

JOSEPH A. BULKELEY



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THESIS  
A Microscopic  
Examination of Wool

J. A. Bulkeley,

1901

1899

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Sheep  
Wool

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Senior Agricultural Thesis

on

"A Microscopic Examination of Wool".

by

*Joseph Arthur*  
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Class of '99.

B.S.

Michigan Agricultural College.

Agricultural College, Mich.

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## A MICROSCOPIC EXAMINATION OF WOOL .

The investigations (the results of which are herein given) have been made for the purpose of ascertaining what differences, if any, exist between fibres of wool representing different breeds of sheep. The objects of the investigation, stated more definitely, have been:

1. To show by means of micro-photographs the relative appearances of the different fibres.
2. To show by means of drawings their cuticle structure as seen under a high power microscope.
3. To ascertain their average diameters, and such other data in reference to the same as will tend to show the differences existing between the wool fibres of the different breeds of sheep.

In order to make the work as complete as possible, the wool selected represented what are commonly known as the fine-woolled, medium-woolled, and long woolled breeds, the samples being considered typical in all respects of the breeds chosen. Following is a list of the varieties.

TABLE 1.

### VARIETIES OF WOOL.

BREED OF SHEEP.	CLASIFICATION OF WOOL.
No. 1 American Merino	XX Clothing.
No. 2 Spanish Merino	X Clothing.
No. 3 American Merino	X Clothing.

No.4	Dickinson Delaine	:	Fine Delaine.
No.5	Rambouillet	:	Fine Delaine.
No.6	Shropshire	:	3/8 Clothing.
No.7	Southdown	:	3/8 Clothing.
No.8	Hampshire Down	:	3/8 Combing.
No.9	Oxford Down	:	1/4 Combing.
No.10	Cheviot	:	1/4 Combing.
No.11	Dorset Horned	:	1/4 Combing.
No.12	Leicester	:	1/4 Combing.
No.13	Lincoln	:	Braid Combing.
No.14	Cotswold	:	Braid Combing.

In order to show photographs a typical sample was selected from each variety above named and a small portion taken from its centre. This was treated with sulphuric ether to remove all fat, then mounted in Canada balsam and examined under the microscope. It was found, however, that it was next to impossible to procure a photo owing to the fact that the fibre under the necessary high power was practically translucent, and gave no contrast with the mounting medium. In order to overcome this difficulty the specimens were treated with silver nitrate; by this means the component parts of the fibre were brought out distinctly. The resulting photographs are here given.

#### W O O L C U T I C L E .

From an examination of the fibres of wool under a microscope it will be seen that they differ materially from the fibres of plant bodies. In each of the two latter cases the outside wall of the fibre is composed of a single continuous layer, which is not divided into sections, and is known as the cell-wall. In the wool fibre on the other hand, the outer





layer, or cuticle, as it is called, is divided into a number of plates, giving it a rough and irregular appearance. These plates are somewhat of the one general shape, though differing greatly in size. Each plate overlaps the adjoining one, the rough exterior of the fibre being due to this fact. The following drawings will give an idea of the size and shape of the plates in question.

#### FIERE DIAMETERS.

The same fourteen varieties shown in the photographs were used to determine the fibre-diameters. Several fibres were first taken, treated with sulphuric ether to remove all fat, and examined under the microscope. Such examination throughout their whole length revealed the fact that in all cases the diameter at the tip of the fibre was much less than at the base, the rate of increase being fairly uniform. In order therefore to make the readings as nearly correct as possible, the samples should all be selected from one given part of the staple, preferably the centre. From each variety of wool twenty typical fibres were selected. From these, portions about one-quarter of an inch in length and cut exactly from the middle, treated with sulphuric ether and silver nitrate and mounted in Canada Balsam. Even after taking all due precautions in selecting the specimens, it was found that the fibres were not of a uniform texture. Indentations were numerous, the fibres in some cases appearing to be almost broken in halves. Care was taken, however, to reject such parts of the samples and to procure readings only from those parts that appeared to be of the most uniform thickness. The following table shows the readings so obtained, the measurements being given in microns (a micron equals the ~~one-thirtieth~~ one-thirtieth part of a millimeter).

TABLE 2.

Showing measurement of fibres in microns.

## Varieties and Measurements in Microns.

American Merino XX Clothing.	Spanish Merino	American Merino X. Clothing.
28.5	28.5	25.7
25.7	30.0	35.7
38.5	28.5	30.0
37.1	34.2	28.5
28.5	31.4	27.1
27.1	31.4	30.0
32.8	31.4	27.1
38.5	28.5	27.1
38.5	30.0	28.5
37.1	32.8	25.7
32.8	27.1	32.8
42.8	32.8	28.5
30.0	35.7	28.5
34.2	31.4	31.4
35.7	30.0	32.8
32.8	34.2	25.7
31.4	35.7	27.1
28.5	31.4	30.0
34.2	38.5	28.5
<u>34.2</u>	<u>25.7</u>	<u>25.7</u>
670.	630.	578.5

	Dickenson Delaine	Rambouillet	Shropshire
	24.3	27.1	21.4
	30.0	20.0	27.1
	25.7	25.7	27.1
	24.3	20.0	28.5
	24.3	25.7	34.2
	27.1	24.3	30.0
	27.1	31.4	37.1
	28.5	28.5	31.4
	28.5	30.0	28.5
	34.2	35.7	35.7
	32.8	28.5	38.5
	35.7	31.4	40.0
	31.4	28.5	41.4
	28.5	40.0	38.5
	34.2	32.8	47.1
	31.4	30.0	38.5
	28.5	27.1	41.4
	32.8	30.0	27.1
	30.0	24.3	45.7
	<u>35.7</u>	<u>25.7</u>	<u>32.8</u>
Totals	594.3	565.7	692.8

Southdown	Hampshire	Oxford Down	Cheviot.
40.0	55.7	44.3	55.7
42.8	42.8	42.8	54.3
44.3	54.3	58.5	55.7
32.8	44.3	57.1	57.1
30.0	40.0	54.3	52.8
28.5	44.3	64.3	55.7
50.0	30.0	40.0	57.4
51.4	48.5	48.5	41.4
34.2	54.3	54.3	42.8
42.8	47.1	40.0	45.7
32.8	57.1	42.8	47.1
44.3	40.0	48.5	50.0
37.1	44.3	55.7	61.4
47.1	44.3	32.8	62.8
37.1	52.8	58.5	47.1
50.0	34.2	40.0	45.7
48.5	45.7	47.1	48.5
44.3	44.3	30.0	45.7
40.0	57.1	50.0	47.1
<u>41.4</u>	<u>32.8</u>	<u>61.4</u>	<u>55.7</u>
Totals	820.	928.5	1024.3

	Dorset Horned	Leicester	Lincoln	Cotswold
	40.0	44.3	50.0	64.3
	51.4	57.1	50.0	62.8
	45.7	57.1	42.8	68.5
	45.7	45.7	41.4	61.4
	37.1	50.0	48.5	68.5
	44.3	41.4	57.1	67.1
	38.5	52.8	57.4	44.3
	35.7	57.1	48.5	55.7
	34.2	55.7	50.0	57.1
	57.1	48.5	51.4	62.8
	35.7	48.5	50.0	45.7
	51.4	44.3	42.8	60.0
	40.0	51.4	47.1	48.5
	51.4	47.1	48.5	44.3
	44.3	58.5	45.7	64.3
	30.0	51.4	42.8	60.0
	38.5	50.0	47.1	57.1
	44.3	61.4	48.5	57.1
	48.5	52.8	47.1	54.3
	<u>50.0</u>	<u>52.8</u>	<u>50.0</u>	<u>48.5</u>
Totals	892.8	1028.5	961.4	1152.8

From the figures given in the foregoing table the varieties of wool can be arranged in order according to their diameters. Such order is given in table 2, the average diameters being expressed in microns and in decimals of an inch.

TABLE 3.

Showing average diameters of wool fibres in microns and in decimals of an inch.

Varieties	Average diameters in microns.	Average diameters in decimals of an inch.
Rambouillet	28.28	.00111
American Merino- XX Clothing	28.93	.00113
Dickenson Delaine	29.71	.00113
Spanish Merino	31.50	.00124
American Merino- XX Clothing	33.50	.00131
Shropshire	34.64	.00136
Southdown	41.00	.00160
Dorset Horned	44.64	.00170
Hampshire	46.43	.00182
Oxford Down	47.85	.00188
Lincoln	48.07	.00189
Leicester	48.57	.00190
Cheviot	57.21	.00201
Cotswold	57.64	.00227

A glance at Table 1 will show that there is a marked difference in the diameters of different fibres of the same variety of wool, and this notwithstanding the fact that the most typical fibres were selected and to the naked eye seemed to be of about the same degree of fineness.

The following table gives the smallest, largest and average diameters, and the difference between the smallest and largest diameters of the fibres examined.

Table 4.

Varieties	: Smallest : Diameters	: Difference : between : smallest : and aver- : age diam- : eters.	: Aver- : age : Diam- : eters	: Differ- : ence : between : largest : and av- : age dia- : meters.	: larg- : est : Diam- : eters	: Differ- : ence : between : largest : and small- : est diam- : eters.
American Merino- X Clothing	: 25.7	: 3.2	: 28.9	: 6.8	: 35.7	: 10.0
Dickinson Delaine	: 24.3	: 5.4	: 29.7	: 6.0	: 35.7	: 11.4
Spanish Merino	: 25.7	: 5.8	: 31.5	: 7.0	: 38.5	: 12.8
Rambouillet	: 24.3	: 4.0	: 28.3	: 11.7	: 40.0	: 15.7
Lincoln	: 41.4	: 7.6	: 49.0	: 9.1	: 57.1	: 15.7
American Merino XX Clothing	: 25.7	: 7.8	: 33.5	: 9.3	: 42.8	: 17.1
Leicester	: 41.4	: 7.1	: 48.5	: 12.9	: 61.4	: 20.0
Cheviot	: 41.4	: 11.1	: 55.5	: 7.3	: 62.8	: 21.4
Dorset Horned	: 34.3	: 10.3	: 44.6	: 12.5	: 57.1	: 22.8
Southdown	: 28.6	: 12.4	: 41.0	: 10.4	: 57.4	: 22.8
Cotswold	: 44.3	: 13.3	: 57.6	: 10.9	: 68.5	: 24.2
Hampshire	: 30.0	: 16.4	: 46.4	: 10.7	: 57.1	: 27.1
Oxford Down	: 30.0	: 17.8	: 47.8	: 16.5	: 64.3	: 34.1



A close examination of two samples of wool taken from the same part of any two fleeces representing distinct breeds of sheep, more particularly if one be a long-woolled and the other a short-woolled breed, will readily show that there is a great difference in the fibre-diameters of the two wools. Even in the case of a single specimen of any one breed, we can easily recognize the fact that the wool on the shoulder is much finer than that covering the belly. But it is hard to believe that there could be any considerable difference in diameter between, say, twenty fibres taken from one spot. It would be only natural to suppose that all fibres taken from a given square inch of skin surface would be of an equal fineness. Yet such is far from being the case. In the twenty samples of each variety examined, a wide variation was found. In some cases the difference in diameter was remarkable; in fact, in a few instances the difference amounted to more than one-half the diameter of the coarsest fibre. It is only to be expected, that, given two different breeds of sheep with fleeces similar in all other respects, the one in which the least variation in fibre diameter occurs, will be the most valuable from the cloth manufacturer's point of view.

In the following table the varieties of wool are given in order with their average variation from the average diameter. In order to obtain this variation the difference between the diameters of each fibre of each variety examined, and the average fibre, have been added together, and divided by twenty, the number of fibres examined. In this way the average variation has been secured.



TABLE 5.

Showing Variations from Average Diameters. Measurements are given in microns.

Variety	American Mer- rino. XX	Spanish Merino Wool	American Meri- no. X Clothing	Dickinson.
Average Diameters:		3.23	28.93	29.71
	5.00	3.00	3.23	5.41
	7.80	1.50	6.77	.29
	5.00	3.00	1.07	4.57
	3.60	2.70	.43	5.41
	5.00	.10	1.83	5.41
	6.40	.10	1.07	2.67
Variations	.70	.10	1.83	2.61
	5.00	3.50	1.83	1.21
	3.60	1.50	.43	1.21
	.70	1.30	3.23	4.49
	9.30	4.40	3.87	3.09
	3.50	1.30	.43	5.99
	.70	4.20	.43	1.69
	3.20	.10	2.47	1.21
	.70	1.50	3.87	4.49
	2.10	2.70	3.23	1.49
	5.00	4.20	1.83	2.61
	.70	.10	1.07	3.09
	.70	7.10	.43	.29
	5.00	5.80	.23	5.99
Total Variations	72.70	47.70	39.58	62.60
Average Variations:	3.63	2.38	1.97	3.18.

Rambouillet	Shropshire	Southdown	Hampshire	Oxford Down
28.28	34.64	41.00	46.43	47.85
1.14	13.20	1.00	9.27	3.55
8.28	7.54	1.80	3.63	5.05
2.58	7.54	3.30	7.87	10.65
8.28	6.14	8.20	2.13	9.25
2.58	.44	11.00	6.43	6.45
3.98	4.64	12.50	2.13	16.45
3.12	2.46	9.00	16.43	<del>7.85</del>
.72	3.86	10.40	2.07	.65
1.72	6.14	6.80	7.87	6.45
7.42	1.06	1.80	.67	7.83
.22	3.86	8.20	10.57	5.05
3.12	5.36	3.30	6.43	.65
.22	6.76	3.90	2.13	7.85
11.72	3.86	6.10	2.13	15.05
4.52	12.46	3.90	5.37	10.65
1.72	3.86	9.00	12.23	7.85
1.18	6.76	7.50	<del>11.73</del>	.75
.22	7.54	3.30	2.13	17.85
3.98	11.06	1.00	10.67	2.15
2.58	1.84	.40	13.63	13.55
68.80	115.80	112.40	124.52	155.60
3.44	5.79	5.62	6.22	7.78

Cheviot	Dorset Horned	Leicester	Lincoln	Cotswold
57.21	44.64	48.57	48.07	57.64
4.49	4.64	4.27	1.93	6.66
3.09	6.76	8.53	1.93	5.16
4.49	1.06	8.53	5.27	10.86
5.89	1.06	2.87	6.67	3.76
1.59	7.54	1.43	.43	10.86
4.49	.34	<del>9.83</del>	9.03	9.46
.19	6.14	4.23	3.33	13.34
9.81	8.94	4.23	.43	1.94
8.41	10.44	8.53	1.93	.54
5.57	12.46	7.13	3.33	5.16
4.11	8.94	.07	1.93	12.94
1.21	6.76	.07	5.27	2.36
10.19	4.64	4.27	.97	9.14
11.59	7.67	2.83	.43	13.34
4.11	.34	1.47	2.37	6.66
5.57	14.64	9.93	5.27	2.36
2.71	.34	2.83	.97	.54
5.51	6.14	1.43	.43	.54
4.11	3.86	12.83	.97	3.34
4.49	5.36	4.23	1.93	9.14
101.50	117.16	96.88	54.82	128.10
5.07	5.85	4.84	2.74	6.40

From the foregoing table we can place the varieties in order of value, based upon the least variation in diameter of fibres.

TABLE 6.

Varieties in order according to least variation in diameter of fibre. Measurements are given in microns.

Varieties	Variation from the Average.
America Merino--X Clothing-----	1.97
Spanish Merino -----	2.38
Lincoln -----	2.74
Dickinson Delaine -----	3.18
Rambouillet -----	3.44
American Merino - XX Clothing -----	3.63
Leicester -----	4.84
Cheviot - -----	5.07
Southdown-----	5.62
Shropshire -----	5.79
Dorset Horned -----	5.85
Hampshire-----	6.22
Cotswold -----	6.40
Oxford Down -----	7.78

A study of the foregoing table will show at a glance the wide difference in uniformity of fibre-diameter that exists between different varieties of wool. Fine wools are more valuable than coarser kinds on account of their finer texture. This table shows them to be more valuable also for a second reason. With the single exception of the Lincoln the finer wools possess the greatest uniformity in diameter.

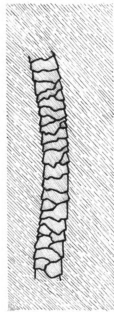
From Table 5 we calculate the average diameter of the whole of the fibres to be 28.72 seven-hundredths of a millimeter, or, .00161 inches. Of the twenty varieties examined, seven were finer and seven coarser than the average, as shown in the following table:-

TABLE 7.

Showing varieties finer and coarser than the average.

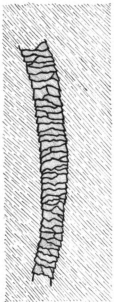
Variety	Comparison with average diameter.
American Merino (X)	Finer
Spanish Merino	Finer
American Merino (XX)	Finer
Dickenson Delaine	Finer
Rambouillet	Finer
Shropshire	Finer
Southdown	Finer
Hampshire	Coarser
Oxford Down	Coarser
Cheviot	Coarser
Dorset Horned	Coarser
Leicester	Coarser
Lincoln	Coarser
Cotswold	Coarser.

*Diagrams showing structure of Cuticle*



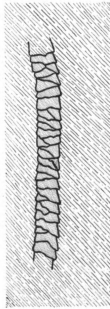
**American Merino.**

xx Clothing.



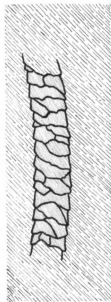
**Spanish Merino.**

x Clothing.



**American Merino.**

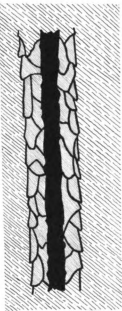
x Clothing.



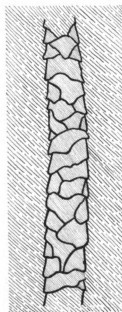
**Dickenson .**

Fine Delaine .

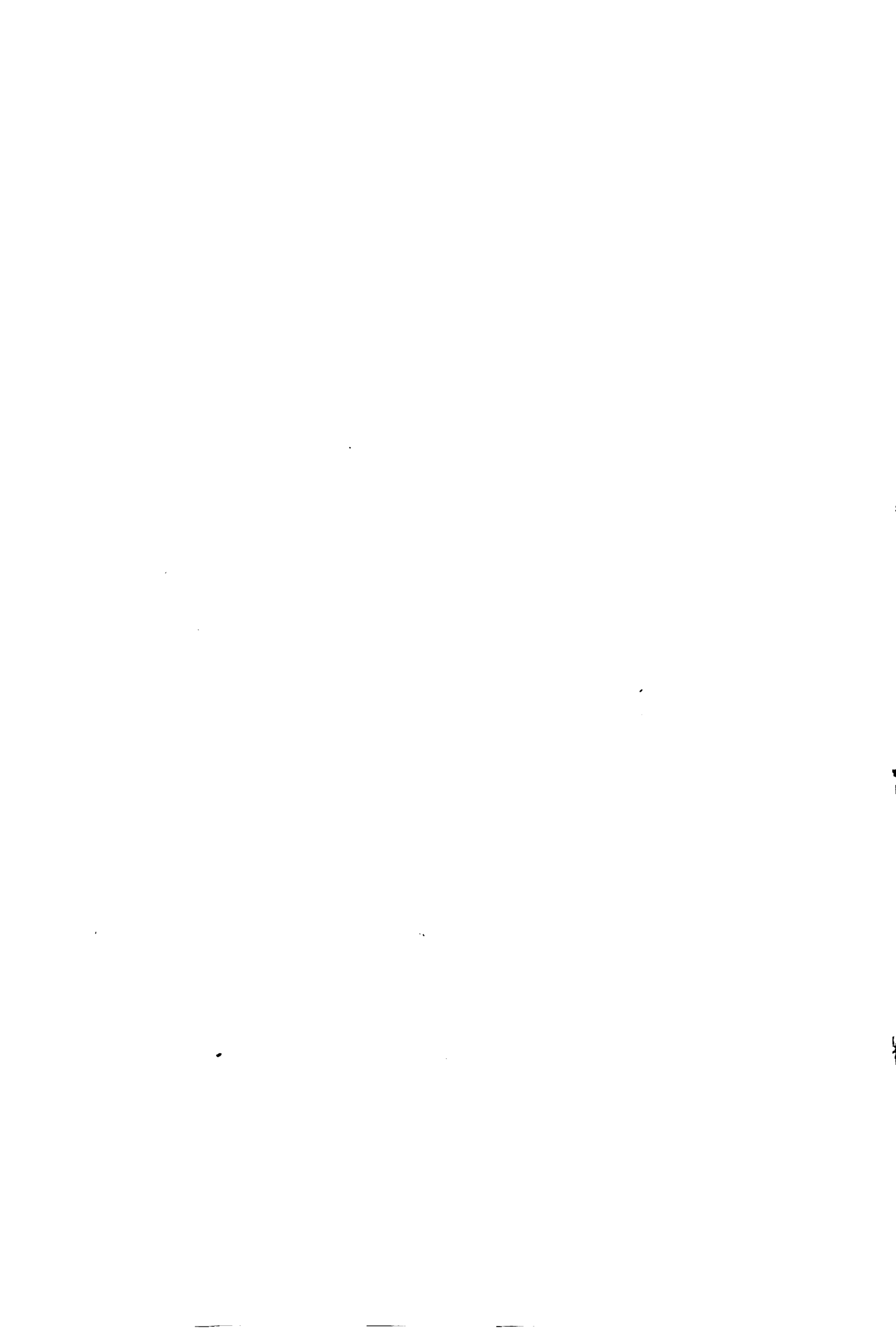




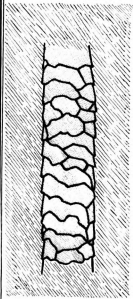
Cotswold.  
Braid Combing.



Lincoln.  
Braid Combing.

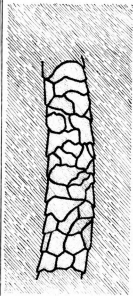


*Diagrams showing structure of cuticle.*



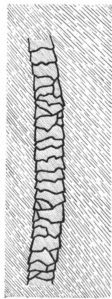
**OXFORD DOWN.**

$\frac{1}{4}$  Combing.



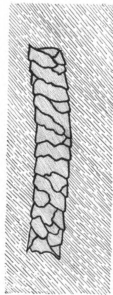
**CHEVIOT.**

$\frac{1}{4}$  Combing.



**DORSET HORNED.**

$\frac{1}{4}$  Combing.

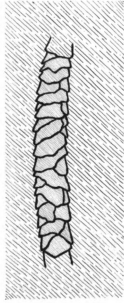


**LEICESTER.**

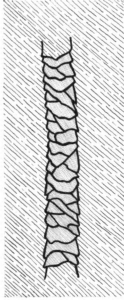
$\frac{1}{4}$  Combing.



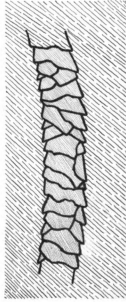
*Diagrams showing structure of Cuticle*



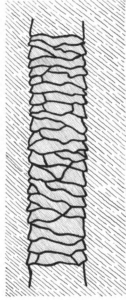
**Rambouillet .**  
**Fine Delaine .**



**Shropshire .**  
 **$\frac{3}{16}$  Clothing .**



**Southdown .**  
 **$\frac{1}{6}$  Clothing .**



**Hampshire .**  
 **$\frac{3}{16}$  Combing .**



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