	1517
Sample No.2 Composite	.2999	1	.0249	100	1204
Sample No.3 Composite	.3192	1	.0196	100	1629
Sample No.4 Composite	.2981	1	.0240	100	1242
Composite of Area No.12	1.2837	4	.0298	100	1077
Area No. 13. Mid Britch.					
Sample No.1 Composite	.3825	1	.0260	101	1276
Sample No.2 Composite	.2878	1	.0262	100	1098
Sample No.3 Composite	.2775	1	.0248	100	1119
Sample No.4 Composite	.2477	1	.0236	100	1050
Composite of Area No.13	1.1548	4	.0307	100	941

APPENDIX.

Table No. 3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Cheviot Ewe No. 117. Sampled Nov.7, 1930.	Air Dry Weights in Grams.				Calculated Density. No.fibres per half inch sq. surface on skin
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas	Weight	No.Fibres	
Area No. 14. Low Britch.					
Sample No.1 Composite	.2665	1	.0241	101	1117
Sample No.2 Composite	.2405	1	.0222	100	1083
Sample No.3 Composite	.2856	1	.0236	100	1210
Sample No.4 Composite	.2658	1	.0268	100	992
Composite of Area No.14	1.0703	4	.0272	101	994
Composite of Britch Region (Areas 12-14)	3.5088	12	.0286	100	1022

APPENDIX.

Table No. 3 Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Border Leicester Ewe K953 Sampled Nov. 7, 1930.	Air Dry Weights in Grams.				Calculated Density.
	Entire Sample		Fractional Portion		No. fibres per half inch sq. surface on skin
	Weight	No. Unit Areas	Weight	No. Fibres	
Area No. 1. Point Shoulder					
Sample No.1 Composite	.5483	1	.0218	100	2515
Sample No.2 Composite	.5061	1	.0257	100	1969
Sample No.3 Composite	.3616	1	.0224	100	1614
Sample No.4 Composite	.5675	1	.0206	100	2755
Composite of Area No.1	1.9984	4	.0238	100	2099
Area No. 2. Mid Shoulder					
Sample No.1 Composite	.4040	1	.0194	100	2083
Sample No.2 Composite	.3017	1	.0187	100	1613
Sample No.3 Composite	.2750	1	.0212	100	1297
Sample No.4 Composite	.3597	1	.0228	100	1578
Composite of Area No.2	1.3598	4	.0207	100	1642
Area No. 3 Top Shoulder					
Sample No.1 Composite	.5689	1	.0269	100	2115
Sample No.2 Composite	.4664	1	.0276	100	1690
Sample No.3 Composite	.5710	1	.0254	100	2248
Sample No.4 Composite	.5144	1	.0248	100	2074
Composite of Area No.3	2.1457	4	.0275	100	1951
Composite of Shoulder Region (Areas 1-3)	5.5039	12	.0254	100	1815

APPENDIX.

Table No. 3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Border Leicester Ewe K953 Sampled Nov. 7, 1930.	Air Dry Weights in Grams. Entire Sample Weight	No. Unit Areas	Fractional Portion Weight	No. Fibres	Calculated Density. No. fibres per half inch sq. surface on skin
Area No. 4 Fore Back.					
Sample No.1 Composite	.6118	1	.0282	101	2191
Sample No.2 Composite	.5714	1	.0282	100	2026
Sample No.3 Composite	.7090	1	.0266	100	2665
Sample No.4 Composite	.4821	1	.0277	101	1758
Composite of Area No.4	2.4081	4	.0279	100	2158
Area No. 5. Mid Back.					
Sample No.1 Composite	.5328	1	.0273	100	1952
Sample No.2 Composite	.4288	1	.0266	100	1612
Sample No.3 Composite	.5432	1	.0264	100	2058
Sample No.4 Composite	.5556	1	.0281	100	1977
Composite of Area No.5	2.0381	4	.0282	100	1847
Area No. 6. Rear Back.					
Sample No.1 Composite	.5684	1	.0297	100	1914
Sample No.2 Composite	.5382	1	.0317	100	1698
Sample No.3 Composite	.5938	1	.0338	100	1757
Sample No.4 Composite	.5310	1	.0292	100	1819
Composite of Area No.6	2.2548	4	.0317	100	1778
Composite of Back Region (Areas 4-6)	6.7460	12	.0304	100	1849

APPENDIX.

Table No.3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Border Leicester Ewe K953 Sampled Nov.7, 1930.	Air Dry Weights in Grams.				Calculated Density. No.fibres per half inch sq. surface on skin
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas.	Weight	No.Fibres	
Area No. 10 Hip.					
Sample No.1 Composite	.7948	1	.0300	100	2649
Sample No.2 Composite	.5980	1	.0308	100	1942
Sample No.3 Composite	.4554	1	.0276	100	1650
Sample No.4 Composite	.5352	1	.0294	100	1820
Composite of Area No.10	2.2825	4	.0294	100	1941
Area No. 11. Low Hip.					
Sample No.1 Composite	.6864	1	.0286	100	2400
Sample No.2 Composite	.5670	1	.0291	100	1949
Sample No.3 Composite	.6069	1	.0297	100	2043
Sample No.4 Composite	.6830	1	.0286	100	2388
Composite of Area No.11	2.5696	4	.0286	100	2246
Composite of Hip Region (Areas 10,11)	4.8521	8	.0289	100	2099
Area No. 12 High Britch.					
Sample No.1 Composite	.5837	1	.0279	100	2092
Sample No.2 Composite	.6033	1	.0279	100	2162
Sample No.3 Composite	.5936	1	.0264	100	2249
Sample No.4 Composite	.5760	1	.0290	100	1986
Composite of Area No.12	2.3528	4	.0283	100	2079

APPENDIX.

Table No. 3. Cont'd.

Unit Area - Half Inch Square Surface on Skin.

Border Leicester Ewe K953 Sampled Nov.7, 1930.	Air Dry Weights in Grams.				Calculated Density. No.fibres per half inch sq. surface on skin
	Entire Sample		Fractional Portion		
	Weight	No.Unit Areas	Weight	No.Fibres	
Area No. 13 Mid Britch					
Sample No.1 Composite	.6524	1	.0306	100	2132
Sample No.2 Composite	.2702	1	.0251	100	1077
Sample No.3 Composite	.4078	1	.0278	100	1467
Sample No.4 Composite	.4232	1	.0260	100	1628
Composite of Area No.13	1.7337	4	.0246	100	1762
Area. No. 14 Low Britch.					
Sample No.1 Composite	.3179	1	.0221	100	1439
Sample No.2 Composite	.3158	1	.0276	100	1144
Sample No.3 Composite	.3604	1	.0242	100	1489
Sample No.4 Composite	.4070	1	.0273	100	1491
Composite of Area No.14	1.4061	4	.0265	100	1327
Composite of Britch Region (Areas 12-14)	5.4926	12	.0279	100	1641

APPENDIX.

Table No. 4. Cont'd.

FLEECE ANALYSIS.

VARIABILITY OF FINENESS.

Coefficient of Variability in Per cent.

Cheviot Ewe No. 117. Sampled Nov.7,1930.	Non Composite of Sample	Composite of Sample	Composite of Area	Composite of Region
Area No. 4 Fore Back				
Sample No. 1	18.09	17.96		
Sample No. 2	17.11	16.46		
Sample No. 3	16.33	17.23		
Sample No. 4	17.08	17.57		
All 4 Samples			17.67	
Area No. 5. Mid Back.				
Sample No. 1	16.19	14.34		
Sample No. 2	*	15.13		
Sample No. 3	*	16.64		
Sample No. 4	*	15.95		
All 4 Samples			16.13	
Area No. 6. Rear Back.				
Sample No. 1		17.95		
Sample No. 2		17.73		
Sample No. 3		17.97		
Sample No. 4		17.06		
All 4 Samples			16.63	
Back Region (Areas 4-6)				17.56

* All remaining samples were composited and were not measured prior to making the composite sample.

APPENDIX.

Table No. 4. Cont'd.

VARIABILITY OF FINENESS.

Coefficient of Variability in Per Cent.

Cheviot Ewe No.117, Sampled Nov.7,1930.	Non Composite of Sample	Composite of Sample	Composite of Area	Composite of Region.
Area No. 7 High Side.				
Sample No. 1		15.15		
Sample No. 2		14.84		
Sample No. 3		13.80		
Sample No. 4		12.91		
All 4 Samples			13.24	
Area No. 8. Mid Side				
Sample No. 1		14.25		
Sample No. 2		14.87		
Sample No. 3		16.87		
Sample No. 4		15.32		
All 4 Samples			15.30	
Area No. 9 Low Side				
Sample No. 1		13.13		
Sample No. 2		15.30		
Sample No. 3		16.11		
Sample No. 4		17.18		
All 4 Samples			13.58	
Side Region (Areas 7-9)				13.42

APPENDIX.

Table No. 4. Cont'd.

VARIABILITY OF FINENESS.

Coefficient of Variability in Per Cent.

Cheviot Ewe No. 117, Sampled Nov.7,1930.	Non Composite of Sample	Composite of Sample	Composite of Area	Composite of Region
Area No. 10 Hip.				
Sample No. 1		12.52		
Sample No. 2		12.30		
Sample No. 3		16.72		
Sample No. 4		13.61		
All 4 Samples			12.94	
Area No. 11. Low Hip.				
Sample No. 1		15.72		
Sample No. 2		17.23		
Sample No. 3		15.34		
Sample No. 4		14.53		
All 4 Samples			15.18	
Hip Region (Areas 10,11)				16.97
Area No. 12. High Britch				
Sample No. 1		22.36		
Sample No. 2		19.69		
Sample No. 3		21.49		
Sample No. 4		20.10		
All 4 Samples			16.73	
Area No. 13 Mid Britch				
Sample No. 1		22.23		
Sample No. 2		20.53		
Sample No. 3		20.27		
Sample No. 4		21.59		
All 4 Samples			20.27	
Area No. 14 Low Britch.				
Sample No. 1		21.50		
Sample No. 2		23.73		
Sample No. 3		21.89		
Sample No. 4		20.95		
All 4 Samples			22.63	
Britch Region (Areas 12-14)				23.46

APPENDIX.

Table No. 4. Cont'd.

VARIABILITY OF FINENESS.

Coefficient of Variability in Per Cent.

Border Leicester Ewe No. K953 Sampled Nov.7,1930	Composite of Sample.	Composite of Area.	Composite of Region
Area No. 1 Pt. of Shoulder			
Sample No. 1	16.60		
Sample No. 2	13.16		
Sample No. 3	15.45		
Sample No. 4	17.12		
All 4 Samples		13.55	
Area No. 2. Mid Shoulder			
Sample No. 1	11.97		
Sample No. 2	12.37		
Sample No. 3	12.57		
Sample No. 4	14.34		
All 4 Samples		13.60	
Area No. 3. Top Shoulder.			
Sample No. 1	14.94		
Sample No. 2	14.35		
Sample No. 3	13.93		
Sample No. 4	15.78		
All 4 Samples		14.12	
Shoulder Region (Areas 1-3)			15.11
Area No. 4. Fore Back			
Sample No. 1	15.84		
Sample No. 2	15.91		
Sample No. 3	16.55		
Sample No. 4	14.92		
All 4 Samples		15.39	
Area No. 5 Mid Back.			
Sample No. 1	15.15		
Sample No. 2	15.94		
Sample No. 3	16.89		
Sample No. 4	15.04		
All 4 Samples		16.19	

APPENDIX.

Table No. 4. Cont'd.

VARIABILITY OF FINENESS.

Coefficient of Variability in Per Cent.

Border Leicester Ewe No. K953 Sampled Nov.7,1930	Composite of Sample	Composite of Area.	Composite of Region
Area No. 6. Rear Back.			
Sample No. 1	16.19		
Sample No. 2	15.17		
Sample No. 3	13.51		
Sample No. 4	15.04		
All 4 Samples		13.53	
Back Region (Areas 4-6)			15.82
Area No. 7. High Side.			
Sample No. 1	15.07		
Sample No. 2	15.14		
Sample No. 3	12.36		
Sample No. 4	14.57		
All 4 Samples		14.86	
Area No. 8. Mid Side			
Sample No. 1	14.50		
Sample No. 2	13.16		
Sample No. 3	14.02		
Sample No. 4	17.08		
All 4 Samples		18.17	
Area No. 9 Low Side.			
Sample No. 1	12.42		
Sample No. 2	12.41		
Sample No. 3	14.93		
Sample No. 4	15.22		
All 4 Samples		13.27	
Side Region (Areas 7-9)			18.21
Area No. 10. Hip.			
Sample No. 1	15.19		
Sample No. 2	15.84		
Sample No. 3	15.11		
Sample No. 4	17.25		
All 4 Samples		16.31	

APPENDIX.

Table No. 4. Cont'd.

VARIABILITY OF FINENESS.

Coefficient of Variability in Per Cent.

Border Leicester Ewe No. K953 Sampled Nov.7,1930.	Composite of Sample	Composite of Area	Composite of Region
Area No. 11. Low Hip.			
Sample No. 1	15.65		
Sample No. 2	12.99		
Sample No. 3	14.26		
Sample No. 4	13.68		
All 4 Samples		16.07	
Hip Region (Areas 10,11)			17.25
Area No. 12 High Britch.			
Sample No. 1	16.19		
Sample No. 2	15.81		
Sample No. 3	13.20		
Sample No. 4	14.63		
All 4 Samples		15.00	
Area No. 13 Medium Britch.			
Sample No. 1	10.57		
Sample No. 2	10.77		
Sample No. 3	13.83		
Sample No. 4	15.45		
All 4 Samples		16.50	
Area No. 14 Low Britch.			
Sample No. 1	18.25		
Sample No. 2	19.28		
Sample No. 3	16.55		
Sample No. 4	18.88		
All 4 Samples		17.84	
Britch Region (Areas 12-14)			16.54

Presented in support of thesis entitled

"STUDIES OF THE INHERITANCE OF WOOL CHARACTERS AND FLEECE ANALYSIS IN SHEEP".
By
Robert H. Burns, B.S., M.S.

Monthly Wool Growth

OF

Rambouillet Ewes

By

ROBERT H. BURNS, M.S.

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6—MONTHLY WOOL GROWTH OF RAMBOUILLET EWES

By Robert H. Burns, M.S.

INTRODUCTION

The physiological phenomena of wool growth are directly related to commercial utility of a fleece, for length of fleece is an important charac in commercial grading of wool.

For many years the law of diminishing returns (i.e. wool attains t thirds of its length during its first six months of growth, and the grow steadily diminishes from that point on), has been applied to wool grow and accepted generally as an accurate statement of fact.

In a study of measurable fleece characteristics in a cross-breeding exp ment at the Wyoming Experiment Station, it was observed that fle characters, length, fineness, and density, were regular rather than spasmo in their development, if environment and disease were regulated.

Keeping in mind the regularity of development in these fleece characte it seemed a necessary and logical step to initiate a study of monthly wo growth in various types and breeds of sheep, in order to confirm or conte the idea that wool grows as much as two-thirds of its yearly length duri the first six months after shearing.

Consequently, in the spring of 1926, a study of monthly wool grow was inaugurated and carried on for the following four years, using in ea breed test six ewes of the following breeds—Rambouillet, Hampshire, Oxfor Corriedale, and Lincoln. All of the common types of wool were represente by these five breeds.

The writer, now studying animal breeding and wool research at Edinburg University, wishes to express his appreciation for the opportunities a courtesies afforded by the Animal Breeding Research Department during th preparation of this paper. The writer wishes particularly to acknowledg the advice and encouragement extended by Professor F. A. E. Cre Director of this Department.

REVIEW OF LITERATURE

Rohde, Stohmann, Heyne, Gartner, and Zorn all reported that the grow of wool was much greater during the first six months after shearing than the succeeding six-month period. These writers' results would uphold th theory of diminishing returns, in that they reported practically no grow during the last two months of the yearly growth, and around two-thirds its yearly growth attained during the first six months after shearing.

Nordmeyer, in a wool growth experiment with mutton merinos, reporte a more or less uniform growth throughout the year, with slightly mo growth during those months when green feed was available, and less grow when the ewes were suckling lambs.

Hardy and Tennyson, who studied the influence of wool growth up wool fineness, gave an illustration of a "tied" lock, showing proportiona monthly growths of wool, but no data were given. From a visual inspecti of the "actual size" illustration it would appear that the monthly wo growth was more or less uniform throughout the year.

A recent publication by Hackedorn and Sotola gives the monthly wo growth in Rambouillet ewes and wethers. In these results there was marked difference in monthly wool growth between wethers whose wo was allowed to grow for four years and in those which were shorn eve twelve months.

A wether's fleece of 48 months' growth weighed 62 lb. and attained a gth of 10 in. There was no difference in winter and summer wool growth, the last 12 months' wool growth was just as long as that of any previous lve months.

EXPERIMENTAL PROCEDURE

mals Used

Five or six ewes were used in each test, the number depending on mortality sales. No substitutions were made during the year, but each spring hearing time young ewes were added so as to have as many ages repreted as possible, and to have as near as possible six ewes for each breed he test.

An inspection of the ear tag numbers of the individual sheep will show distribution of ages once one is acquainted with the system of numbering. lambs born in 1921 were numbered from 100 to 199; all those born in 2 were numbered from 200 to 299; and so on up to 1930, when the lambs e numbered from 0 to 99. In this system an animal with the same nber appears once in ten years, but as sheep rarely are kept in the flock that length of time, this system of numbering is quite simple and practical is widely used.

The ewes in this experiment were run with the rest of the Rambouillet s of the Wyoming Experiment Station flock. This experiment station located at an elevation of 7,200 ft. and has little pasture land. Consetly the sheep are kept under shelter the greater part of the year, and led on alfalfa hay, a grain mixture consisting of barley, oats, and bran, occasionally some sunflower silage or cabbage.

During the summer months they are turned out during the day on ture and obtain some green feed, but are returned to the sheep barn he evening. Some seasons they are fed on green oats as a "soiling p" during the summer months.

EXPERIMENTAL PROCEDURE

mpling Methods

The right mid-shoulder area was chosen as the area on which the wool wth studies would be conducted. Three methods of sampling were ed out—

(1) Length of staple on the sheep.
(2) Growth clippings of each month's growth.
(3) Individual staples tied each month and the distance between "ties" measured.

DESCRIPTION OF SAMPLING METHODS

(1) The fleece was parted in the mid-shoulder region and a steel rule rted with the zero point resting on the surface of the skin. The fleece s then allowed to fall back on the rule, and an average reading of the gth of staple in the fleece recorded. Each month this procedure was owed, and the difference between staple lengths represented the growth ing the intervening time.

(2) At the beginning of the test a small area of about 2 sq. in. in extent s clipped close to the skin. This area was located in the mid-shoulder ion. In order to clip the wool fibres off as close to the skin as possible, pecial type of shears were obtained. These were surgeon's shears (8 in.) with blades angled at 30° on the flat. By pulling the wool fibres up tly against the blades of the shears, the fibres were cut as close to the n as would be the case had the area been shaved.

Each month a growth clipping sample was taken from the middle of area, and the remaining portion of the small area was cleared so that no fibres could be accidentally included in the following month's growth clipp

(3) At the beginning of the test a small staple the size of one's finger was selected and tied with dental floss (similar to surgeon's silk ligat using a surgeon's knot to counteract any tendency of the knot to slip. loose ends of the floss were clipped off close to the knot, so that these would not catch and pull the "tie" off the staple. Each month a " was made on the same staple, as close to the skin as possible, and at the of the year's growth each month's growth was plainly marked by the ti

METHODS OF MEASUREMENT

Staple length on the sheep and the growth as represented by the dista between the "ties" were measured directly by the use of a steel rule gradu in tenths of an inch.

The small sample of monthly growth clippings, when laid out, natur arranged itself in the form of a thin "sheaf," and as both the proximal distal ends were cut off at the surface of the skin, the sample would be the shape of a parallelogram, and a measurement of the average length of growth clipping was easily taken to the nearest tenth of an inch. In cases two readings out of three taken were identical, and in over 90% of cases all three readings were identical.

It was thought advisable to analyse the length of the individual fib when stretched taut, so as to know whether it would be best to get a frequen table of length of a number of fibres making up a staple or growth clipp "sheaf" or take the average measurement on the entire staple or clippi "sheaf" as one unit.

The old method of clamping each fibre in the jaws of a testing appara was thought to be entirely too tedious and slow, and an attempt was ma to devise a simpler and faster method.

The following method of measuring individual stretched fibre length been worked out—

A NEW METHOD OF MEASURING STRETCHED (TAUT) FIBRE LENGTH

A black chenille rug swatch (12 × 18 in. in size), with a deep "pil (1 in. deep), and a pair of cork or rubber-tipped tweezers, make up t equipment used in this simple method. The deep "pile" of the chenille r partially holds the individual wool fibres when they are pressed down i it. A steel rule, graduated in tenths of an inch, is laid on the rug in fr of the fibre which has been pressed down into the "pile" of the rug. T end of the fibre on the right-hand side is grasped near its end by the co tipped tweezers, and the thumb nail of the left hand is placed over the fi so that the thumb nail is even with the zero point on the rule. Thus wh the fibre is drawn taut it pulls along under the thumb nail, but only v gradually as it is gently held by the deep "pile" of the rug in which it embedded. The tip of the tweezers makes a good pointer, and as the attached end of the fibre slips out from under the thumb nail, the tens on the fibre as held by the "pile" of the rug is sufficient, so that there is tendency for the tip of the tweezers to "jump," and an accurate leng reading can be made.

The whole "set-up" is shown in illustration Fig. 1. Either 25 or fibres were measured for stretched length, according to the length of fibres. The growth clippings were much shorter and showed less varia

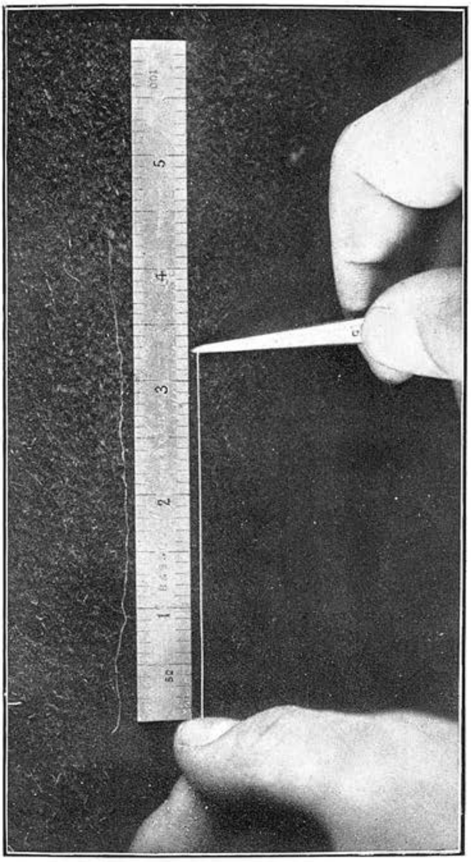


FIG. 1

an the staple samples, and hence 25 fibres were measured from the former d 50 fibres from the latter.

A test was made to find out how many fibres should be measured out of staple to ensure reasonable accuracy. Six samples were used from the lowing breeds—F_1 Crossbred (Hampshire × Rambouillet), Rambouillet, ncoln, Corriedale, Oxford, and Hampshire. All samples were from the 25 fleeces, which were a full 12 months growth. One hundred fibres were asured for stretched (taut) length from each sample, using the chenille method previously described. The measurements were taken to the arest tenth of an inch, and grouped in units with five fibres in each unit.

mber of Fibres to be Measured to Determine Stretched (Taut) Fibre Length
Length of Stretched (Taut) Fibre in Inches

er of s ed	F_1 Crossbred (Hampshire × Rambouillet)		Rambouillet		Lincoln		Corriedale		Oxford		Hampshire		All Six Samples	
	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100
	4·70	·49	3·46	·05	6·54	·11	3·50	·15	6·66	·14	4·04	·23	4·82	·20
	4·64	·43	3·47	·06	6·57	·14	3·45	·10	6·89	·37	4·11	·30	4·86	·24
	4·51	·30	3·47	·06	6·65	·22	3·41	·06	6·95	·43	4·08	·27	4·85	·23
	4·38	·17	3·48	·07	6·69	·26	3·39	·04	6·85	·33	4·06	·25	4·81	·19
	4·31	·10	3·47	·06	6·74	·31	3·40	·05	6·80	·28	4·05	·24	4·80	·18
	4·25	·04	3·45	·04	6·83	·40	3·38	·03	6·67	·15	4·00	·19	4·76	·14
	4·23	·02	3·45	·04	6·75	·32	3·36	·01	6·68	·16	3·98	·17	4·74	·12
	4·19	·02	3·44	·03	6·74	·31	3·41	·06	6·65	·13	3·96	·15	4·73	·11
	4·19	·02	3·44	·03	6·75	·32	3·39	·04	6·62	·10	3·91	·10	4·72	·10
	4·20	·01	3·44	·03	6·71	·28	3·37	·02	6·59	·07	3·93	·12	4·71	·09
	4·18	·03	3·42	·01	6·68	·25	3·39	·04	6·55	·03	3·89	·08	4·69	·07
	4·18	·03	3·40	·01	6·63	·20	3·38	·03	6·55	·03	3·89	·08	4·67	·05
	4·17	·04	3·39	·02	6·53	·10	3·36	·01	6·59	·07	3·87	·06	4·65	·03
	4·17	·04	3·40	·01	6·54	·11	3·37	·02	6·59	·07	3·86	·05	4·66	·04
	4·20	·01	3·40	·01	6·55	·12	3·36	·01	6·61	·09	3·86	·05	4·66	·04
	4·20	·01	3·39	·02	6·50	·07	3·36	·01	6·57	·05	3·86	·05	4·65	·03
	4·23	·02	3·41	none	6·48	·05	3·35	none	6·55	·03	3·84	·03	4·64	·02
	4·22	·01	3·41	none	6·43	none	3·35	none	6·53	·01	3·82	·01	4·63	·01
	4·21	none	3·42	·01	6·45	·02	3·36	·01	6·52	none	3·83	·02	4·63	·01
	4·21	—	3·41	—	6·43	—	3·35	—	6·52	—	3·81	—	4·62	—
of of	·032	—	·017	—	·066	—	·020	—	·046	—	·035	—	·040	—
s	—	·096	—	·051	—	·198	—	·060	—	·138	—	·105	—	·120

When comparing the variation of differences from the mean of the entire fibres, it will be noted that in some samples the measurement of 35 es was sufficient, while in others as many as 60 fibres should be measured re the difference was less than three times the probable error of the an length of 100 fibres. The point of accuracy in all the samples seemed be when around 50 fibres had been measured, so this number was chosen a standard number of fibres to be measured from each sample.

EXPERIMENTAL PROCEDURE

parison of Sampling Methods

"Tied" Staple Method Compared with Growth Clipping Method—It was nd impossible, in spite of all precautions, to keep the "ties" on the staples ng the first two months after shearing, for all "ties" made in this period e lost. After that period of time was past the "ties" held, with a few

exceptions, and the resulting growth figures agreed closely with those obtained with monthly growth clippings from the same animals.

However, because of the loss of the first two or three "ties" made after shearing, and the strong possibility of later "ties" slipping, the "tie" method was discarded as not comparable to the growth clipping method in accuracy as one method is positive and the other doubtful in the results obtained.

COMPARISON OF SAMPLING METHODS

Average Staple Length Difference Method, compared with Average Growth Clipping Length Method—In 161 growth determinations with individuals from four different breeds (Rambouillet, Oxford, Hampshire, and Corriedale) the following frequency distribution of monthly wool growth was obtained:

Twelve Months Period of Growth, April 1926 to April 1927
Frequency Distribution

Monthly Growth in tenths of an inch	Staple Length Difference Method					Growth Clipping Length Method Average Length of "Sheaf"				
	Breeds*				All four breeds	Breeds*				All four breeds
	R	O	H	C		R	O	H	C	
Loss	1	0	2	7	10	0	0	0	0	0
0	7	5	5	0	17	0	0	0	0	0
1	10	8	5	2	25	0	0	0	0	0
2	12	7	9	4	32	32	1	12	7	52
3	11	4	2	5	22	15	15	16	11	57
4	7	7	7	2	23	4	10	8	7	29
5	1	4	2	5	12	3	10	3	2	18
6	0	3	3	0	6	0	4	0	0	4
7	3	1	0	0	4	0	0	0	1	1
8	1	1	1	2	5	0	0	0	0	0
9	1	0	1	0	2	0	0	0	0	0
10	0	0	0	1	1	0	0	0	0	0
11	0	0	2	0	2	0	0	0	0	0
Total	54	40	39	28	161	54	40	39	28	161
Mean length ...	·256	·288	·318	·300	·286	·259	·403	·305	·329	·318
†P. E. of mean ...	·019	·022	·031	·034	·128	·008	·011	·010	·014	·060
Coef. of Variability ...	81	73	91	88	84	33	26	30	34	35
‡P. E. of Coef. of Variability ...	8	8	11	13	5	2	2	2	3	1

* Breeds— R=Rambouillet; O=Oxford; H=Hampshire; C=Corriedale.
† P. E.=Probable error.
‡ Coef. of Variability=Coefficient of Variability or per cent. Standard Deviation

It will be noticed that the staple length method recorded 27 cases or 16·75% of the total with a loss or no growth, a fact which in itself is enough to condemn the method. However, the extreme variability of 84% as compared with 35% is the final convincing argument of the futility of using the staple length difference method.

At no time during the test was there any similarity between measurements by the two methods of sampling, and the violent fluctuations of the figures obtained by the staple length difference method did not show any regularity in their occurrence. The inter-relationship of breeds is interesting. As would be expected, the breeds with longer wool gave the greatest error in the average growth by staple length difference method. However, the dency was practically the same in all breeds, and the futility of using ple length differences for ascertaining wool growth is quite apparent.

COMPARISON OF MEASUREMENT METHODS

Stretched (Taut) Fibre Length of Staple compared with Average Length of Growth Clippings—In this test an area of some four or five square inches xtent was cleared, and a staple of wool taken from this area at the end ach month of growth. It was hoped that by the use of this method of pling a cumulative "stair-step" perspective of wool growth could be ined. As the experience with using average staple length differences growth determination had given extremely unreliable results, the measur- of average staple length was discarded, and a measurement of 50 vidaul stretched (taut) fibres was substituted.

The results of 86 growth determinations with three breeds (Corriedale, mpshire, and Rambouillet) over a period of six months in the 1928–29 wth test gave the following frequency distribution.

Frequency Distribution

onthly Growth in tenths of an inch	Staple Length Method. Mean stretched fibre length of 50 fibres				Growth Clipping Method. Average Length of "Sheaf"			
	Breeds*			All three breeds	Breeds*			All three breeds
	C	H	R		C	H	R	
Loss	0	0	2	2	0	0	0	0
0	0	0	0	0	0	0	0	0
1	2	0	3	5	0	0	0	0
2	4	4	6	14	12	4	28	44
3	6	2	5	13	12	9	3	24
4	6	5	6	17	6	6	3	15
5	6	3	6	15	1	2	0	3
6	3	5	4	12	0	0	0	0
7	4	1	2	7	0	0	0	0
8	0	1	0	1	0	0	0	0
l	31	21	34	86	31	21	34	86
length	·413	·448	·359	·400	·287	·329	·226	·273
of mean ...	·021	·025	·022	·013	·010	·013	·007	·006
of Variability ...	42	38	54	46	29	26	27	32
E. of Coef. of riability ...	4	4	6	3	3	3	2	2

Breeds—C=Corriedale; H=Hampshire; R=Rambouillet.

gain the extreme variation of the length of stretched (taut) fibres in staple makes itself evident, and although the stretched fibre length gave er results than the staple length difference, still it was not as accurate uniform as the average length of clipping ("sheaf.") Either by inspection e distribution data or by comparison of the coefficients of variability, marked superiority of the average length of the clipping method of surement is apparent.

Stretched (Taut) Fibre Length of Growth Clippings compared with Average gth of Growth Clippings—Only the growth clipping method has stood s most reliable in the series of tests thus far reported. It was thought sable to compare the two methods of measuring the growth clippings.

In 258 growth determinations with four breeds (Corriedale, Hampshi
Rambouillet, and Lincoln), over a period of 14 months from March 19
to May 1930, the following frequency distribution was obtained—

Frequency Distribution

Monthly Growth in tenths of an inch	Growth Clipping Method. Average Length of "Sheaf"					Growth Clipping Method. Mean Stretched Fibre Lengt[h] of 25 Fibres				
	Breeds*				All four breeds	Breeds*				All f[our] bree[ds]
	C	H	R	L		C	H	R	L	
2	7	7	19	0	33	0	3	16	0	19
3	20	24	43	1	88	13	22	42	0	77
4	24	30	4	2	60	31	31	5	3	70
5	16	4	1	13	34	21	8	1	20	50
6	1	0	0	13	14	3	0	1	11	15
7	0	0	0	13	13	0	1	1	7	9
8	0	0	0	7	7	0	0	1	7	8
9	0	0	0	5	5	0	0	0	7	7
10	0	0	0	2	2	0	0	0	2	2
11	0	0	0	0	0	0	0	0	1	1
12	0	0	0	2	2	0	0	0	0	0
Total	68	65	67	58	258	68	65	67	58	258
Mean growth length ...	·376	·348	·281	·612	·411	·421	·374	·304	·650	·430
P. E. of length	·008	·006	·005	·016	·008	·006	·007	·009	·016	·007
Coefficient of Variability ...	26	22	21	27	44	19	22	35	27	40
P. E. of Coefficient Variability	2	1	1	2	2	1	1	2	1	[illegible]

*Breeds—C=Corriedale; H=Hampshire; R=Rambouillet; L=Lincoln.

As would be expected, the stretched fibre method gave a slightly la
figure than average length of "sheaf."

COMPARISON OF MEASUREMENT METHODS

The difference between the two systems of measuring growth clippi
was so small as to be negligible. In fact the difference ·19 was sma
than three times the probable error of the mean (·21). The coefficients
variability were also quite close together, and here again the difference
practically the same as the probable error. The tendencies were the sa
in all four breeds under test.

Thus no particular advantage was gained by measuring individ
stretched (taut) fibre lengths of a growth clipping "sheaf" rather th
taking an average measurement of the "sheaf" as a whole.

In view of the results of all the tests concerning methods of samp
and measurement, the average length of the growth clipping "sheaf"
used throughout the wool growth studies reported in this paper.

As later results will show, the stimulation of the skin by the shears w
taking the growth clipping sample, and clearing the area, was not a fa
and physiologists have confirmed this fact in conversations with the wr

During the first few months after shearing, there was a stimulation
wool growth.

EXPERIMENTAL RESULTS

A frequency distribution of the data given on page T106 gives the lowing table—

Monthly Growth in tenths of an inch	Frequency	
1	1	Mean —·25
2	133	P. E. of Mean—·003
3	95	
4	8	
5	3	
Total	240	

Maximum Variation in Monthly Wool Growth Same Ewe; Same Month; Different Years

Readings in Tenths of an Inch												No. Months in Test	Total Variation	No.	Avg. Variation
May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.				
1	1	3	2	1	1	0	1	1	1	0	1	33	13	12	1·08
0	0	2	1	0	1	1	0	0	1	1	1	43	8	12	·67
1	1	2	2	0	1	0	0	1	0	0	1	24	9	12	·75
0	0	1	1	0	1	2	1	1	1	1	0	31	9	12	·75
0	1	1	1	1	0	1	1	1	0	0	1	31	8	12	·67
0	1	1	0	1	1	1	1	1	1	1	–	23	9	11	·82

he average maximum variation of growth in the same ewe during the month in different years varied from ·067 of an inch to ·108 of an inch, ing a strong tendency for the same individuals to grow wool uniformly ghout a period of 43 months.

WOOL GROWTH BY SEASONS

wo hundred and forty determinations from the Rambouillet growth ing samples, over the four-year period, gave the following table of th by seasons—

Season	Actual Wool Growth in inches	Per cent. of Yearly Growth
g—March, April, and May	·74	25
er—June, July, and August	·79	27
September, October, and November ...	·74	25
r—December, January, and February ...	·70	23
growth for the year	2·97	100

he above table shows a remarkable uniformity of growth throughout the seasons of the year. As would be expected, Fall, Winter, and Spring, seasons when feed was not so good, and when nourishing the unborn later the suckling lamb, gave less growth than during the summer hs when green feed was available. Thus do the wool growth determinations co-ordinate as would be expected with the physiological and onmental conditions, favourable circumstances increasing, and those are unfavourable retarding wool growth.

order to compare these wool growth figures with those reported by nber of investigators in Germany, an arrangement has been made of

Monthly Wool Growth of Rambouillet Ewes 1926-1930. Average Length (Three Readings) of Clipping "Sheaf" in Tenths of an Inch
‡Averages and Variation Figures in Hundredths of an Inch. Right Mid-shoulder Area

Year	1926 to 1927					1927 to 1928					1928 to 1929						1929 to 1930						Total	Number	Avg. Mo. Grwth	Variation*
Ear Tag Number	116	356	379	446	447	116	379	447	454	526	116	379	454	526	618	703	379	454	526	611	703	847				
Sampled May ...	3	4	2	2	3	2	2	2	2	3	2	2	2	3	3	3	2	2	3	3	3	3	56	22	25	none
June ...	3	3	2	2	3	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	3	2	50	22	23	—·02
July ...	5	5	4	5	4	3	3	2	3	3	2	2	2	2	2	3	3	3	3	3	3	3	67	22	30	+·05
August ...	3	2	2	3	4	3	2	2	2	3	1	2	2	2	2	3	3	3	3	4	3	3	57	22	26	+·01
September	2	3	2	3	2	3	2	2	3	3	2	2	3	2	3	2	2	3	3	4	3	2	56	22	25	none
October ...	2	2	3	2	3	3	2	2	3	3	2	2	2	3	3	2	3	3	3	4	3	3	58	22	26	+·01
November	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	3	4	3	3	3	2	51	22	23	—·02
December ...	2	2	2	2	2	3	2	2	3	3	2	2	2	2	sold	2	sold	sold	sold	2	3	3	41	18	23	—·02
January ...	2	2	2	2	2	3	2	3	3	3	2	2	2	2	–	2	–	–	–	3	3	2	42	18	23	—·02
February ...	3	2	3	3	2	2	2	2	3	2	died	2	2	2	–	2	–	–	–	2	3	3	40	17	24	—·01
March ...	3	2	2	2	2	3	3	2	3	2	–	2	2	2	–	2	–	–	–	3	3	3	41	17	24	—·01
April ...	2	2	2	2	3	3	2	2	3	3	–	–	–	–	–	–	3†	3	2	3	2	3	40	16	25	none
Total Growth ...	32	31	28	30	32	32	26	25	32	34	17	22	23	24	17	24	21	23	22	37	35	32	599	—	—	—
No. Months Growth ...	12	12	12	12	12	12	12	12	12	12	9	11	11	11	7	11	8	8	8	12	12	12	—	240	—	—
‡Avg. M'thly. Growth ...	27	26	23	25	27	27	22	21	27	28	19	20	21	22	24	22	26	29	28	31	29	27	—	—	25	—

*Variation of mean monthly growth by months from average monthly growth for the entire year.

data showing the wool growth for the first six months, and the following months after shearing.

As before, there were 240 growth determinations over the period from 6 to 1930—

	Actual Wool Growth in inches	Per cent. of Yearly Growth
t six months after shearing	1·55	52
owing six months	1·42	48
l growth for the year	2·97	100

The remarkable uniformity of growth as shown in the four seasons of year is also apparent when the data are arranged with two growth iods of equal duration from one shearing to the next shearing twelve nths later.

THE EFFECT OF SHEARING ON WOOL GROWTH

It has always been a popular idea that wool grows more the first month two after shearing than during later months. In order to see just how ificant the differences would be, the data on five breeds have been arranged hat a comparison could be made of the first and second months indepen-tly against the remaining months of the year.

nparison of First Month's Wool Growth after Shearing with subsequent Growth until the next Shearing

Average Length of Growth Clipping "Sheaf"

Frequency Distribution

owth tenths n inch	First Month's Growth						Subsequent 11 Months' Growth					
	Breeds*					All breeds	Breeds*					All breeds
	L	C	O	H	R		L	C	O	H	R	
1	–	–	–	–	–	–	–	–	–	–	1	1
2	–	1	–	2	11	14	–	27	3	40	122	192
3	–	9	3	9	10	31	4	66	34	83	85	272
4	–	6	2	5	1	14	25	53	22	59	7	166
5	5	2	0	1	–	8	59	24	17	11	3	114
6	8	0	1	1	–	10	73	1	5	0	–	79
7	7	0	3	2	–	12	36	1	0	1	–	38
8	4	1	0	1	–	6	20	–	0	–	–	20
9	1	–	0	–	–	1	11	–	1	–	–	12
0	–	–	1	–	–	1	2	–	–	–	–	2
1	–	–	–	–	–	0	0	–	–	–	–	0
2	–	–	–	–	–	0	2	–	–	–	–	2
...	25	19	10	21	22	97	232	172	82	194	218	898
in ies ...	·652	·374	·540	·400	·255	·441	·603	·347	·390	·323	·249	·388
of in ... ies	·015	·019	·048	·024	·008	·136	·007	·005	·009	·004	·003	·004
r of in ...	–	–	–	–	–	·408	–	–	–	–	–	·012

=Lincoln; C=Corriedale; O=Oxford; H=Hampshire; R=Rambouillet.

The difference between the average growth the first month and the other eleven months shows a greater growth in the first month. The difference ·053 is over twelve times the probable error, and upholds the general idea that wool grows more the first month after shearing. The same tendency is noted in the different breeds.

A similar arrangement of data comparing the second month's growth with the other eleven months shows the second month's growth to be slightly greater, but the difference this time is only ·018, which is four times the probable error of the mean, a significant figure, but not nearly as conclusive a difference as in the first month's growth.

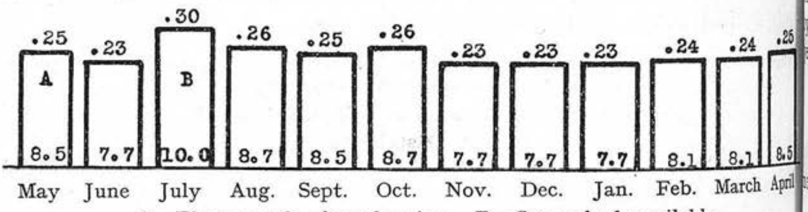
CONCLUSIONS

Rambouillet ewe wool grows more or less uniformly during the year, but is affected slightly during the winter, spring, and summer by the lambing season, and the abundance or lack of green food.

Monthly Wool Growth in Rambouillet Ewes. Growth in hundredths of an inch.
240 Monthly Growth Determinations.
4–6 Ewes, 1926–1930. Sheared on 27th April each year.

Figures on top of columns represent growth in hundredths of an inch.

Figures within columns represent each month's proportionate growth in per cent of the total growth for the year.



A = First month after shearing. B = Green feed available.

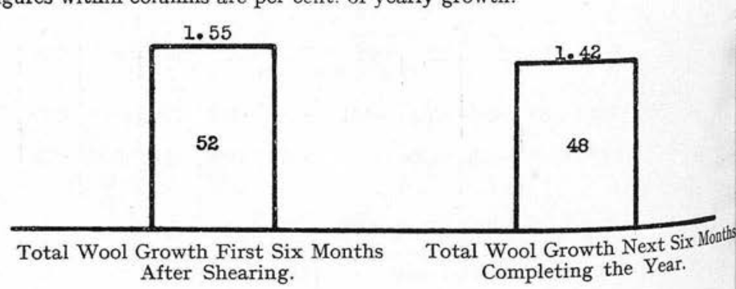
It will be noticed that the monthly wool growth was quite uniform throughout the year, the minimum and maximum monthly growth varying by only ·07 of an inch.

In July only was an abundance of green feed either in the form of green pasture or oat fodder available, and the effect on the wool growth was startling.

If these data are arranged in two periods of six months' growth, they give information which can be compared directly with those reported in the review of literature in this paper.

Comparison of Wool Growth in Rambouillet Ewes by Six-months' Periods, beginning from Shearing Time.

Figures on top of columns are total growth in inches.
Figures within columns are per cent. of yearly growth.



The results in the wool growth test at the Wyoming Experiment Station re in direct opposition to those reported by Rohde, Stohmann, Heyene, artner, and Zorn, and in agreement with the results reported by Nordmeyer nd Hackedorn and Sotola.

Although there was more growth during the first six months after shearing, was nowhere so great as the differential of $\frac{2}{3}$ to $\frac{1}{3}$ reported by these vestigators. The time of shearing would have no appreciable effect for king place as it did in the spring (April) it included the large growth in ly and October in the first six months of growth, thus raising the proortionate ratio of growth of the first six month's period to the following x month period, making up the year.

Physiologically it would seem logical for wool to grow more or less iformly if nutrition and health are normal. Fluctuations in growth, due nutrition and health and reproductive processes, occur according to the verity of these factors. However, the monthly growth inter-relationships em to keep about the same, even though the yearly growth may be nsiderably less. Ewe No. 116 gives some interesting information on this int. She was getting old, and during the last year of her life she grew nsiderably less total length of wool, but the variation from month to onth was in the same ratio as in other years, and in the same year for her individuals. This relationship is so evident that it can easily be seen y a mere inspection of the detailed table of data for all ewes in all four ears.

SUMMARY

(1) Monthly growth clippings proved out the most accurate and practical ethod of sampling for wool growth.

(2) The average length of the growth clipping "sheaf" gave results which re so very close to those obtained by measuring 25 individual stretched ut) fibre lengths that the extra labour in measuring the stretched fibre gths was unwarranted.

(3) The monthly wool growth of Rambouillet ewes was remarkably iform throughout the year, and in the four different years.

(4) Wool growth during the first six months after shearing was only ghtly greater (52%) than during the following six months (48%).

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By

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33—MONTHLY WOOL GROWTH STUDIES, II; (a) HAMPSHIRE DOWN EWES; (b) CORRIEDALE EWES

By Robert H. Burns, M.S.

INTRODUCTION

In a former paper* the writer stated that monthly wool growth studies with five different breeds of sheep were started at the Wyoming Experiment Station in 1926, and carried on for the following four years up to and including 1930. The former paper gave the technique of measurement, which proved most satisfactory and gave the results of monthly wool growth in Rambouillet ewes. This paper, the second of the series, gives the results obtained in monthly wool growth studies in two breeds, Hampshire Down and Corriedale ewes.

The writer, now studying sheep breeding and fleece analysis at the Institute of Animal Genetics, University of Edinburgh, wishes to acknowledge his indebtedness to this Institute for the courtesies and suggestions extended to him during the preparation of this paper.

EXPERIMENTAL PROCEDURE

The same procedure as followed with Rambouillet ewes, described in the former paper, was used for the other breeds. Four to six ewes were used during each year, the number depending on mortality and sales. No substitutions were made during the year, but each spring at shearing time young ewes were added to have as many different ages represented as possible. Any ewes substituted for those sold, or deceased, were as nearly as possible of the same age as those which they replaced. Environmental conditions were the same as already reported for the Rambouillet ewes. Wool growth determinations were made by measuring the average length of clipping "sheaf" from the right mid-shoulder area of each sheep.

If the growth data for the Hampshire Down ewes is arranged in the form of a frequency distribution, the following figures are obtained—

Monthly Growth in tenths of an inch	Frequency		
2	42	Mean Monthly Growth	·33
3	92		
4	64	Probable Error of Mean	±·005
5	12		
6	1	Maximum Allowable Error (three times probable error of mean)	·02
7	3		
8	1		
Total	215		

A study of the large table of experimental results shows that there was a strong tendency for the wool of Hampshire ewes to grow uniformly throughout the year, for a comparison of the variation figures in the last column of the large table with the maximum allowable error (three times the probable error of the mean monthly growth) shows that during five months of the year the variation in average monthly wool growth is significantly different from the average monthly wool growth for the entire year, and during the other seven months making up the year the variation figure is not significan

* *J. Text. Inst.*, 1931, **22**, T98-T109.

Year	1926 to 1927					1927 to 1928					1928 to 1929					1929 to 1930						Total	Number	Avg. Mo. Growth (in 0·01 inch units)	Variation* (in inch units)
Ear Tag Number	272	418	467	87880	87886	325	403	418	87880	87886	325	418	610	707	87880	325	418	610	724	802	87880				
Sampled June ...	4	8	7	6	7	3	3	5	2	2	3	4	3	3	3	4	4	4	3	3	3	84	21	40	+·07
July ...	5	7	5	5	4	3	3	4	2	2	2	3	4	3	2	4	sold	5	4	4	3	74	20	37	+·04
August ...	3	5	4	4	3	3	4	4	3	2	3	4	4	3	3	4		4	4	3	3	70	20	35	+·02
September	3	4	4	4	3	3	3	4	3	3	3	4	5	3	2	4		4	4	3	3	69	20	35	+·02
October ...	3	4	3	3	2	3	3	4	3	2	2	4	3	3	2	4		4	4	3	3	62	20	31	−·02
November	sold	3	4	3	2	4	4	4	4	sold	3	4	3	3	2	3		4	4	4‡	3	61	18	34	+·01
December ...		3	3	2	2	3	2	3	2		3	4	3	3	2	died		4	4	2	3	48	17	28	−·05
January ...		3	2	2	2	3	3	4	2		3	3	3	4	2			4	4	4‡	4	52	17	31	−·02
February ...		5	3	2	3	3	3	4	2		2	3	3	3	2			4	4	3	2	51	17	30	−·03
March ...		4	3	2	2	3	3	3	4		2	4	3	died	2			5	4	3	2	49	16	31	−·02
April ...		5	3	2	2	3	3	4	3		2	5	3		3			5	3	4	2	52	16	33	none
May ...		3	2	2	2	3	died	3	3		—	—	—		—	3†	4	4	4	3	3	39	13	30	−·03
Total Growth ...	18	54	43	37	34	37	34	46	33	11	28	42	37	28	25	26	8	51	46	39	34	711	—	—	—
No. Months Growth ...	5	12	12	12	12	12	11	12	12	5	11	11	11	9	11	7	2	12	12	12	12	—	215	—	—
Av. Monthly Growth (in 0·01 in. units)	36	45	36	31	28	31	31	38	28	22	25	38	34	31	23	37	40	43	38	33	28	—	—	33	—

* Variation of mean monthly growth by months from average monthly growth for the entire year. ‡ Five weeks growth.
The maximum growth occurred in June and the minimum in December.
† In 1929–30 all areas were cleared one month sooner than in former years.

EXPERIMENTAL RESULTS

Corriedale Ewes

Monthly Wool Growth of Corriedale Ewes 1926–1930. Average Length (Three Readings) of Clipping "Sheaf" in Tenths of an Inch. Right Mid-Shoulder Area. Averages and Variation Figures in Hundredths of an Inch

Year	1926 to 1927					1927 to 1928				1928 to 1929					1929 to 1930					Total	Number	Avg. Mo. Growth (in 0·01 inch units).	Variation* (in inch units).
Ear Tag Number ...	465	2101	2139	2175	2252	2101	2091	2139	2252	2091	2101	2139	2252	701	701	842	2091	2139	2252				
Sampled June ...	–	–	–	–	–	3	4	3	3	4	3	4	3	4	4	4	4	3	5	51	14	36	+·01
July ...	–	–	–	–	–	4	5	3	4	3	3	3	3	4	4	4	4	4	4	52	14	37	+·02
August ...	–	–	–	–	–	4	4	4	4	3	died	3	3	3	5	5	5	4	5	52	13	40	+·03
September	5	5	4	4	8	4	4	4	4	5		3	4	4	5	6	5	4	5	83	18	46	+·11
October ...	4	4	3	5	7	4	4	3	3	4		3	3	3	4	5	4	4	4	71	18	39	+·04
November	4	4	4	3	3	5	5	3	3	4		4	3	3	4	5	5	4	3	69	18	38	+·03
December	3	3	3	4	3	3	5	3	3	4		3	2	3	4	5	5	3	3	62	18	34	–·01
January ...	3	2	2	2	2	3	5	3	3	2		2	2	2	3	5	4	3	4	52	18	29	–·06
February ...	died	3	2	died	3	3	3	2	2	2		2	2	3	3	5	4	4	3	46	16	29	–·06
March ...		3	5		4	2	2	3	2	3		3	2	2	3	4	3	3	2	46	16	29	–·06
April ...		3	3		3	3	4	4	2	3		2	2	2	4	4	5	3	3	50	16	31	–·04
May ...		3	4		3	2	3	3	2	–		–	–	–	2†	3	3	3	3	34	12	28	–·07
Total Growth	19	30	30	18	36	40	48	38	35	37	6	32	29	33	45	55	51	42	44	668	—	—	—
No. Months Growth	5	9	9	5	9	12	12	12	12	11	2	11	11	11	12	12	12	12	12	—	191	—	—
Av. Monthly Growth (in 0·01 in. units)	38	33	33	36	40	33	40	32	29	34	30	29	26	30	38	46	43	35	37	—	—	35	—

SUMMARY

(1) Hampshire Down ewe wool showed a tendency to grow uniformly ughout the year, as shown by monthly and seasonal growth, and the rly growth did not vary markedly during the four years of the eriment.

(2) Hampshire Down ewe wool grew slightly more during the first six ths after shearing (54%) than during the succeeding six months (46%), pleting the year.

If the wool growth data for the Corriedale ewes is arranged into a uency distribution, the following figures are obtained—

Monthly Growth in tenths of an inch	Frequency	
2	28	Mean Monthly Growth ·35
3	75	
4	59	Probable Error of Mean ±·005
5	26	
6	1	Maximum Allowable Error ·02
7	1	(three times probable error
8	1	of mean).
Total	191	

A study of the large table of experimental results shows that there was h more variation in wool growth in the Corriedale ewes than in any of other breeds studied. A comparison of the variation figures in the last mn of the large table with the maximum allowable error shows only three ths when the variation was not significant, and nine months in which variation exceeded the maximum allowable error. This would indicate the Corriedale breed was more variable in wool growth from month to th than either the Rambouillet or Hampshire Down.

Maximum Variation in Monthly Wool Growth
Same Ewe; Same Month; Different Years. Corriedale Ewes

[illegible]	Readings in Tenths of an Inch												No. Months in Test	Total Variation	No.	Avg. Variation inches
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May				
[illegible]	0	0	2	1	1	1	1	1	0	1	2	–	23	10	11	·09
[illegible]	0	2	2	1	0	1	1	3	2	1	2	0	35	15	12	·13
[illegible]	0	2	–	1	0	1	0	1	0	1	0	1	23	7	11	·06
[illegible]	1	1	1	1	1	1	0	1	2	2	2	1	44	14	12	·12
[illegible]	2	1	3	4	4	0	1	2	1	2	1	1	44	22	12	·18

he average maximum variation in growth of wool on the same ewe g the same month in different years is about the same in the Corriedales the Hampshire Downs, varying from ·06 to ·18 of an inch. Thus in dales, as in Hampshires and Rambouillets, there is a tendency for the individuals to grow the same amount of wool during the same months ferent years.

WOOL GROWTH BY SEASONS

Corriedale Ewes

One hundred and ninety-one determinations from the Corriedale growth clipping samples over the four-year period, gave the following table of growth by seasons—

Season	Actual Wool Growth in inches	Per cent. of Yearly Growth
Spring—March, April, and May	·95	23
Summer—June, July, and August	1·23	29
Fall—September, October, and November ...	1·11	27
Winter—December, January, and February	·87	21
Total growth for the year	4·16	100

There is more variation in the Corriedales than in either the Hampshires or Rambouillets, the maximum difference in percentage of growth amounting to 4% in the Hampshires and Rambouillets, and to 8% in the Corriedales.

If these figures are arranged so as to compare the growth the first six months after shearing with the succeeding six months making up the year, one obtains the following figures. As before, there were 191 growth determinations.

	Actual Wool Growth in inches	Per cent. of Yearly Growth
First six months after shearing	2·36	57
Succeeding six months	1·80	43
Total growth for the year	4·16	100

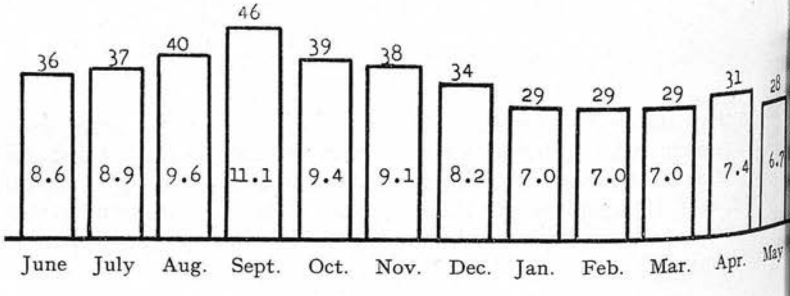
The Corriedale ewes showed the greatest growth during the first six months after shearing (57%) of any of the breeds under study (Hampshires, 54%, and Rambouillets, 52%).

CONCLUSIONS

Monthly Wool Growth in Corriedale Ewes. Growth in hundredths of an inch.
191 Monthly Growth Determinations. 1926–1930.
Sheared on 4th May of each year.

Figures on top of columns represent growth in hundredths of an inch.

Figures within the columns represent each month's proportionate growth in per cent. of the total growth for the entire year.

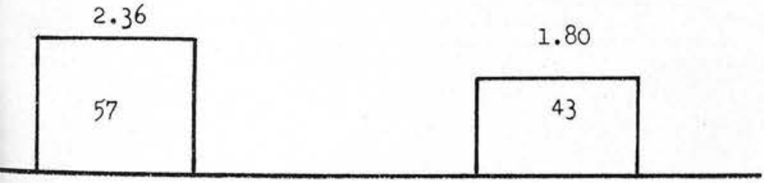


orriedale ewe wool did not grow uniformly during the year, being much variable in monthly and seasonal wool growth than either the bouillet or Hampshire Down. Although there was a decline in wool th beginning in December it did not become dormant during the last two hs completing the year, as suggested by Zorn, Heyne, Stohman, Gartner, Rohde.

arison of Wool Growth in Corriedale Ewes by Six-months' Periods, beginning at Shearing Time.

gures on top of column give total growth in inches.

gures within columns give the per cent. of yearly growth attained during the onth period.



Total Wool Growth First Six Months after Shearing.

Total Wool Growth next Six Months, completing the year.

The Corriedale ewes' wool growth was 10% greater during the first six ths' period than during the succeeding six months completing the year. first six months of wool growth from the Corriedale ewes represented of the growth for the entire year. This figure is 10% under the figure rted by Zorn, Heyne, Stohman, Gartner, and Rohde.

The wool growth studies made at the Wyoming Experiment Station Rambouillet, Hampshire, and Corriedale ewes support the view that l has an inherent tendency to grow uniformly throughout the year, and se the view that wool grows by the law of diminishing returns and ins two-thirds of its yearly length during the first six months after ring, and then gradually diminishes until during the last two months pleting the year there is no appreciable growth.

he tendency of wool to grow uniformly is affected by environmental rs which give dissimilar reactions in different breeds and even in indi- ls within the breed. The results obtained at Wyoming agree with the ts reported by Hackedorn and Sotola using Rambouillets, and Nord- r using Mutton-Merinos (Merinofleischschaf).

UMMARY OF MONTHLY WOOL GROWTH RESULTS USING MBOUILLET, HAMPSHIRE DOWN, AND CORRIEDALE EWES

) Monthly wool growth in Rambouillet and Hampshire Down ewes d a tendency to be uniform throughout the year, as shown by monthly asonal growth, and the total yearly wool growth tended to be the same g the four years of the experiment.

Wool grows slightly more (average difference 9%) during the first nths after shearing than during the succeeding six months completing ar.

The Corriedale ewes showed much more variability in monthly and al wool growth than the Rambouillets and Hampshires.

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CORRIGENDUM

30—THE DETERMINATION OF SOLUBILITY NUMBER: A MICRO-METHOD FOR MEASURING THE EXTENT T[illegible] WHICH A CELLULOSIC MATERIAL HAS BEEN CHEMICALL[illegible] MODIFIED OR DEGRADED

By C. R. Nodder
(The Linen Industry Research Association).

An error occurred in this paper which appeared in the August issue [illegible] the Journal (T416-T424). The second paragraph of the Conclusion (p. T42[illegible] should read as follows, the words to be changed being printed in italics.

"The cuprammonium viscosity method is considerably more sensitive [illegible] indicating the initial stages of attack, that is, when the solubility number [illegible] less than 5·0 in the case of linen goods (log. viscosity 2% solution *grea[illegible]* than 1·0) or less than 2 or 3 in the case of cotton goods (log. viscosity 2[illegible] solution *greater* than about 0·5)."

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Presented in support of thesis entitled

"STUDIES OF THE INHERITANCE OF WOOL CHARACTERS AND FLEECE ANALYSIS IN SHEEP".

By

Robert H. Burns, B.S., M.S.

BULLETIN NO. 141 **MAY, 1925**

UNIVERSITY OF WYOMING

AGRICULTURAL EXPERIMENT STATION

THE UNIVERSITY OF WYOMING
EQUALITY
LARAMIE

The Micrometer Caliper as an Instrument for Measuring the Diameter of Wool Fibers

Bulletin will be sent free upon request

Address: Director of Experiment Station, Laramie, Wyoming

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*In cooperation with U. S. Department of Agriculture.

The Micrometer Caliper as an Instrument for Measuring the Diameter of Wool Fibers*

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W. B. KOEHLER—GRADUATE STUDENT 1923-'24

INTRODUCTION

For a number of years the microscope has been the standard instrument for measuring the diameter of wool fibers.[1] In 1921 Hill[2] of this station reported on use of the machinist's micrometer caliper for measuring fibers in his student laboratory, in order that students might train themselves in the accurate judgment of the fineness of wool. At first it was thought that the micrometer caliper was not as accurate as the microscope but was accurate enough for teaching students the practical discrimination of fineness. However, as time went on and a large number of measurements were made with the micrometer caliper by various individuals, it appeared to be fairly accurate.

J. I. Hardy[3] was the first to use the micrometer in the scientific study of wool.

Hill[2] states that he found that an average student, after some practice is able to measure 100 fibers with a micrometer in less than 30 minutes, which agrees entirely with the writers' experience. Gordon[1] asserts that one can make up the necessary amounts and measure the same number of fibers microscopically in an hour. Inasmuch as a student will probably acquire skill in measurement much more quickly with the micrometer than with the microscope the time-saving factor is very evident.

*Papers from the Wool Laboratory of the University of Wyoming Experiment Station—No. 10. This bulletin has been prepared from a thesis submitted by W. B. Koehler in partial fulfillment of the degree of Master of Science.

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   Terho T. Ztschr, Induktive Abstam. U. Vererbungslehre 32 (1923), No. (pp. 37-60 fig.).
2. Hill, J. A., American Society of Animal Production, 1921 proceedings, p. 8.
3. Hardy, J. I., Journal of Agricultural Research, Vol. 14, No. 8, pp. 285-296.

As far as the writers are aware, no comparison of micrometer and microscopic measurements of wool fibers has been made. Inasmuch as the micrometer is a very useful instrument in the wool laboratory for training students to discriminate fineness, it seemed desirable to test out its accuracy.

OBJECTS OF EXPERIMENT

1. To compare measurements of the same portion of a wool fiber, made first with a micrometer caliper, and then with a microscope with a measuring eyepiece.

2. To compare the variations between the measurements of the diameter of relatively fine fibers and relatively coarse fibers as influenced by the two methods of measurement.

METHOD OF EXPERIMENTATION

Instruments Used.

1. Machinist's Micrometer Caliper.

An ordinary machinist's micrometer caliper graduated in ten-thousandths of an inch was used. The micrometer caliper used in this study was made by the Brown & Sharpe Manufacturing Company. (See Fig. 1.)

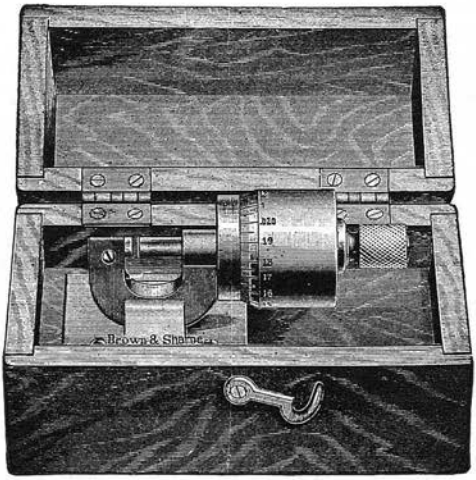

Fig. 1. Micrometer caliper used for measuring wool fibers.

2. Microscope.

   A compound microscope and filar mikrometer (measuring eyepiece with movable crosshair) made by E. Leitz was used. An 8 mm. objective and 145 mm. tube length were used, which gave a magnification of 185 diameters.

The measuring eyepiece was calibrated with a stage micrometer reading in hundredths of a millimeter. One unit on the eyepiece was found to be equal to .02 mm.

The filar eyepiece which was used in this study has on its side a wheel graduated in 100 equal parts. A complete turn of this wheel moves the crosshair in the eyepiece over one division in the eyepiece. Therefore, one unit on the wheel equals .0002 mm.

These microscopic units were converted to ten-thousandths of an inch by dividing by 12.7.

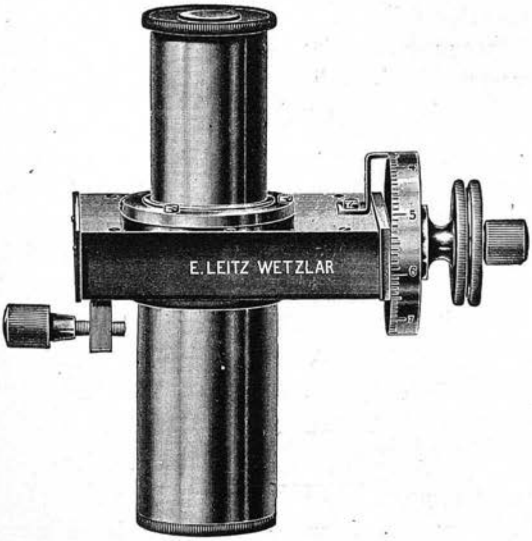

Fig. 2. Filar eyepiece used on microscope for measuring wool fibers.

Source of Samples.

Twenty-seven samples of wool ranging from fine to braid were used in this study. They were divided into three series, A, B, and C, according to their origin.

Series A.

Sixteen of these samples were obtained from the U. S. Sheep Experiment Station at Dubois, Idaho. Their classification follows:

Seven Rambouillet samples ranging from 70's to 58's.

Four crossbred samples (Corriedale sire; Lincoln-Rambou-lette crosbred dam) ranging from 56's to 50's.

Three crossbred samples (Lincoln sire; Rambouillet dam) ranging from 44's to 40's.

Two Corriedale samples classed as 48's to 46's.

One sample of fine in Series A was obtained from a large wool commission house in Boston.

Series B.

Five samples were from Australia and four of these came from the well-known Wanganella station of Australian Merinos. Their classification follows:

Four Wanganella samples ranging from 66's to 68's.

One sample of Australian hogget wool selected by W. T. Ritch, the Australian wool expert.

Series C.

Five samples of coarse wools all of United States origin. Their classification follows:

One Romney Marsh sample from University of Wyoming flock.

One Oxford Down sample from University of Wyoming flock.

One Low Quarter grade sample of U. S. origin.

One Common grade sample of U. S. origin.

One Braid grade sample of U. S. origin.

Preparation of Samples.

Small sub-samples from each of the large samples were washed in benzine, pressed between filter paper and exposed to the air for further drying. When the samples were dry both tip and base were clipped squarely off so as to have all the fibers as nearly the same length as possible.

Measurement of Samples.

Individual fibers were drawn from the small sample, taking large and small fibers without discrimination and always drawing from the same side of the sample.

The fiber was straightened between the fingers, one end held by the thumb and third finger and the other end held by the first and second fingers and was then placed between the jaws of the micrometer. The micrometer was turned up slowly until the fiber lay snugly between the jaws and the ratchet clicked twice. One soon learns the right amount of speed to use in closing the jaws of the micrometer and should use the same relative speed in measuring the wool fibers as in checking the zero point of the micrometer.

After the fiber had been measured by the micrometer and the size recorded, the ends of the fiber were cut off as close to the jaws of the micrometer as is possible with a safety razor blade. The portion of the fiber remaining between the jaws of the micrometer was then removed and placed on a glass slide. A cover glass was placed over it to keep the fiber flat (in one plane). No mounting medium was used. Holden[4] having found that glycerine, Canadian balsam, and air gave identical results within the limits of experimental error.

The slide with the fiber on it was placed under the microscope and three measurements were taken at various parts of the fiber. Inasmuch as the length of the fiber when clipped on either side of the micrometer jaws was about one-quarter of an inch and the visible microscopic field was about one-seventh as large, it was necessary to move the slide and follow the outline of the fiber, taking measurements at typical portions of the fiber at each end and in the middle.

One hundred fibers from each small sample were measured in this way.

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4. Holden, H. S., Journal Textile Institute, V. 8, No. 8, pp. 157, 160.

TABLE I.—Showing a comparison of the average thickness of 100 fibers from various samples of wool as measured by the microscope and by the micrometer caliper

Sample[1]	Microscopic Mean	Caliper Mean	Corrected Caliper Mean	Percent of Caliper Mean Represented by Microscope	Percent of Corrected Caliper Mean Represented by Microscope
Fine	6.74±.08	5.69±.07	6.69	118.5	100.7
58s............	7.20±.11	5.91±.12	6.91	121.8	104.2
68s............	7.18±.08	6.02±.06	7.02	119.3	102.3
62s............	7.46±.09	6.26±.07	7.26	119.2	102.8
Wang. Ram...	7.56±.07	6.54±.09	7.54	115.6	100.7
66s............	7.82±.11	6.59±.10	7.59	118.7	103.0
60s............	7.93±.08	6.77±.10	7.77	117.1	102.1
70s............	7.97±.06	6.72±.07	7.72	118.6	103.2
Hoggett	7.81±.11	6.87±.07	7.87	113.6	99.2
Wang. R. 68s	7.93±.08	6.98±.08	7.98	113.6	99.2
Wang. R. 66s	8.07±.09	6.93±.09	7.93	116.5	101.8
Wang. E. 68s	8.31±.07	6.99±.06	7.99	118.9	104.0
64s............	8.58±.12	7.48±.10	8.48	114.7	101.2
56s............	8.83±.11	7.82±.10	8.82	112.9	100.1
54s............	9.51±.10	8.37±.13	9.37	113.6	101.5
48s............	9.90±.10	8.80±.14	9.80	112.5	101.0
42s............	10.32±.13	9.20±.12	10.20	112.2	101.2
52s............	10.45±.17	9.56±.16	10.56	109.3	99.0
50s............	11.02±.13	9.98±.12	10.98	111.0	100.4
46s............	11.43±.16	9.98±.16	10.98	114.5	104.0
40s............	12.12±.17	11.79±.20	12.79	105.3	97.1
Low ¼........	13.32±.22	11.57±.20	12.57	115.1	106.0
Oxford........	13.13±.09	12.44±.09	13.44	105.5	97.7
44s............	13.75±.14	13.00±.15	14.00	105.8	98.2
Romney.......	14.84±.16	13.37±.14	14.37	111.0	103.3
Braid..........	15.43±.16	14.43±.16	15.43	106.9	100.0
Common......	15.76±.21	14.33±.20	15.33	111.0	102.8
				Mean 113.8±.6	Mean 101.4±.3

[1]All measurements in units of ten-thousandths of an inch.
[2]Addition of one ten-thousandths of an inch to caliper mean.

cording to their thickness measured by the micrometer caliper.

GENERAL SUMMARY OF MICROMETER-MICROSCOPIC COMPARISONS[1]

Caliper Group		3	4	5	6	7	8	9	10	Mean	11	12	13	14	15	16	17	18	19	20	Mean
Frequency	Government	1	33	187	296	290	235	186	150	.....	104	59	63	50	33	8	5	......	......	......	.....
	Australian	......	3	43	151	164	103	26	8	.....	2	......	......	......	......	......	......	......	......	......	.....
	Coarse	......	......	......	3	10	12	12	32	.....	50	70	93	61	67	35	23	19	9	4	.....
Average Micro. Diameter	Government	4.55	5.42	6.23	7.12	8.14	9.12	10.02	10.90	.....	12.10	12.95	13.94	14.63	15.75	16.39	17.36	......	......	......	.....
	Australian	......	4.92	6.35	7.13	8.04	8.95	9.81	10.61	.....	11.59	......	......	......	......	......	......	......	......	......	.....
	Coarse	......	......	......	7.09	8.51	9.51	10.36	11.38	.....	12.33	13.27	14.10	15.20	16.45	17.40	18.15	19.13	19.74	21.46	.....
Amont which Micro. exceeds Caliper	Government	1.55	1.42	1.23	1.12	1.14	1.12	1.02	.90	.....	1.10	.95	.94	.63	.75	.39	.36	......	......	......	.....
	Australian	......	.92	1.35	1.13	1.04	.95	.81	.61	.....	.59	......	......	......	......	......	......	......	......	......	.....
	Coarse	......	......	......	1.09	1.51	1.51	1.36	1.38	.....	1.33	1.27	1.10	1.20	1.45	1.40	1.15	1.13	.74	1.46	.....
Percentage which Micro. exceeds Caliper	Government	51.7	35.5	24.6	18.7	16.3	14.0	11.3	9.0	.....	10.0	7.9	7.2	4.5	5.0	2.4	2.1	......	......	......	.....
	Australian	......	23.0	27.0	18.8	14.9	11.9	9.0	6.1	.....	5.4	......	......	......	......	......	......	......	......	......	.....
	Coarse	......	......	......	18.2	21.6	18.9	15.1	13.8	.....	12.1	10.6	8.5	8.4	9.7	8.8	6.8	6.3	3.9	7.3	.....
Totals	Frequency	1	36	230	450	464	350	224	190	.....	156	129	156	111	100	43	28	19	9	4	.....
	Average[2]	4.55	5.38	6.25	7.13	8.11	9.08	10.01	10.96	.....	12.17	13.11	14.04	14.94	16.22	17.21	18.01	19.13	19.74	21.46	.....
	Difference[3]	1.55	1.38	1.25	1.13	1.11	1.08	1.01	.96	.....	1.17	1.11	1.04	.94	1.22	1.21	1.01	1.13	.74	1.46	.....
	Percentage[4]	51.7	34.5	25.0	18.8	15.9	13.5	11.2	9.6	.....	10.6	9.3	8.0	6.7	8.1	7.6	5.9	6.3	3.9	7.3	.....
	Corrected[5] caliper diameter	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	.....	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	.....
	Percent of corrected caliper mean repersented by microspopic mean	113.7	107.6	104.2	101.9	101.4	100.9	100.1	99.6	103.7	101.4	100.9	100.3	99.6	101.4	101.2	100.1	100.7	98.7	102.2	100.7

[1]All measurements stated in units of ten-thousandths of an inch.
[2]Average microscopic diameter.
[3]Amount which microscope exceeds caliper.
[4]Percentage which microscope exceeds caliper.
[5]Addition of one ten-thousandths of an inch to caliper mean.

TABLE III.—Showing correlation between measurements obtained by the microscope and those obtained by the micrometer caliper on the same wool fibers.

			FREQUENCY OF MICROSCOPIC MEASUREMENTS																	
Caliper Group	Frequency	Micro-scopic Mean	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	1	4.55±.06	1	...	...	...	...	...	..	..	..	..	..	..	..	..	..	..	..	..
4	36	5.38±.06	22	14	...	...	...	...	..	..	..	..	..	..	..	..	..	..	..	..
5	230	6.25±.02	10	145	74	1	...	...	..	..	..	..	..	..	..	..	..	..	..	..
6	450	7.13±.02	..	38	316	93	3	...	..	..	..	..	..	..	..	..	..	..	..	..
7	464	8.11±.02	..	...	53	306	96	9	..	..	..	..	..	..	..	..	..	..	..	..
8	350	9.08±.02	..	...	...	53	226	59	12	..	..	..	..	..	..	..	..	..	..	..
9	224	10.01±.03	..	...	...	2	44	123	51	4	..	..	..	..	..	..	..	..	..	..
10	190	10.96±.04	..	...	...	...	3	39	98	42	7	..	11	..	..	..	..	..	..	..
11	156	12.17±.05	..	...	...	...	...	2	37	71	29	14	33	..	..	..	..	..	..	..
12	129	13.11±.05	..	...	...	...	...	...	2	22	73	24	7	1	..	..	..	..	..	..
13	156	14.04±.05	..	...	...	...	...	...	..	5	31	80	29	9	1	1	..	..	..	..
14	111	14.94±.07	..	...	...	...	...	...	..	2	7	26	49	19	6	1	1	..	..	..
15	100	16.22±.08	..	...	...	...	...	...	..	..	1	3	18	42	26	6	..	3	..	..
16	43	17.21±.13	..	...	...	...	...	...	..	..	..	..	2	12	16	5	7	..	1	..
17	28	18.01±.12	..	...	...	...	...	...	..	..	..	..	..	1	7	11	8	1	..	..
18	19	19.13±.14	..	...	...	...	...	...	..	..	..	..	..	..	..	5	9	3	2	..
19	9	19.74±.15	..	...	...	...	...	...	..	..	..	..	..	..	..	..	4	4	1	..
20	4	21.46±.17	..	...	...	...	...	...	..	..	..	..	..	..	..	..	..	..	2	2

[1]All measurements in units of ten-thousandths of an inch.

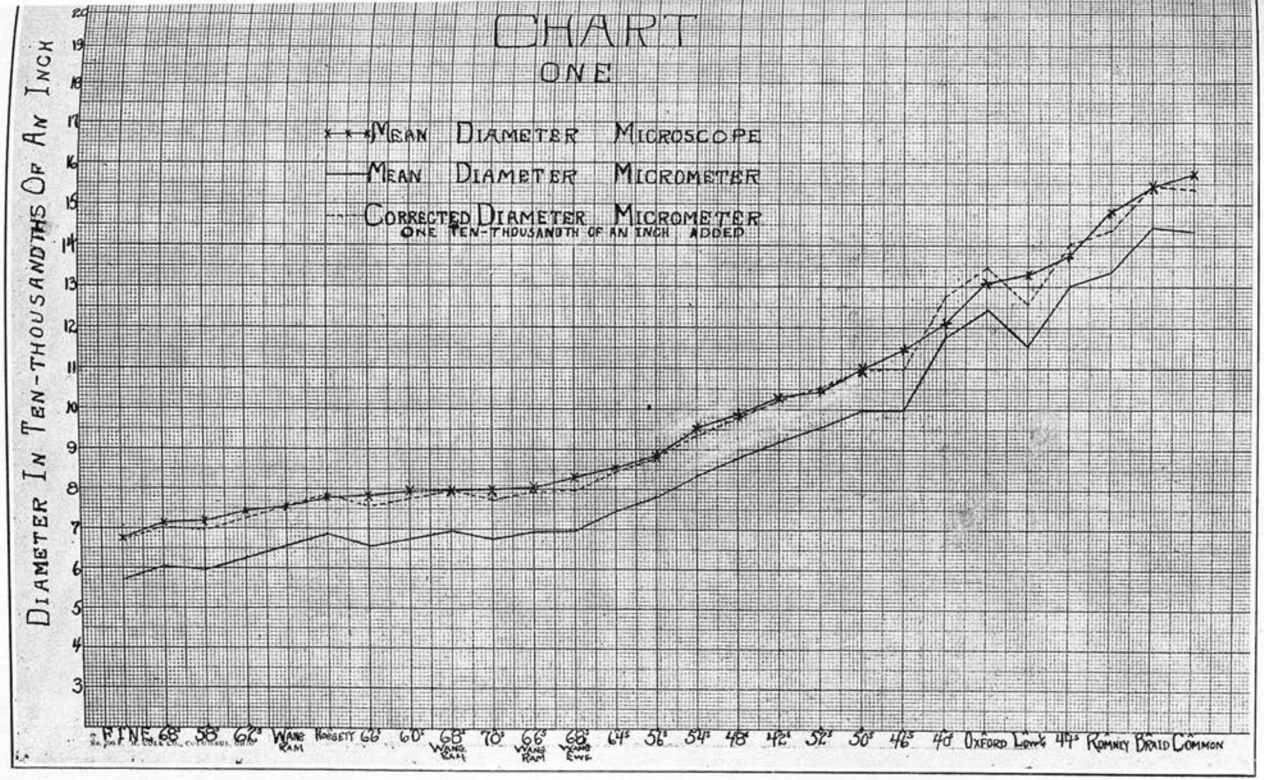
CHART
ONE
Mean Diameter Microscope
Mean Diameter Micrometer
Corrected Diameter Micrometer
One Ten-Thousandth of an Inch Added
Diameter In Ten-Thousandths Of An Inch
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
Fine 68s 58s 62s Wane Ram Hogget 66s 60s 68s Wane Ram 70s 66s Wane Ram 68s Wane Ewe 64s 56s 54s 48s 42s 52s 50s 46s 40s Oxford Lonk 44s Romney Braid Common

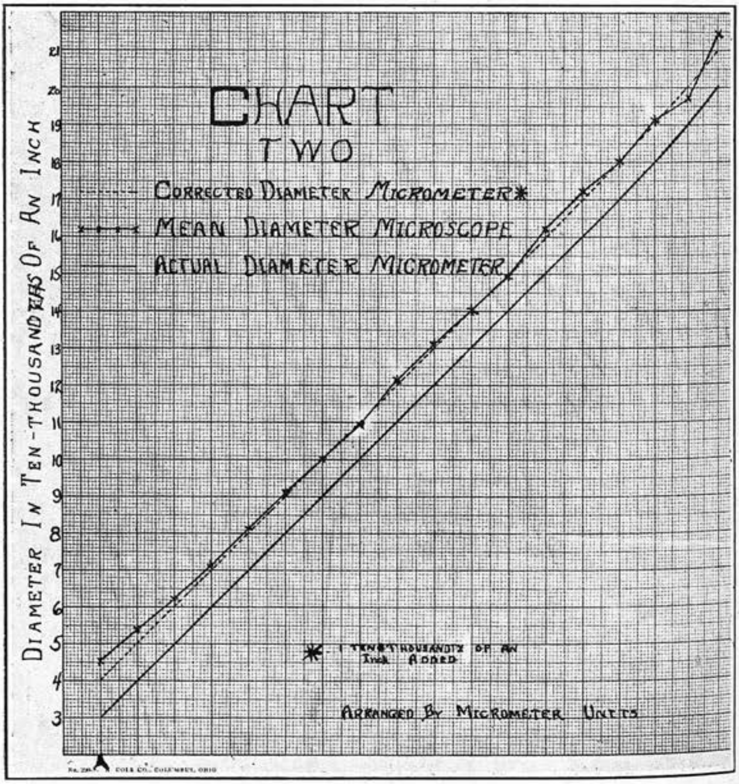
CHART
TWO
CORRECTED DIAMETER MICROMETER *
MEAN DIAMETER MICROSCOPE
ACTUAL DIAMETER MICROMETER
DIAMETER IN TEN-THOUSANDTHS OF AN INCH
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
ARRANGED BY MICROMETER UNITS

The two methods of measurement are compared in Tables I, II and III and in Charts One and Two.

In Table I the average diameter of each sample as measured by the micrometer caliper is compared with the average diameter obtained with the microscope. This comparison is shown graphically in Chart One.

The relation between the measurements obtained by the microscope is shown more in detail in Table II. The fibers are grouped according to their diameters measured on the micrometer caliper. This average microscopic measurements for each group is then used as a basis of comparison. For example, there were only 33 fibers among all those measured in the Government series that measured 4 ten-thousandths of an inch by the caliper and only 3 fibers of the Australian series. The average diameter of these groups measured by the microscope was 5.42 and 4.92 ten-thousandths, respectively, and the mean of the combined group of 36 fibers was 5.38. It is on this basis that the comparisons in the column headed "4" in Table II are made. The comparisons of Table II are shown graphically in Chart Two.

Table III shows in detail the frequency distributions of the microscopic measurements from which the means in Table II were obtained. Thus it is shown that the 36 fibers that measured 4 ten-thousandths in the caliper and had an average diameter of 5.38 ten-thousandths by the microscope, contained 22 fibers in the 5 group and 14 fibers in the 6 group, this grouping being on the basis of microscopic measurement to the nearest ten-thousandth of an inch.

RESULTS

Object No. 1.

The number of samples was relatively small (27) and so the results of this experiment are not to be taken as entirely conclusive, but are representative of only a relatively small number of samples.

The microscopic measurements were larger than the micrometer measurements in practically every fiber. This would be expected, for the micrometer has a slight crushing action on the fiber. Moreover, the fiber, when put between the glass slides, will tend to lie on its flat side and thus present its greatest diameter in the microscopic field. There is also a tendency for oval fibers to twist when the jaws of the micrometer are closed upon them and thus the smallest diameter is obtained when measuring fibers with the micrometer.[5]

All of these factors would seem to add more reliability to the results obtained in this experiment.

There were some variations in the difference between micrometer and microscopic measurements in the different samples, but, as shown by the table, the relation is fairly uniform.

Table I shows that the microscopic measurements of the entire series of samples average 113.8±.6 per cent larger than the micrometer caliper measurements. However, it can be seen from Chart One that if one ten-thousandth of an inch is added to the micrometer caliper reading, it will closely approximate the microscopic reading.

In the last column of Table I this addition has been made and in this case the microscopic measurements are 101.4±.3 per cent of the micrometer caliper measurements so adjusted. Thus the microscopic measurements are only 1.4 per cent greater than the micrometer caliper measurements corrected by the addition of one ten-thousandth of an inch.

Object No. 2.

If all of the fibers having a certain micrometer measurement are gathered together we have the results given in Tables II and III and in Chart Two.

Now, if these fibers are divided into two, large groups placing all fibers measuring from 3 to 10 ten-thousandths of an inch, inclusive, in diameter in one group, and all those measuring from 11 to 20 ten-thousandths of an inch in diameter, inclusive, in the other group, some interesting facts are disclosed.

If the correction of one ten-thousandth of an inch is added to the micrometer caliper measurements the resulting figure is very close to the microscopic measurement. To be fairly accurate so far as the results of this experiment go the corrected

5. Hardy, J. I., Journal of Agricultural Research, V. 14, No. 8, pp. 285-296.

micrometer caliper mean if between 1 and 10 ten-thousandths would have to be multiplied by 103.7 per cent and if between 10 and 20 it would have to be multiplied by 100.7 per cent.

Thus the fact is brought out that there is less variation between the two methods of measuring diameter in the large fibers than in the small fibers. This difference is expressed in percentage and thus would naturally be larger in the smaller fibers. Then also the larger fiber has more area in contact with the jaws of the micrometer than the smaller fiber.

Effect of softness on the accuracy of the micrometer.

Since it seems evident that one of the sources of error in the use of the micrometer is the compression of the fiber between its jaws, the question arose whether fibers from wool that feels soft to the touch would be compressed more than fibers of wool that lack the feeling of softness. The samples of Australian wool used in these experiments had been kept in the laboratory to illustrate the softness of certain types of Australian wool.

But the Australian samples did not show as much variation in diameter between the two methods of measurement as did American wools of corresponding fineness. Hence it would seem that soft Australian wools do not yield to a crushing force any more readily than American wools of similar fineness, and that any special softness of Australian wools is not caused by a weak-celled fiber that is easily compressed. It may be the gloss and oiliness of the surface or some other characteristic of the fiber which gives it its reputation for softness in the manufacturing trade.

In this connection it must be remembered that only five samples of Australian wools were used, which is a small number, but, nevertheless, was about the same number as was used of similar American grades.

SUMMARY

Object. I.

A. The average microscopic measurements of any sample were always larger than the average caliper measurements.

B. For all practical purposes this difference amounts to 1 ten-thousandth of an inch.

Object No. 2.

Larger fibers do not give us as great a proportionate difference of diameters measured by the two instruments as do the smaller fibers. No important difference was found that could be attributed to the difference in the softness of the samples measured.

CONCLUSION

The micrometer caliper is much easier for students to use than the microscope for measuring wool. It has been proved to be fairly accurate, and the measurements obtained by it bear a rather close relationship to the microscopic measurement. For all practical purposes this relationship may be expressed as follows:

The diameter as measured by the caliper + 1 ten-thousandth of an inch equals the diameter measured by the microscope.

Presented in support of thesis entitled

STUDIES OF THE INHERITANCE OF WOOL CHARACTERS AND FLEECE ANALYSIS IN SHEEP".

By

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WYOMING EXPERIMENT STATION

Wool Measurement Technic

By Robert H. Burns

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WOOL MEASUREMENT TECHNIC

By Robert H. Burns

Wyoming Experiment Station

For a number of years wool measurements of various kinds have been advocated as a means of standardizing materials in the wool trade. Kereszturi, A. F. Barker, Duerden, Henseler, Kronacher, Gordon, Willingmyre, and a number of others have advocated standards of measurement in both the raw wool and the finished product. Slowly wool measurements are being recognized as essential in the wool trade. A standard of comparison is always very useful, if not essential, in any line of work which requires an individual to pass judgment on a product, particularly where physical dimensions are involved.

The following dimensions of wool fibers have been measured by various means and will form the basis of this paper:

1. Length of staple.
2. Length of fiber or length of individual fibers with crimp removed.
3. Crimps per unit length, length of crimp, or percentage of crimp.
4. Strength or breaking load.
5. Elasticity or extensibility under stress.
6. Diameter.
7. Density, number of fibers per unit area of skin, or specific gravity.
8. Scales and luster.
9. Structure and kemp.

Length of Staple

Length of staple is measured on the sheep and on the fleece, usually by the simple method of laying a rule alongside the staple.

Length of Fiber

Length of fiber, that is, length stretched taut with the crimp removed has been measured in various ways. Davenport and Ritzman used a MacKenzie fiber-testing machine, stretching the fiber between two clamps. This is the same machine that has been widely used for strength and elasticity studies, and is fully described by Hill in Wyoming Bul. No. 92. Length of fiber and elasticity are closely related. However, length of fiber usually is understood to mean normal extension without any stress on the internal structure of the fiber. The amount of stress which will just remove the crimp will not affect the internal structure of the fiber.

J. F. Wilson, of California, has recently devised a new method which is a simplified application of the MacKenzie testing machine. The fiber to be tested is fastened in a clamp so that the end of the fiber corresponds with a zero mark on a standard in back. The other end of the fiber is clamped in a safety pin clamp weighing .8 of a gram, which gives a constant stress to all fibers.

The writer has recently tried out a simple method of measuring fiber length which has worked to good advantage. The chief piece of equipment is a dark brown Chenille rug swatch with a *half-inch* pile. The tweezers used are equipped with cork tips. Cork will hold the fiber fairly well and still will not stick to it and thus break it as will wax and some other materials. The rule is laid out on the rug swatch. The fiber is laid in front of the ~~swatch~~ rule and worked down into the pile, then the thumb nail of the left hand is placed over the fiber at the end of the rule and the other end of the fiber caught with the tweezers and drawn through the pile of the swatch until the tip of the fiber comes out from under the nail. A reading of stretched length to the nearest tenth of an inch is then easily taken, using the tweezer tips as a pointer on the rule. The *half-inch* pile of the rug swatch gives just the right amount of friction to straighten out the crimps in the fiber.

Not much work has been done on the number of fibers to be measured for fiber length. The writer has measured a series of wool samples of different types, grouping the measurements in groups of five up to one hundred measured from each sample. There were six samples, including Rambouillet, Corriedale, Hampshire, Oxford, Lincoln, and a cross-bred Hampshire-Rambouillet.

How Many Fibers Should be Measured for Length of Fiber?

Average of all six samples.

No. fibers measured	Mean length inches	Variation from entire hundred, inches	No. fibers measured	Mean length inches	Variation from entire hundred, inches
5	4.82	Plus .20	55	4.69	Plus .07
10	4.86	Plus .24	60	4.67	Plus .05
15	4.85	Plus .23	65	4.65	Plus .03
20	4.81	Plus .19	70	4.66	Plus .04
25	4.80	Plus .18	75	4.66	Plus .04
30	4.76	Plus .14	80	4.65	Plus .03
35	4.74	Plus .14	85	4.64	Plus .02
40	4.73	Plus .11	90	4.63	Plus .01
45	4.72	Plus .10	95	4.63	Plus .01
50	4.71	Plus .09	100	4.62	....

The probable error of the mean for the hundred fiber is ±.04. Three times this probable error (.12) would indicate that in the neighborhood of 50 fibers could be considered a fair sample for this measurement.

Other methods used in measuring elasticity could also be adapted for the measurement of fiber length. However, all of these methods are more complicated, and the method outlined above should suffice for the determination of fiber length for all practical purposes. The other methods will be discussed under elasticity.

Crimp Determination

Number of Crimps Per Unit Length. In this method the number of crimps per unit length in either the English or metric system are counted along a rule. The writer has used two methods: first, cutting a half-inch notch in a piece of black cardboard and using this notch as a gauge of unit length; and second, using a pair of dividers. Both methods worked well and are much better than trying to count the number of crimps along a straight rule. Another method is described by McMurtrie, and also by Heyne, and more recently by Duerden, in which standard gauges of sawtooth graduations are cut on a rule, separate sections being constructed with sawtooth graduations varying from 5 to 35 crimps per inch. These sections are most conveniently grouped in segments around the perimeter of a circular instrument. The graduated segments are placed over the fiber rotating the instrument until a segment is reached which matches with its own sawtooth graduations the crimp of the fiber.

S. G. Barker has recently classified crimp and reported a new method of measuring the length of crimp by means of a projected image, using an apparatus devised by Doctor Nichols, of Edinburgh. The essential feature is the measurement on a graduated glass screen of the dark shadows cast by the crimps when the wool is placed in front of a subdued light. Readings are taken on 25 locks and the average number of crimps per inch calculated.

Measuring the individual crimps or waves was early used, Nathusius being one of the first to report this method. On account of the difficulty of defining the top or trough of the waves to make the measurements from one definite point to another this method has not been used much in late years.

Percentage of Crimp. This method, used by Davenport and Ritzman, is one of the most satisfactory methods of measuring the utility value of crimp. The percentage of increase in length of stretched fiber over the normal fiber with natural crimp is determined.

Duerden gives an interesting account of the formation of crimp in wool; and Speakman, in his articles on the internal structure of wool, also gives an account of the shape and contraction of cells which are concerned in the production of crimp.

Strength or Breaking Load

An enormous amount of work has been done on the strength of wool fiber. A number of different apparatuses have been developed for the determination of breaking strength. McMurtrie made a very comprehensive report on American wools; while later work was done by Hill, Hardy, Miller, Joseph, and J. F. Wilson. All of this work was done with the MacKenzie fiber-testing machine designed at the Philadelphia Textile School. The importance of atmospheric conditions has been forcefully illustrated in most climates, but is not so important in drier climates. Barker and King worked at ordinary room temperature keeping records of humidity and made slight corrections. However, a large number of determinations have to be made. Tänzer gives a review of the German work on strength and elasticity, and gives descriptions of a number of different apparatuses. Shorter, Speakman, and A. F. Barker, of England, have done considerable work on strength, going into the structure of the wool fiber to explain the observed action of fibers while under stress.

Elasticity or Extensibility under Stress

The same apparatus which is used for breaking strength is, in most cases, used also in the determination of elasticity. However, the Deforden apparatus, described by Kronacher, and the apparatus developed by the British Research Association for the Woolen and Worsted Industry and made by the Cambridge Instrument Company are used entirely for the determination of elasticity. Both apparatuses record the extensibility of fibers under different stresses. Speakman has done some excellent work on the structure of wool fibers in relationship to their elasticity. He has found the remarkable fact that a fiber stretched as far as 70 per cent of its length failed to take a permanent set of more than .8 per cent.

Diameter

This was one of the first characters of wool to be measured, and a number of methods have been developed. McMurtrie and Probst review the history of wool diameter determination. After the discovery of the microscope in 1608 and the production of the micrometer eyepiece the microscope was used for wool measurement. According to Probst, Daubenton, in 1777, was the first to mention the determination of wool fiber diameter with the microscope. Later the Filar eyepiece with moveable cross-hair was developed, and today this eyepiece is the one which is used in direct microscopic measurement. However, Doehner, Henseler, Kronacher, Davis, and others have used a modification of the microscopic method with projection of the magnified image on a screen.

Measurement with the Micrometer Caliper. Hill, Hardy, Burns, and Koehler have reported on the use of the machinist's micrometer caliper graduated in ten-thousandths of an inch for the measurement of wool diameters. The methods used in micrometer caliper measurement have been described by Burns and Hultz. Koehler compared microscopic measurements with micrometer caliper measurements and found that on the average the micrometer measurements were one ten-thousandth of an inch finer. This is probably due to the fact that the narrow axis is measured in the micrometer caliper and the wide axis measured with the microscope. Air-dry mounting was used. The British Research Association reporting identical results with balsam, glycerine, water, and air-dry mountings. The writer offers, in the following table, some preliminary results on the number of fibers which must be measured to insure mathematical accuracy in the determination of diameter.

How Many Fibers Should be Measured to Determine the Mean Diameter of a Sample?

Average of 4 samples.

Number of fibers measured	Mean diameter .0001 inch	Variation from 500 .0001 inch
100	5.56	Plus .34
200	5.41	Plus .17
300	5.37	Plus .13
400	5.31	Plus .07
500	5.24	....

As the probable error of the mean for 500 fibers is ±.02, three times this error (.06) indicates that one should measure around 500 fibers to insure mathematical accuracy. One should, however, take into consideration the nature of the data before taking the probable error figure above too literally. The maximum difference due to the number of fibers measured was .34. If the difference between the two factors being studied is more than three times the difference, due to the number of fibers measured, the measurement of 100 fibers should be sufficient. If, on the other hand, the difference between the two factors being studied is less than three times the difference, due to the number of fibers measured, 500 fibers should be measured. Duerden recommends measuring at least 500 fibers to determine the thickness of wool.

Optical Refraction Instruments for Determining Diameter. The need of a method of quickly determining the average diameter of an entire sample has led to the development of optical refraction instruments. Ewles, of Leeds University, and McNicholas, of the U. S. Bureau of Standards, have brought out instruments of this type. The writer has one of the Ewles instruments and finds it satisfactory for the medium and coarse wools, but not so adaptable for the finer wools.

The writer tested a sample of fine range wool and a sample of Lincoln wool. A wisp of wool from each sample the right size to permit the passage of light readily through it was placed in the Ewles instrument and ten separate readings taken. These were taken by turning over the instrument and turning the tube so that each reading was independent of the others. The average diameter of each sample was then determined by measuring 100 fibers with the micrometer caliper.

Sample	Ewles instrument mean diameter .0001 inch	Micrometer caliper mean diameter .0001 inch
Fine range wool	7.50	5.69
Lincoln wool	14.57	12.44

These preliminary results show that the micrometer caliper measured about two ten-thousandths of an inch finer than the Ewles optical instrument. The close correspondence of differences, i. e., 1.81 and 2.13 is very interesting. The McNicholas instrument is still in the experimental stage according to recent correspondence.

The Weight-Length Ratio for Determining Diameter. This method, developed in part by Barker and King and further by Roberts, is to determine the number of centimeters of fiber that weigh a milligram. Where the fibers are free from an air-filled medulla this method gives very good results. When the medulla is present the weight-length ratio gives much finer measurements than the diameter measurement by microscope.

Wilkinson has worked out a mathematical method of determining the diameter of worsted yarns. He derives the following formula:

$$D = \frac{1}{1.01 \sqrt{560\, cd}}$$

D Average diameter of a cross-section of a yarn

c Count

d Relative density $= 1.164$

Density Determination

This term is interpreted in two different ways. Originally the term was thought of as meaning the specific weight or specific gravity of wool. Nathusius, in his work, takes this interpretation and speaks of the number of fibers on the skin instead of density. Later, however, particularly in the United States, the term density is thought of as referring to the number of fibers per unit area of skin.

Hill suggested the method of density determination, which has been used by the writer and other workers in this department since 1921. This method was first reported by the writer in the 1924 proceedings of this society. Later work established the standard error of sampling for the writer of around 425 fibers.

The only other density work the writer has found reported is that of Nathusius, who reports the number of fibers per square millimeter of skin. He took sections parallel to the skin surface, mounted the sections, and counted the hair follicles with a microscope. His results with Merinos correspond with the results at Wyoming with Rambouillets.

Nathusius and Wilkinson, among others, report on the specific weight or density of wool. Nathusius gives figures from 1.25 to 1.95, while Wilkinson uses the figure 1.288.

Various instruments have been used for taking density samples. The Wyoming station originally used a pair of outside measuring calipers, but later work proved a pair of 4-inch dividers, with the legs altered so that they were parallel for the last inch on the tip, to be just as accurate in all cases and much easier to handle, particularly in long, dense wools. Later Nordby, of the Idaho station, came out with a pair of calipers mounted together, but these would have the same faults that our original pair of calipers had in being hard to handle.

Pelt Samples Compared with Fleece Samples for Density Determination. The writer compared fleece density and pelt density on a cross-bred wether, taking eight samples from the fleece (different body locations) before slaughter and eight samples from the pelt while wet, marking the one-half inch square areas on the flesh side and cutting the area out with a razor blade, and then clipping the wool samples from the pelt samples.

An average of the eight samples showed a density of 4,395 for the fleece samples and a density of 3,945 for the pelt samples—a difference of 450 fibers, which is not a significant difference, as the standard error of sampling on duplicate fleece samples worked out to be 425 fibers.

Scales and Luster

Very little work has been done on the measurement of scales and luster. Hausman has done considerable work with mammal hairs, particularly with fur hairs, and his measurements of scales on fur hairs should be applicable to wool. McMurtrie gives a description of the scales in different types of wool, but no measurements were taken.

Denham and Lonsdale give the fundamental features concerning the reflection of light from lustrous materials.

Saxinger reports some measurement work on the epithelial scales of different kinds of mammalian hairs, counting the number of scales in a definite length of fiber (.21 mm.) on base, middle, and tip of the fibers.

Structure and Kemp

Nathusius was one of the first to report on the structure of wool fibers, and his carefully planned experiments yielded results which have stood the test of time. Speakman has recently made some excellent contributions to this field in trying to tie up fiber structure with observed changes in the fiber while under stress. Recently a large amount of work has been done on kemp by various workers in the United States, England, South Africa, and New Zealand. S. G. Barker recently completed some very interesting work on the characteristics of wool as affecting worsted spinning. His results show that contour of fiber is one of the other factors besides diameter which markedly affect the spinning quality of a fiber, and the more circular the contour the better it will spin.

Progress and Future Needs

Although a great deal has been done in wool measurement, a still larger task remains to be done. Wool measurement methods need to be standardized. Hardly any two investigators use the same methods, and consequently results cannot be compared without correction factors, which are not altogether suitable for use in the comparison of data. Simplicity of apparatus is another point which needs attention. In all physical measurements the more measurements made the more reliable the data. With a simple apparatus more measurements can be made in less time, and it is quite likely that the greater number of measurements, probably made more accurately because of less strain on the operator, will be of much more value than a much smaller number of measurements made in the same length of time on a more complex apparatus, with much more preparation of material and adjustment of apparatus. This fact is mentioned by Naumann in recommending the microscopic-projected image method of diameter determination against the original microscopic-micrometer ocular method. The Wyoming station has always recommended the micrometer caliper over any microscopic method for diameter determination for the same reason. The third factor the writer would mention, which has already been mentioned by Hill in the 1925-26 proceedings of this society is the need of co-ordination of wool experiments. So much experimental work is needlessly duplicated, and again some portions of experiments are done poorly at one station on account of lack of facilities which could better be done at some other station. Each experiment station has its own peculiar advantages, and in planning wool measurement work quicker and better progress could be made by co-ordination and co-operation between stations. To recapitulate the three corners of the triangle of more successful wool measurement research are as follows:

1. Standardization of methods.
2. Simplification of apparatus.
3. Co-ordination of problems and co-operation between stations.

A very recent book by Frolich, Spottel, and Tänzer, entitled "Wollkunde," covers the field of wool measurement very well; in fact, it is the best single book on the subject that has come to the writer's attention.

A list of the literature cited will be sent upon request.