N.Z. DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

BULLETIN No. 7.

NEW ZEALAND WOOL FIBRES.

Investigations of the Structural Characteristics of New Zealand Wool.

BY

E. F. NORTHCROFT, M.Sc.

WELLINGTON, N.Z.

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Domestic sheep have undoubtedly evolved from some wild-sheep ancestors, which attained their maximum size and numbers in Central Asia, and it is very likely that the wild sheep, or moufflon, of Corsica, Sardinia, Persia, and Armenia is one of the progenitors. The covering of this sheep was very different from that of the sheep of domestication. This original covering consisted of two distinct coats, the outer of long and the inner of short fibres. The outer long fibres were medullated, brittle, and very coarse, while the inner short fibres were elastic, fine, and wavy. In other words, the outer coat was composed, for the most part, of a kempy fibre, while the inner was wool. This kempy coat was very strongly developed and comprised the main covering of the sheep, while the inner coat was only scantily developed and consequently of no commercial value. This woolly coat has, by the aid of very careful breeding, and in the course of evolution, developed considerably, and it now represents the main covering of the sheep under domestication, the kemp having almost entirely disappeared: that is, the under coat has developed at the expense of the ancestral outer coat. Unfortunately, up to the present, breeding has not managed entirely to eliminate the coarse fibres, for it is still evident in all breeds of sheep except the Merino, where it scarcely appears at all. Generally speaking, kemp or hairy fibres are very noticeable on the head, legs, and britch, though the proportion is very variable in the numerous breeds now in use. In the lamb is seen a very striking example of the theory of recapitulation, for here early in life there are two coats—an outer one of medullated coarse kemp fibres, and an inner one of very fine curly wool. Later the kemp is shed, and the body becomes covered mainly with the fine wool.

The fibres now present in the adult are as follows (see fig. 1):—

(1) True wool:—
- (*a*) Fibres running throughout the length of the staple.
- (*b*) Fibres at the base of the staple and running only for a short distance.
- (*c*) Fibres which have been shed and appear anywhere in the staple. These may sometimes be much longer than (*a*), and lower ends are frequently to be found at the same level in the staple and so form a distinct zone—the cotted zone (see Plates II and III). This necessarily varies very considerably in degree of cotting. Sometimes it is so bad that the wool is in a dense tangled mat (Plate II).

(2) Heterotype fibres:—
- (*a*) Growing fibres running throughout the length of the staple.
- (*b*) Shed heterotypes, which are found as a rule towards the end of the staple, the proximal end being found in the cotted zone.

(3) Kemp:—
- (*a*) Fibres shed from the follicle. They are short, wavy, tapering towards each end, dead-white or opaque, with a large amount of medulla, and very coarse and brittle.

(4) Dead fibres:—
- (*a*) Long fibres running throughout the staple.
- (*b*) Short fibres which may run in any direction, either straight or inclined.

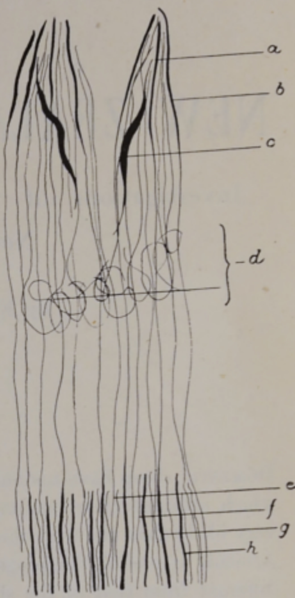

FIG. 1.

a, heterotype fibre thickened at tip (*a*) and base (*g*); *b*, heterotype fibre thickened only at tip; *c*, kemp fibre; *d*, cotted zone; *e*, true wool fibre; *f*, developing fibre; *h*, developing medullated fibre which may result in a heterotype of the *a* or *b* class or in *c*, the kemp fibre.

For a drawing of these four types of fibres in a staple see fig. 1: this will give a very diagrammatic representation.

ANIMAL-FIBRES—FUR, WOOL, HAIR.

The three main types of animal-fibres used for spinning, weaving, and clothing generally are fur, hair, and wool. They are all epidermal appendages, and even now there is much controversy regarding their evolution, as to whether they had some common original form or whether they each represent some distinct and totally unrelated structure. It is an extremely difficult thing to draw any clear line of demarcation between these three groups and to be able to say definitely one is hair and one is wool, as will be seen from the following.

Under the high power of the microscope, fur (fig. 2, *b*) is seen to consist of a central core or medulla which consists of irregular thin-walled cells. Surrounding this is a fibrillated layer of cells known as a cortex, while covering the whole fibre is a layer of scales which have their upper edges quite free and projecting very slightly. Hair (fig. 2, *a*) is constituted in very much the same way except that the medulla is more strongly marked and the covering scales of the fibre are closely pressed together, so that the edges do not project from the surface, which consequently presents a perfectly smooth appearance. Wool (fig. 6, *e*) has no medulla. The fibrillated layer extends right to the centre, hence wool presents a very homogeneous appearance. The scales are much more characteristic, being very irregular in outline, with the distal portion perfectly free from the surface of the fibre, and turned slightly outwards, and, being longer and deeper, give the fibre a sawlike or serrated appearance, and it is to this serrated condition that the felting properties of the wool fibre are supposed to be due. Though some workers maintain that this felting property is due entirely to crimp — that is, the number of curves, curls, or undulations in the individual fibres—actually it is very difficult to say exactly where wool ends and where hair and fur begin.

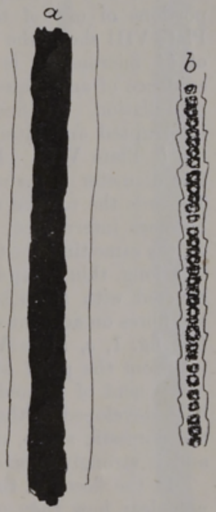

FIG. 2.

In fig. 2, *a*, is shown a hair 50 microns in diameter with a medulla 23 microns in diameter. Fig. 2, *b*, is a drawing of a fur fibre 16 microns in diameter, and showing a medulla of 6 microns. (1 micron = one-thousandth part of a millimetre.)

Heterotype fibres (fig. 1, *a*, *b*) are wool fibres which have the characteristics of both wool and hair, hence the name " heterotype " : that is, they may have certain parts which are perfectly fine and possess all the characters of true wool, while another part presents very hairy characters. This portion is, as a rule, strongly medullated, while the rest is perfectly homogeneous, and therefor true wool. It is generally found that the tip is medullated, a condition which I shall refer to as "thickened tip," or "kempy tip," while the rest of the fibre is true wool (fig. 1, *b*) ; or the base may be medullated while the distal portion is clear ; or, finally, the tip and the base may be medullated (fig. 1, *a*, and fig. 3), the central portion remaining perfectly fine and homogeneous. The fibre with medullated tip and true-wool middle and base is the most frequent condition.

Kemp fibres (fig. 1, *c*, Plates VII and VIII), though of comparatively frequent occurrence in samples of our New Zealand wool, do not, as a rule, appear in very great abundance in any one sample, being somewhat sparsely scattered. Fortunately these fibres are seldom ever found in the better class fine grades, but only in the coarse wool, and in wool coming from stations where little or no attention is paid to breeding ; for it is certain that with the proper selection of rams and ewes—that is, animals showing very few or none of these fibres—kemp would greatly decrease in each succeeding generation till it would finally disappear altogether. As stated above, the kemp fibre is present in the ancestral coat of the wild sheep, and even now is seen to a certain marked degree during the early period of the lamb's life in some breeds, quite possibly in all breeds ; but up to the present I have not been able to examine specimens of fleeces from nearly all the breeds in New Zealand. However, where they do appear the fibres are shed very early in life, so are of little or no practical importance except to the evolutionist, to whom their presence is of very great interest. They are of importance from a practical point of view when they make their appearance in the fleece of the adult, and even though they may not be in very great abundance, yet their presence has a seriously depressing effect on the possibility of bringing a good price.

Kemp fibres are found, as a rule, towards the end of the staple, very occasionally scattered through it, or else among the fine-wool fibres and developing heterotypes. Microscopically they are very strongly medullated smooth, and tapering at each end (Plate VIII). This plate shows three portions of one of the kemp fibres illustrated in Plate VII. Fig. *a* of Plate VIII shows the bulbous base (i) and the shaft (ii), which has a diameter of 44 microns, it is clear, non-medullated, homogeneous, and there is no evidence of any scales till a short distance below the commencement of the medullation. At first the medulla, consisting of large air-filled cells, is interrupted and later continuous, reaching its greatest diameter at (ii) in fig. *b*, Plate VIII. Here the total diameter of the fibre is 90 microns, and this diameter is maintained for almost the whole length of the kemp-fibre. Towards the tip the medulla commences to taper again to a point, it then becomes interrupted, and finally disappears, leaving the tip entirely free. At the same time the fibre itself decreases in diameter, eventually terminating in a long, thin, whip-like tip (fig. *c*, Plate VIII), which, unlike the base, is covered with small scales. They stand out very clearly from the rest of the fibres on account of their greater thickness, and, as a rule, duller lustre (see fig. 1, *c*, Plate VII).

From the point of view of evolution the true wool fibre is clearly the component of the old inner fine-woolled coat of the wild sheep, which has been developed at the expense of the outer or kempy coat, and this has, in the domestic sheep, dwindled down to a few scattered fibres in the adult, and is strongly represented only in the first coat of some young lambs.

In the fleece of the wild sheep there are no heterotype fibres, and it is not clear how they originated. May it not be that they are a result of suddenly changed conditions in the life of the individual ? The heterotype fibre most commonly found is that with a thickened tip and with a great part of the fibre a pure-wool fibre. The thickened part is, of course, the part that was first formed after shearing. The sudden need for a covering, and perhaps a sudden stimulus to fibre-growth, was responded to by a production of fibres many of which had the character that preponderated in the coat of the ancestral forms. When a sufficient growth had taken place many of the follicles that had thus responded by forming coarse fibres resumed their more modern function of forming wool. They may have formed kemp because that constituted the best form of protective covering, but it is more likely that it was because the forming of this type of fibre was a function older in time and therefore one to which they naturally reverted when a sudden call was made upon them. If a wattle-tree that normally produces only phyllodes in the adult condition is cut back it produces leaves such as it produced in its first year, or such as its ancestors produced. The view here put forward as to the origin of thickened tip is rendered the more probable seeing that it is more common in rigorous climates. Further, where tip and base are both thickened, it may be that adverse conditions have occurred twice in the year.

For some years now there have been complaints from manufacturers in England with regard to the Romney and Romney-cross wool. They maintain that New Zealand wool is going back in quality. This word "quality" seems to have a whole host of meanings. Even manufacturers give varied interpretations to the word. According to Nathusius, Bohm, Konigsbon, Bowman, and McMurtrie, "quality" depends on quite a number of characters, such as (*a*) fineness of fibre, (*b*) number of crimps per unit length of fibre, (*c*) length of fibre, and (*d*) lustre.

More recently, through getting into personal touch with many people interested in wool, and especially wool-buyers, a very much clearer knowledge had been obtained as to the points on which the "quality" of New Zealand

FIG. 3.

wool is deteriorating. Briefly, the following are the points which are regarded as evidence for the falling-off in quality:—

(1) The presence of thickened tip, while the rest of the fibre is pure wool.
(2) The presence of long straight fibres running right through the staple.
(3) The presence of thick tip and base, with the centre of the fibre pure wool.
(4) The presence of dead fibres, which may be (*a*) long fibres, or (*b*) short fibres.
(5) The lack of uniformity in the length of the pure-wool fibres in the fleece and the frequent presence of "under wool."
(6) Loss of crimp in the wool.
(7) Loss of lustre.
(8) Increase in the proportion of coarse to fine wool in the whole fleece.
(9) The increasingly high proportion of fat and dirt in the wool.

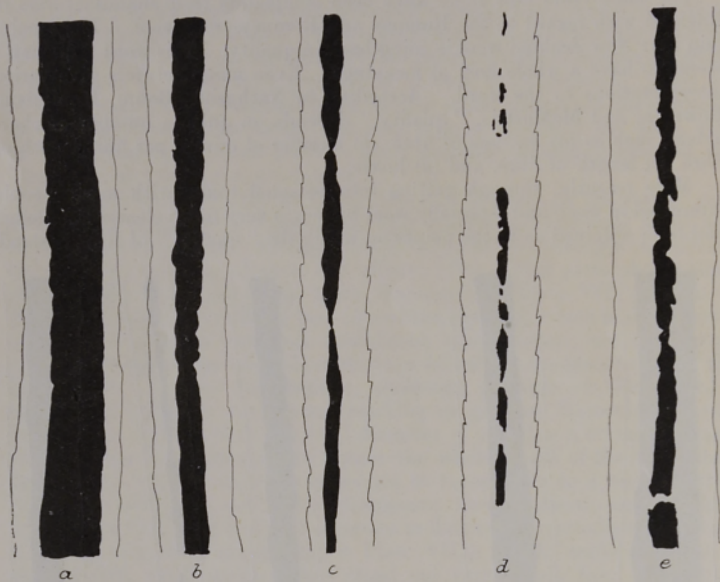

Fig. 4.

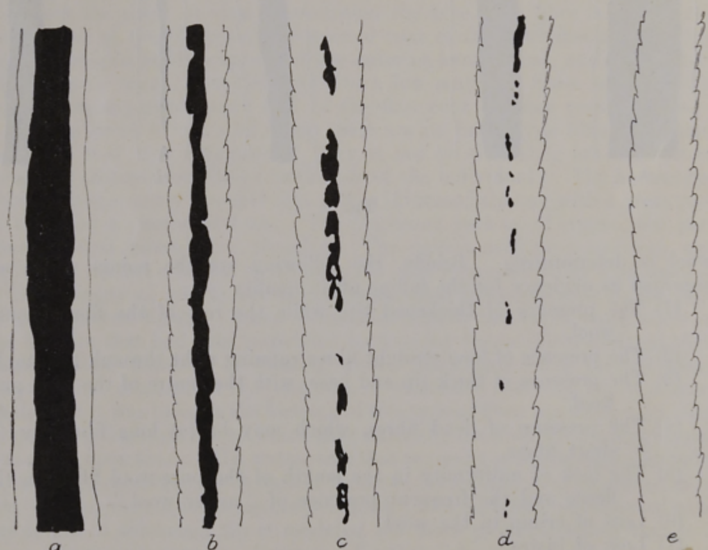

Fig. 5.

1. *Thickened Tip, or Heterotype Fibres.*—These have been described above, and are shown in fig. 1, *a*, *b*. It is very generally agreed that this condition is becoming more and more marked each year, and appears to be present in almost all our wools, even the so-called fine wools, and to a certain extent in the Merino, which is recognized to produce by far the finest wool in the Dominion. The degree of tip-thickening is most variable: it may extend only for the matter of about 2 centimetres to as much as 5 or 6. In fact, in some cases nearly all the distal half of the fibre has become medullated. As a rule, the greater the thickness of the tip the greater the proportion of medulla to cortex. However, this cannot be laid down as a hard-and-fast rule, as it is not invariably the case. While the tip has thickened, the rest of the fibre has all the characters of true wool, in that there is no medulla, the cortex is homogeneous, the scales are of the wool

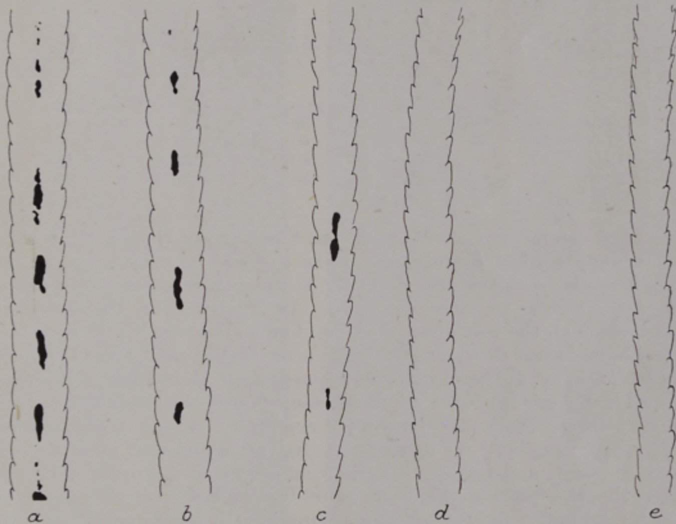

Fig. 6.

type, and there is a good crimp; but in spite of this the machines in the manufacturing houses cannot as yet manage to get rid of this thickened portion, and consequently the wool cannot be used for as fine worsted as would be the case if all the fibre had the character of the middle and lower portions, hence a much lower price has to be accepted. Hand in hand with thickening of the tip goes the straightening out or complete loss of crimp at this part of the fibre (Plates V and VI).

Plate I shows four groups (A, B, C, D) of fibres with various grades of thickening. In the case of A these three fibres show a very hairy condition, having the tip very strongly thickened, this thickening extending right down to the waved or crimp portion (4), then the base (5) again shows very strong thickening. The average length of these fibres was 29·5 centimetres, and fig. 3, *a*, *b*, *c*, *d*, *e*, gives enlarged drawings of the fibre at the positions indicated in Plate I. Group B on this plate shows fibres of a little better class. The thickening of the tip still extends a long way down the fibre, but though the base also shows thickening there is much more and much finer crimp. Fig. 4, *a*, *b*, *c*, *d*, *e*, are as before, and illustrate group B. Groups C and D (figs. 5 and 6) are very much better type fibres. They are both free from thickening of the base and both show a considerable amount of crimp, this being much finer and more marked in D than in C. In the former the tip has noticeably thickened, but in D this defect is almost absent. The following are the measurements of the fibres illustrated :—

TABLE 1.

Fig. No.	Length of Fibre in Centi-metres.	Position of Measurememt of Fibre illustrated on Plate I.									
		1.		2.		3.		4.		5.	
		Total Diameter.	Diameter Medulla.	Total Diameter.	Diameter Medulla.	Total Diameter.	Diameter Medulla.	Total Diameter.	Diameter Medulla.	Total Diameter.	Diameter Medulla.
		Micron.	Micron.	Micron.	Micron.	Micron.	Micron.	Micron	Micron.	Micron.	Micron.
3	29·5	80	60	70	40	56	23	40	10	63	28
4	27·0	90	50	70	27	60	12	64	..	85	20
5	19·0	67	40	57	15	60	..	56	..	50	..
6	20·5	43	..	42	..	30	..	38	..	28	..

In these figures it is seen that all the fibres except that in fig. 6 have a very strongly marked medullation at the tip, and on examining the table above it is also seen that the diameter of these three is very considerable, going up as high as 80 microns in fig. 3. In this last figure the medullation is continuous all the way down the fibre, but at position No. 4 (*d*, in fig. 3) it reaches its lowest development. The same is the case for fig. 4, but here in No. 3 (*c*, in fig. 4) the medulla is commencing to show signs of disappearing, and in the section No. 4 (*d*, in the same figure) the medulla is in what is known as the broken or interrupted condition. Fig. 5 shows a fibre of slightly better quality : the diameter at the various selected intervals is not nearly so great, and the medullation commences to disappear very much nearer the tip, leaving the base quite free though still of considerable diameter. Finally, fig. 6 illustrates a fibre of fairly good quality pure wool. The medullation is nowhere continuous : even at the tip it is interrupted, and very little in amount, while in Nos. 2 and 3 (*b*, *c*, in fig. 6) medullation has almost disappeared, leaving Nos. 4 and 5 (*d*, *e*,) quite free and of the true wool type, the total diameter at the base (No. 5) falling to 28 microns—the lowest diameter of all these measurements.

2. *The Presence of Long Straight Fibres running right through the Staple.*—This is a common fault, and seen in very many samples of wool. It is a factor which is responsible for the wool-buyer quickly passing over certain lots. Such a fault is easy to detect by merely separating out a small piece of the staple, where these fibres are seen to stand out very clearly from the others.

3. *The Frequent Presence of Thick Base, Fine Middle, and Thickened Tip.*—This character together with thickened tip is quite the most common of the wool faults in New Zealand. As mentioned above, the thickening of the fibre is very frequently indicative of medulla presence, and a fibre which has lost all its crimp and become straight is almost certain to be thick and to show a considerable amount of medulla. Hence a fibre which has a

large number of crimps from the base to the tip is very much finer than one which has developed a straightened tip and base or a straightened tip. A sample which exhibits the fault of thickened tip, may, from the wool-buyers' point of view, be tolerable; but a wool with both tip and base thickened is really of little value and can only bring a comparatively low price, as the machines can do very little with wool of this character—certainly far less than they can with wool showing thickened tip alone.

PLATE V.—Staple showing a considerable amount of under wool at *a* and a very straight tip.

PLATE VI.—Staple of wool showing less crimp and very much more pronounced straightening of the tip.

4. *The Presence of Dead Fibres.*—Generally these are of two types (*a*) long fibres, (*b*) short fibres. Some wools contain both the long and the short, but this is not often the case, for, as a rule, only the one type is present in any one sample. However, the presence of dead fibres, whether short or long, is a very serious fault. Either class is very easily detected in just the same way as the straight fibres. Of the short dead fibres there are three classes: First, the fibres which are all at the same level at the bottom of the staple (these are not to be confused with " under wool "); second, those which are scattered all through the staple and may be running straight or in any direction; third, those which have been shed very early in the growth of the fleece and are all found towards the tip of the staple.

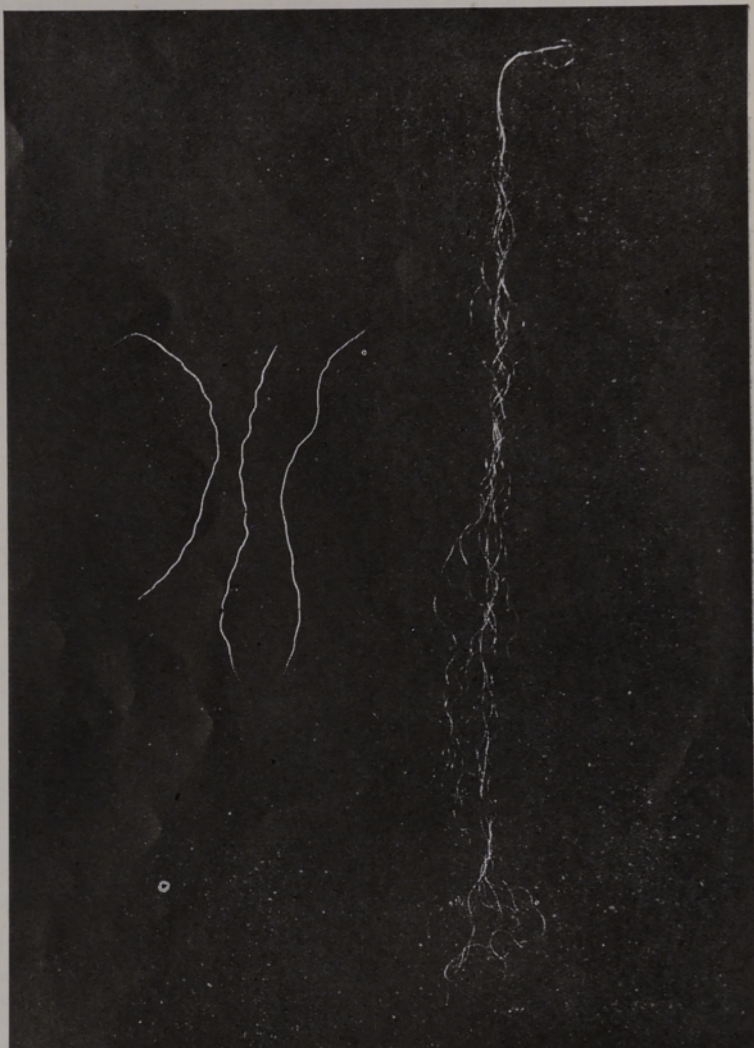

PLATE VII.—Three kemp-fibres, each about 5·45 cms., and of average diameter 90 microns, photographed alongside eight fibres of fairly fine wool, having an average diameter of 44·5 microns.

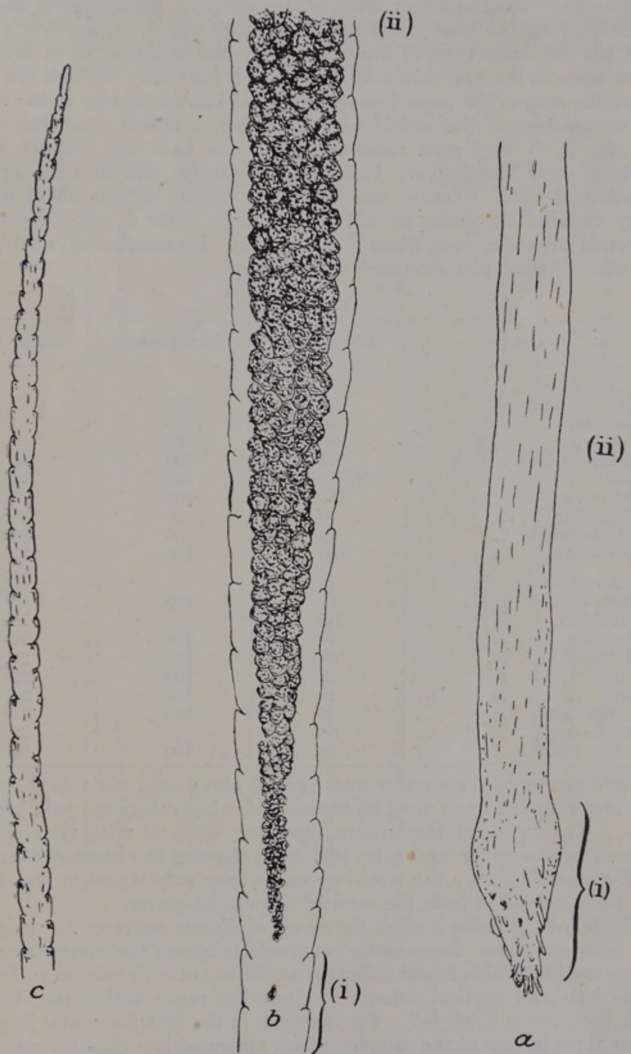

Plate VIII.—Microscopic drawing of parts of one of the kemp-fibres illustrated in Plate VII. *a*, the bulbous base showing no medulla for a few millimetres; *b*, commencement of medullated portion up to its maximum diameter; *c*, fine, tapering, whip-like tip.

5. *Lack of Uniformity in the Length of the Pure-wool Fibres in the Fleece.*—The pure-wool fibres are very often of three types: First there is the fibre which runs from the base to the tip of the staple (fig. 1, *e*), and it is a fleece which has only this type of fibre, which should be aimed at in breeding. Second there is the fine true-wool fibre, which runs only through the outer part of the staple, the inner free end being about the middle of the staple, and, on account of the ends becoming curled, a cotted condition of the wool (fig. 1, *d*) very soon results. Finally we have the "under wool" (fig. 1, *f*, *g*). This is very variable in quantity, and in some cases is altogether absent. Even in one fleece the density of this under wool is a very variable character, as will be seen from Table 2, which shows the proportion of under-wool fibres to long fibres in samples of wool taken from nine different places on each of two sheep.

TABLE 2.

Position.	Under Wool.	Long Fibres.	Sample No.
Fleece No. 1:—			
Back of neck	20	100	9
Shoulder	60	100	10
Fore leg	60	100	11
Middle of back	45	100	12
Side	Numerous	100	13
Belly	117	100	14
Upper britch	40	100	15
Middle britch	80	100	16
Lower britch	120	100	17
Fleece No. 2:—			
Back of neck	10	100	18
Shoulder	Nil	..	19
Fore leg	10	100	20
Middle of back	64	100	21
Side	63	100	22
Belly	40	100	23
Upper britch	20	100	24
Middle britch	Nil	..	25
Lower britch	28	100	26

The diameter of these under-wool fibres is also a most variable character: some represent the finest wool on the animal, while others are pure hair and kemp. The point of importance regarding them is that they are not favoured by the buyer, and bales with wool showing this character are very quickly passed over by the wool-buyers, as they only represent waste, and have to be got rid of from the wool by the manufacturer.

The following Table 3 gives the result of fibre-measurements made with wool from one fleece, the samples being selected from the same nine places as were used for Table 2, and indicated at the top of each column in Table 3. In the left-hand vertical column is given the range within the limits of which the various fibres fall. For instance, in the first horizontal line there are no fibres in any of the samples which measured less than 0·5 cm., while in the next line there occur the numbers 11, 6, and 1, indicating that these numbers, each of which belonged to a different sample, measured anything from 0·5 cm. to just under 1 cm. In each case in this table the range selected is the same—that is, 0·5 cm.—and in each horizontal line are entered the number of fibres which measured 1 cm. up to but not including 1·5 cm., those which measured 1·5 cm. up to 2 cm. but not including 2 cm., and so on up to 24·5 cm.

This table is of considerable interest and importance, for it can be very clearly seen at a glance that there are two groups of fibres, as indicated by the big gap between 6 cm. and 11 cm.: that is, there are a large number of very short fibres, which are most numerous between the lengths 1 cm. and 3 cm., though they may run up as far as 5·5 cm. These are the under-wool fibres (see fig. 1, *f*, *h*), and, as indicated in the table, are present in each sample selected from this fleece. The fibres running from 11 cm. up to 24·5 cm. are the ordinary long fibres of the staple.

TABLE 3.

Length of Fibre in Centimetres.	1. Wool on Back of Neck.	2. Fore Shoulder.	3. Fore Leg.	4. Middle of Back.	5. Side.	6. Belly.	7. Upper Britch.	8. Middle Britch.	9. Lower Britch.
0·0 ..	0	0	0	0	0	0	0	0	0
0·5 ..	0	11	0	0	0	6	0	0	1
1·0 ..	5	8	1	0	5	10	4	3	15
1·5 ..	5	6	7	0	4	7	7	9	7
2·0 ..	10	..	13	6	4	2	4	9	1
2·5 ..	0	..	4	9	7	..	3	2	0
3·0 ..	5	..	..	5	3	..	4	0	0
3·5 ..	..	..	..	4	2	..	2	0	0
4·0 ..	..	..	..	1	..	..	1	1	1
4·5 ..	..	..	..	..	..	..	..	0	..
5·0 ..	..	..	..	..	..	..	..	0	..
5·5 ..	..	..	..	..	..	..	..	1	..
Totals ..	25	25	25	25	25	25	25	25	25
11·0 ..	..	..	4	..	..	..	..	..	..
11·5 ..	..	..	0	..	..	..	..	..	..
12·0 ..	..	..	12	..	..	..	..	..	..
12·5 ..	..	..	0	1	..	..	..	..	..
13·0 ..	..	..	0	5	..	..	..	..	..
13·5 ..	..	..	4	1	..	..	..	..	..
14·0 ..	..	1	4	1	..	1	..	..	..
14·5 ..	1	1	2	2	..	2	1	..	..
15·0 ..	..	0	2	1	..	6	4	..	3
15·5 ..	..	0	4	0	1	7	1	..	0
16·0 ..	4	2	6	2	0	5	1	1	1
16·5 ..	..	4	2	5	1	5	3	0	1
17·0 ..	1	3	..	1	3	3	2	6	0
17·5 ..	1	2	..	6	1	3	3	2	1
18·0 ..	3	9	..	2	6	5	8	9	4
18·5 ..	1	3	..	4	1	0	1	5	1
19·0 ..	5	7	..	2	5	3	4	6	6
19·5 ..	2	4	..	3	4	..	4	2	4
20·0 ..	6	4	..	3	8	..	6	4	12
20·5 ..	4	..	..	1	3	..	1	2	2
21·0 ..	5	..	..	..	5	..	1	0	3
21·5 ..	3	..	..	..	0	..	..	1	1
22·0 ..	4	..	..	..	1	..	..	2	0
22·5 ..	..	..	..	..	0	..	..	..	1
23·0 ..	..	..	..	..	0	..	..	..	..
23·5 ..	..	..	..	..	0	..	..	..	..
24·0 ..	..	..	..	..	1	..	..	..	..
24·5 ..	..	..	..	..	..	..	..	..	..
25·0 ..	..	..	..	..	..	..	..	..	..
Totals ..	40	40	40	40	40	40	40	40	40

6. *Loss of Crimp in the Wool.*—In most samples of wool the staple is seen to be in waves or corrugations (Plates IV, V, VI), and the number of these corrugations is found to vary very considerably with the different samples of wool. In the finer wools these corrugations or crimps are very much more numerous than in the coarser, and it is a well-known fact that the greater the number of crimps to unit length the finer will be the wool. The crimps are also most marked on the individual fibres if they are separate from the staple, and are much more numerous than the crimps seen

in the staple as a whole. This relation of number of corrugations or crimps per unit length to the fineness of the fibre has been well known to many observers for a number of years, and the following table, adapted from Bohn, will be of interest, as it gives the relation between crimp and fibre-diameter in a number of grades of wool:—

TABLE 4.

Quality.	Number of Curls Per Inch.	Diameter Measurements in Microns.	Quality.	Number of Curls Per Inch.	Diameter Measurements in Microns.
1	32 and above	13 to 15	8 ..	20 to 21 ..	24 to 25
2	30 to 32 ..	15 to 16	9 ..	19 to 20 ..	25 to 27
3	28 to 30 ..	16 to 18	10 ..	17 to 19 ..	27 to 29
4	26 to 28 ..	18 to 19	11 ..	16 to 17 ..	29 to 33
5	24 to 26 ..	19 to 20	12 ..	13 to 16 ..	33 to 37
6	23 to 24 ..	20 to 22	13 ..	0 to 13 ..	37 and over.
7	21 to 23 ..	22 to 24			

The crimp of wool is a character watched very carefully by the wool-buyers, and they all admit that year by year this loss in crimp is becoming more and more marked.

7. *Loss of Lustre.*—Lustre or sheen of a fibre is its power to reflect light. This power varies very noticeably in the different fibres, and it has for some time now been declared by users of New Zealand wool that the lustre is not nearly as high as it was years ago, and that our wools are becoming more and more dull. Lustre is a very important character to the manufacturer, for in the processes the wool has to go through the lustre of the individual fibre cannot in any way be produced or improved. In the modern practice of dealing with wool it is unusual to find any very great loss in lustre occasioned by its varied treatment from scouring to the finished fabric. Wools of high lustre when dyed have a very much brighter appearance than wools of low lustre used for the same purpose, and consequently the former have a very much greater market value. To what this sheen is due in the raw material is not at all clear, but it is certain that it depends to a great extent on the constitution of the fibre—that is, on the physiological condition of the animal—for in a good-conditioned sheep the lustre is high and it is generally seen that when the animal is not in good condition the wool has lost a great deal of its brightness. The degree of lustre, or the power of a fibre to reflect light, is of sufficient importance to warrant close investigation, and it would not be a very difficult matter to estimate in a staple the light absorbed and the light reflected by the fibres of that staple.

8. *Increase in the Proportion of Coarse to Fine Wool in the Whole Fleece.*—There are three positions on the fleece where the very fine wool is found: first, a small patch just behind the neck; second, the middle of the back; third, the wool on the belly. The wool on the shoulder and that on the sides is, as a rule, fine wool; but it is not nearly as fine as the wool on the portions just mentioned. The coarsest is on the upper, middle, and lower britch. The area of the upper britch, stretching from the tail forwards up the back for a short distance, is an area which each year is becoming more and more extensive, advancing farther and farther towards the very fine wool on the middle of the back. Consequently the total amount of fairly fine wool in the fleece is becoming less and less, and the proportion of very coarse wool is becoming correspondingly larger.

9. *The Increasingly High Proportion of Grease and Dirt in the Wool.*—One of the characters on which wool is graded is the quantity of grease and dirt the fleece contains. The greater the quantity of fat and dirt the less will be the yield of the scoured wool. In many cases the quality of the wool is good, hairiness and thickened tip are not very greatly marked, and there are few dead hairs, yet the wool contains so much grease and dirt that 100 lb. of the wool after it has been scoured could at the most only yield about 60 lb. or 65 lb. of clean wool.

Methods for the determination of the quality of the wool are becoming more numerous each year. The following are some of the principal methods in vogue at the present time in different parts of the world: (1) Diameter-measurement by means of fibre-magnification; (2) the use of calipers; (3) methods involving the use of the most delicate weighing-machines.

1. The diameter-measurements by means of fibre-magnification seems to be easily the most widespread method, and also the quickest and easiest to carry out. However, there is still a great deal of controversy regarding the best method of carrying out this work. The most rapid, though doubtless the least accurate, is to mount the specimen of fibres in some fluid such as Canada balsam, euparal, glycerine, &c., and by the aid of the micrometer-eyepiece quickly to run off the diameters of a large number of fibres. A very much more accurate method is to project the image of the fibres on to a table on which has been marked off a scale made by previously projecting a very fine and accurately graduated stage micrometer on to the same table. This serves as a very handy scale, and the diameters of the fibres can be run off very rapidly. In both these methods different practices are adopted in mounting the fibres. For instance, some workers arrange a selected number of fibres parallel on the slide, while others simply cut off an unknown number and by the aid of dissecting-needles roughly separate the fibres so that they are in a more or less parallel arrangement. This latter method is rough, and in the end entails more work for the man reading off the diameters than would be the case if the fibres were running parallel and not crossing each other in all directions. Even the question of the correct mounting-medium is still in some doubt, and so far it has not been determined what change, if any, the mounting-medium has on the diameter of the fibre. It is more than likely that some fluids will cause a certain amount of shrinkage in the fibre-diameter, while others may cause a swelling. Another method for fibre-measurement does not consist of laying the fibre flat and then measuring the diameter, but it involves the very laborious method of imbedding the fibres and cutting cross-sections. Here again there are several methods in use, the quickest being to imbed the wool to be examined in a solution of celluloid in acetone, and when this has solidified round the fibres cross-sections may be cut. Another method, but one which takes very much longer to carry out, is to embed a bundle of fibres in hard high-melting paraffin, and after the blocks have been kept in water for a week or more they are set in a microtome, when sections only a few microns thick can be made. This method, though it entails the very long process of thoroughly dehydrating the fibres in several grades of alcohol up to absolute and then in either chloroform or xylol, gives quite the best results as regards the cross-section methods. By means of projection the diameter of these transverse sections can readily be found by employing simple scales or a mathematical device. There are a number of methods in use, but the two following could also with ease be used for this purpose. First the transverse sections of the fibres could be projected on to a scale consisting of

circles of known diameter against which the fibre sections are matched. The second method is very much more exact, but entails a great deal of calculation. However, it has the advantage of taking into account the fact that the transverse section of a wool fibre may be any shape from a circle to a narrow ellipse. By very careful measurement the area of these transverse sections can be calculated by making use of the formula $\frac{\pi}{4}$ $(x\text{-}y)$, which gives the area of an ellipse—x and y being the major and minor axes respectively. As the value of these axes tend to approach each other we get nearer to the circle, the area of which is given by the formula $\frac{\pi}{4}$ x^2 when $x = y$. From these areas can be calculated the mean diameter, which will be correct for all practical purposes if sufficient readings are made.

2. *Engineer's Calipers.*—This method is claimed to give very great accuracy, but at the present time it does not seem to have a very wide application, and, on account of the fibre varying in shape from regular cylinder to a narrow ribbon, it is more than likely that the greatest axis would be measured each time.

3. *Measuring and Weighing.*—This is a new method for the determination of the fineness of wool and of the fleece, worked out by J. A. Fraser Roberts, of the Animal Breeding Research Department in the University of Edinburgh. Previously Barker and King used a very similar method, so that they could in a much more easy manner calculate the diameter of the fibre from their weight-length ratio. They took a number of fibres all cut to the same length, and after weighing determined the average diameter. In this method they assumed a cylindrical shape for the fibres and a constant density of 1·30, all the weighings being done on a micro-balance. The fibres were not measured dry, but conditioned, and suitable allowance has to be made for this in the calculations. Since one of the most important qualities or the most important quality of wool is the fineness, it is easy to explain why so much time and energy have been expended on its measurement, with a view in almost all cases of arriving at the diameter measurements. Fraser Roberts uses a modification of the method mentioned above and worked out by Barker and King, and it consists of the determination of a weight-length ratio—an easy method entailing simply the determination of the length of fibre per unit weight; for, as Fraser Roberts says, "the manufacturer uses a measurement—viz., the 'counts,' which represent the length to which a unit weight of wool can be spun."

In the early stages of this work all the measurements were diameter estimations. The first wool samples received were taken from too few regions, and their selections left a great deal to be desired, for the sampling was not done in such a way that a good average idea of the whole coat could be gained. A further disadvantage was that the rams selected had a great deal of merino blood, and consequently the wool was of a particularly good quality as regards lustre and fineness (small diameter). The wool showing the most marked signs of deterioration is that of the Romney cross, and this is the wool on which should be directed the most intensive research for some considerable time yet. Table 5 will give some idea of the difference between the diameters of Merino and Romney cross. In each case 100 fibres were drawn at random from the end of the staple, and diameter measurements were taken from the tip, from the middle, and from the base of the fibres. An examination of this table will show that the Merino did not show any fibres higher than 55·9 microns in diameter and had fibres as low as 10 microns, while the Romney had fibres ranging from 30 up to 75 microns.

TABLE 5.

Range in Microns.	Merino. Tip.	Middle.	Base.	Total.	Romney Cross. Tip.	Middle.	Base.	Total.
10	0	0	4	4	..	..	..	..
15	0	5	2	7	..	..	..	..
20	15	41	16	72	..	..	..	..
25	11	15	21	47	..	..	..	..
30	30	30	38	98	1	1	1	3
35	15	4	7	26	0	0	0	0
40	13	3	9	25	19	30	20	69
45	8	0	2	10	2	1	6	9
50	8	2	1	11	52	50	49	151
55	..	..	..	..	5	0	5	10
60	..	..	..	..	17	15	15	47
65	..	..	..	..	1	0	1	2
70	..	..	..	..	3	3	3	9
Total ..	100	100	100	300	100	100	100	300

Further, the degree of medullation was as follows: Merino—Tip, 4 per cent; middle, 3 per cent.; base, 1 per cent. Romney cross—Tip, 54·2 per cent.; middle, 26·0 per cent.; base, 32·5 per cent.

For the early measurements samples were taken from (*a*) shoulder, (*b*) side, (*c*) belly, (*d*) upper britch, (*e*) middle britch, (*f*) lower britch; and, as can be seen at a glance, when one realizes how varied is the quality of the wool at different places on the fleece, these samples cannot in any way give an average idea of the whole fleece.

It is clear that to investigate samples as selected above with the object of gaining a good average idea of the condition of the wool of any fleece is far from satisfactory, because the samples were not selected from nearly sufficient localities. For instance, there are three areas where the wool is of a particularly fine nature and only one of these areas has been represented—*i.e.*, the belly; the back of the neck and the middle of the back being entirely neglected. This area of light wool on the middle of the back has some attention paid to it by the more careful farmers, but there are many who still neglect it and use rams showing this weakness, and consequently this defect is accentuated in the offspring, the condition becoming worse and worse in the succeeding generations. The grades of wool in the different parts of the sheep may be tabulated roughly as follows:—

Very Fine Wool.	Fine Wool.	Coarse Wool.
Back of neck.	Shoulder.	Upper britch.
Middle of back.	Sides.	Middle britch.
Belly.		Lower britch.

In sampling as above referred to only the following regions are represented:—

Very Fine Wool.	Fine Wool.	Coarse Wool.
Belly.	Shoulder.	Upper britch.
	Side.	Middle britch.
		Lower britch.

Showing that the bad qualities of the fleece are stressed and the good qualities suppressed. Consequently, in order that a better idea of the average quality of the fleece of a sheep could be obtained, the following positions have been selected for sampling :—

Very Fine Wool.	Fine Wool.	Coarse Wool.
Back of neck (sample 1).	Fore leg (sample 5).	Upper britch (sample 3).
Middle of back (sample 4).	Shoulder (sample 2).	Middle britch (sample 6).
Belly (sample 7).	Side (sample 8).	Lower britch (sample 9).

But even this is far from ideal, for it would indicate that the fleece of the animal is composed of one-third very fine wool, one-third fine wool, one-third coarse wool ; whereas this is far from the truth, since the area of very fine wool does not nearly occupy one-third of the fleece of the animal, and the area of fine wool, as a rule, occupies very much more than half the whole fleece. Actually the area of fine wool occupies the smallest area, the coarse wool a larger area, and one which is becoming greater and greater each year where little care is taken in the proper selection of rams.

The sheep whose wool was used for these investigations were in 1920 crossbred, being mostly Romney-Lincoln crosses. Since then pure-bred Romney rams have been used, so that each season's lambs are getting nearer and nearer to the pure Romney.

All my recent measurements have been on the line of the weight-length ratio, and it will not be till some later date that any fibre-diameter determinations can be attempted.

The nine samples have been selected from the sheep as above shown. Each sample was very carefully washed, and great care was taken so that each received exactly the same treatment. Next, the proportion of under coat for each sample was determined. Fibres were then drawn from the tip of each staple and grouped into bundles of ten. The selection was more or less done at random, but care was taken to discard any fibres which seemed to be particularly short. The shed fibres were very quickly noted, and thrown away, for in the drawing of these fibres from the tip it was easy to feel if they were running right to the bottom of the staple. Each separate fibre was then measured as accurately as possible, recorded, and placed back into the group to which it belonged. Before the actual weighing these groups of fibres had to be very carefully washed in the following way : First they were washed in several changes of distilled water, and then dried overnight in a low-temperature oven running not over 60·0° centigrade. Next, the samples were very carefully washed in three changes of ether and then air-dried. The bundles of ten fibres were then weighed and the weight-length ratio worked out. Thus for each sample ten groups of ten fibres were used, making a total of ninety groups of ten fibres for each sheep.

The following will give some idea of these measurements, only those for one fleece being included. Tables 6 to 14 inclusive give the result of these nine samples. In these tables each sample is shown made up of ten sub-samples, these sub-samples being composed of the groups of ten fibres to which I have referred above. The length of the individual fibres are seen to run from 11 cm. to 25 cm. ; but there appeared to be no correlation between the length and the fineness of the fibre. For instance, the following tables represent the wool from the three regions of finest wool, yet the fibre lengths are seen to have the following range : 16 cm. to 25 cm. in Table 6, 14 cm. to 23 cm. in Table 7, 11 cm. to 20 cm. in Table 8 ; showing median values respectively as follows : 19·93, 18·69, 16·37.

In each of the following tables, 6 to 14 inclusive, the first column shows the range taken for the corresponding horizontal line. For instance, in

Table 6 the range selected is 1 cm. in each case. That is, fibres measuring 16 cm., or between 16 cm. and 16·99 cm., but not so high as 17 cm., 17 cm. and 17·99 cm. are grouped, and so on up to 24·99 cm., in columns numbered 1 to 10, which are sub-sample numbers of fibres found in the various bundles of ten fibres which fell within these range limits. Again referring to the same table, in column No. 1 (representing a bundle of ten fibres), one fibre fell between 16·00 cm. and 16·99 cm. (roughly 16–17 cm.); no fibres fell between 17·00 cm. and 17·99 cm. (roughly 17–18 cm.); one fibre fell between 18·00 cm. and 18·99 cm. (roughly 18–19 cm.); two fibres fell between 19·00 cm. and 19·99 cm. (roughly 19–20 cm.); and so on for all the columns, the last vertical column on the right showing the total number of instances for all the groups in that sample which fell within that particular range. From this last vertical column was calculated the median, which is a value such that greater and smaller values occur with equal frequency—or, in other words, an item which divides the distribution into equal parts. The median 19·93 of these frequencies shows, therefore, that there are the same number of instances of fibres measuring less than 19·93 cm. as there are fibres measuring more than 19·93 cm. By mean is meant the arithmetic mean which represents a true average, and it is this which is most frequently used in work of this nature on account of simplicity in calculation. The standard deviation of a group of data is a measure of the dispersion or scatter of the data in the group. The relative dispersion as defined by Pearson is the percentage ratio of the standard deviation to the arithmetic mean. It is also a measure of variability, but it differs from the standard deviation in that it is absolute, whereas the relative dispersion or coefficient of variation is a relative measure or a ratio. (For the graphs of Tables 6, 7, and 8 see fig. 7.)

TABLE 6.

Sample No. 1.—Wool from Back of Neck.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
16	1	..	..	2	..	..	..	..	1	..	= 4
17	..	..	..	..	..	..	2	1	1	..	= 4
18	1	3	1	1	2	2	1	1	3	1	= 16
19	2	3	4	4	3	3	2	2	3	2	= 28
20	2	1	2	1	3	4	3	5	1	4	= 26
21	4	1	..	2	2	..	2	1	..	3	= 15
22	..	..	3	..	..	1	..	..	1	..	= 5
23	..	1	..	..	..	..	..	..	..	..	= 1
24	..	1	..	..	..	..	..	..	..	..	= 1
	10	10	10	10	10	10	10	10	10	10	=100

Median = 19·93. Standard deviation = 1·4853.
Mean = 19·44. Relative dispersion = 7·6404.

Referring to Table 6: Ten sub-sample numbers (1 to 10—top horizontal line) have been selected from a staple of wool taken from the middle of the back. The lengths of the fibres range between 16 cm. and 25 cm. (see left-hand vertical column). In sub-sample No. 9 one fibre was approximately 16 cm., one was 17 cm., three were 18 cm., three 19 cm., one 20 cm., and one 22 cm.

The distribution of fibres of different lengths through the whole sample appears in the right-hand vertical column: *e.g.*, the greatest number (28) were found to be about 19 cm. long. The subsequent tables may be similarly interpreted.

TABLE 7.

Sample No. 4.—Wool from Middle of Back.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
14	..	1	..	1	..	..	..	..	1	..	= 3
15	..	..	1	..	2	..	..	..	1	..	= 4
16	2	5	1	..	2	..	..	1	..	1	= 12
17	1	2	..	1	1	4	3	3	1	2	= 18
18	2	..	4	3	..	..	2	3	2	3	= 19
19	2	2	2	3	2	4	1	1	4	3	= 24
20	3	..	2	2	3	1	3	1	1	1	= 17
21	..	..	..	..	..	1	1	..	..	..	= 2
22	..	..	..	..	..	..	..	1	..	..	= 1
	10	10	10	10	10	10	10	10	10	10	=100

Median = 18·69. Standard deviation = 1·6612.
Mean = 18·02. Relative dispersion = 9·2131.

TABLE 8.

Sample No. 7.—Wool from Belly.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8	9.	10.	
11	..	..	..	..	1	..	..	1	..	..	= 2
12	..	..	..	..	..	..	..	..	..	..	= 0
13	..	1	2	1	2	1	..	3	3	..	= 13
14	..	1	1	..	1	2	..	2	1	2	= 10
15	1	3	1	4	2	3	3	..	3	4	= 24
16	2	2	2	4	2	4	3	2	2	4	= 27
17	4	3	..	..	1	..	3	2	1	..	= 14
18	2	..	4	1	1	..	..	..	..	..	= 8
19	1	..	..	..	..	..	1	..	..	..	= 2
	10	10	10	10	10	10	10	10	10	10	=100

Median = 16·37. Standard deviation = 1·6202.
Mean = 15·43. Relative dispersion = 10·5003.

In the Tables 9, 10, and 11 are shown the results of measurements of the wool of average fineness—that is, the wool I have referred to above as "fine wool." Here the range of fibre-lengths is fairly close in Tables 9 and 10, but there is a very sudden increase in the individual fibre-lengths in Table 11, as follows: 15 cm. to 21 cm. in Table 9, 12 cm. to 19 cm. in Table 10, 17 cm. to 24 cm. in Table 11; and the median results are respectively as follows: 18·53; 16·04; 20·06; showing the highest median value where the range is greatest. Fig. 8 shows these three tables graphically.

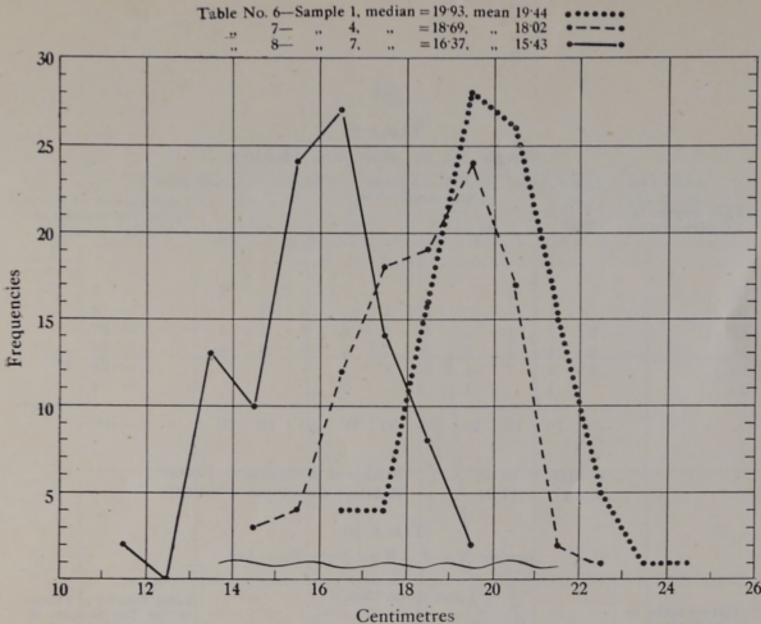
Table No. 6—Sample 1, median = 19·93, mean 19·44
„ 7— „ 4, „ = 18·69, „ 18·02
„ 8— „ 7, „ = 16·37, „ 15·43
Frequencies
30
25
20
15
10
5
10
12
14
16
18
20
22
24
26
Centimetres

Fig. 7.

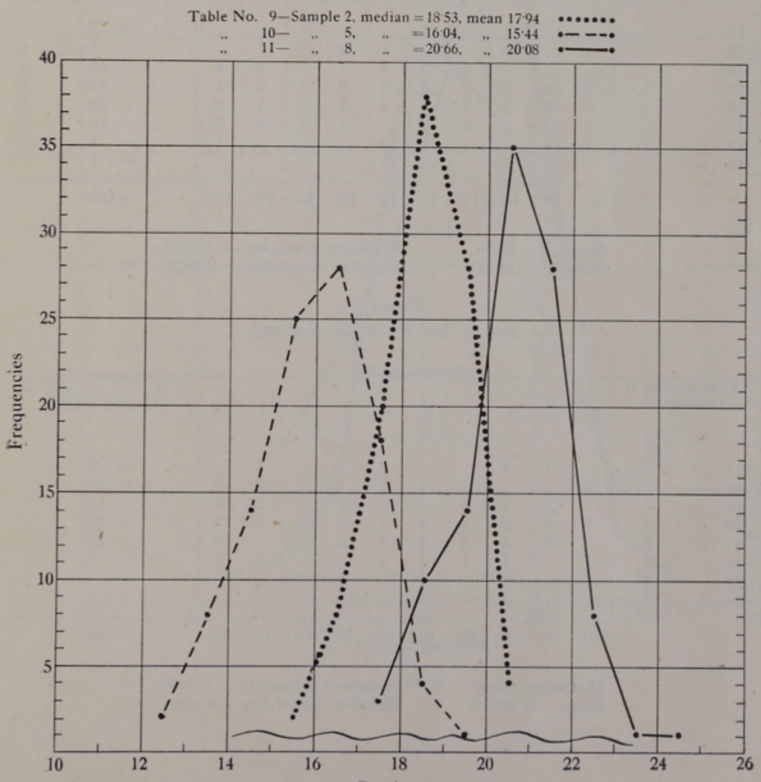
Table No. 9—Sample 2, median = 18·53, mean 17·94
„ 10— „ 5, „ = 16·04, „ 15·44
„ 11— „ 8, „ = 20·66, „ 20·08
Frequencies
40
35
30
25
20
15
10
5
10
12
14
16
18
20
22
24
26
Centimetres

Fig. 8.

Table 9.

Sample No. 2.—Wool from Shoulder.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
15	..	..	1	..	..	..	..	..	..	1	= 2
16	..	1	..	..	1	1	..	2	3	..	= 8
17	2	..	1	..	4	4	3	1	1	4	= 20
18	5	4	1	5	2	2	5	6	4	4	= 38
19	3	4	7	4	3	3	..	1	2	1	= 28
20	..	1	..	1	..	..	2	..	..	..	= 4
	10	10	10	10	10	10	10	10	10	10	=100

Median = 18·53. Standard deviation = 1·0660.
Mean = 17·94. Relative dispersion = 5·9420.

Table 10.

Sample No. 5.—Wool from Fore Leg.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
12	..	..	..	..	1	..	..	1	..	..	= 2
13	1	..	1	..	..	1	2	2	1	..	= 8
14	..	..	..	1	3	1	1	2	2	4	= 14
15	2	2	6	2	3	3	3	1	2	1	= 25
16	5	5	2	2	1	4	3	3	1	2	= 28
17	1	2	..	5	2	..	1	1	4	2	= 18
18	1	1	..	..	..	1	..	..	..	1	= 4
19	..	..	1	..	..	..	..	..	..	..	= 1
	10	10	10	10	10	10	10	10	10	10	=100

Median = 16·04. Standard deviation = 1·4023.
Mean = 15·44. Relative dispersion = 9·0826.

Table 11.

Sample No. 8.—Wool from Side.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
17	..	1	1	..	..	..	..	..	1	..	= 3
18	2	..	..	1	..	1	..	1	3	2	= 10
19	1	1	1	2	..	..	1	3	2	3	= 14
20	3	5	2	3	4	4	5	4	3	2	= 35
21	3	3	4	3	4	3	3	2	..	3	= 28
22	1	..	1	1	2	2	..	..	1	..	= 8
23	..	..	..	..	..	..	1	..	..	..	= 1
24	..	..	1	..	..	..	..	..	..	..	= 1
	10	10	10	10	10	10	10	10	10	10	=100

Median = 20·66. Standard deviation = 1·2859.
Mean = 20·08. Relative dispersion = 6·4038.

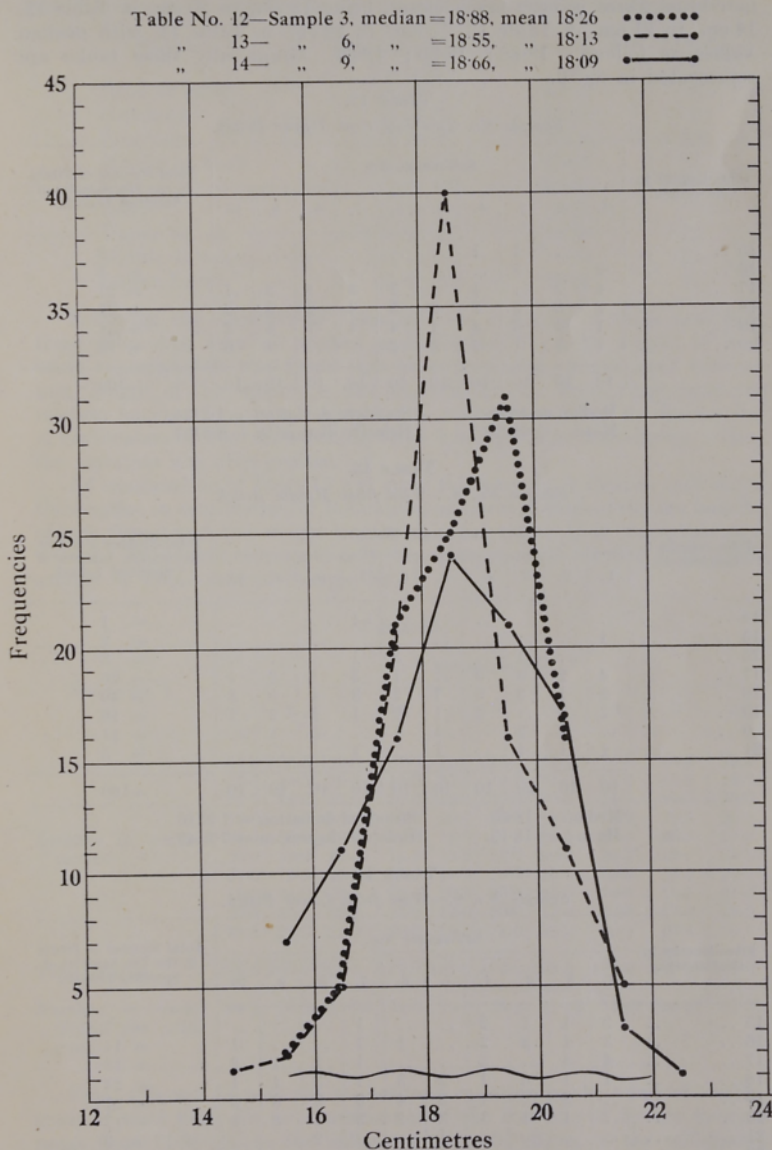
Table No. 12—Sample 3, median=18·88, mean 18·26
„ 13— „ 6, „ =18·55, „ 18·13
„ 14— „ 9, „ =18·66, „ 18·09
Frequencies
45
40
35
30
25
20
15
10
5
12
14
16
18
20
22
24
Centimetres

FIG. 9.

In Tables 12, 13, and 14 the range of variation in the length of the individual fibres is very much closer, being 15 cm. to 20 cm. in Table 12, 14 cm. to 21 cm. in Table 13, 15 cm. to 22 cm. in Table 14, with median values as follows: 18·88; 18·55; 18·66. Graphically these tables are represented in fig. 9.

Table 12.

Sample No. 3.—Wool from Upper Britch.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
15	..	..	1	1	..	..	..	..	..	..	= 2
16	2	..	3	..	..	..	..	..	..	..	= 5
17	4	2	..	1	4	1	5	1	2	1	= 21
18	2	3	2	2	2	3	4	2	3	2	= 25
19	1	4	3	4	1	4	1	7	4	2	= 31
20	1	1	1	2	3	2	..	..	1	5	= 16
	10	10	10	10	10	10	10	10	10	10	=100

Median = 18·88. Standard deviation = 1·2134.
Mean = 18·26. Relative dispersion = 6·6451.

Table 13.

Sample No. 6.—Wool from Middle Britch.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
14	..	..	..	..	..	..	1	..	..	..	= 1
15	1	..	..	..	..	1	..	..	..	..	= 2
16	..	..	1	..	..	3	1	..	..	..	= 5
17	4	2	3	3	..	1	3	1	2	1	= 20
18	2	1	3	5	7	2	3	4	5	8	= 40
19	2	3	..	2	1	2	1	2	2	1	= 16
20	..	3	2	..	1	1	..	3	1	..	= 11
21	1	1	1	..	1	..	1	..	..	..	= 5
	10	10	10	10	10	10	10	10	10	10	=100

Median = 18·55. Standard deviation = 1·3316.
Mean = 18·13. Relative dispersion = 7·3447.

Table 14.

Sample No. 9.—Wool from Lower Britch.

Fibre-lengths in Centimetres.	Sub-sample Nos.										Total Number of Fibres in the Ten Samples of Specified Length.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
15	2	1	1	2	..	..	1	..	..	..	= 7
16	3	1	2	2	..	1	1	..	..	1	= 11
17	4	4	..	3	..	..	1	1	1	2	= 16
18	1	1	6	1	3	3	1	3	4	1	= 24
19	..	2	..	1	3	4	3	3	3	2	= 21
20	..	1	1	1	3	2	3	1	2	3	= 17
21	..	..	..	..	1	..	..	2	..	..	= 3
22	..	..	..	..	..	..	..	..	..	1	= 1
	10	10	10	10	10	10	10	10	10	10	=100

Median = 18·66. Standard deviation = 1·5943.
Mean = 18·09. Relative dispersion = 8·8131.

Taken from the point of view of position on the fleece, the following are the ranges of variation in the fibre-lengths and the medians :—

Position.	Range of Variation.	Median.	Table No.
	cm. cm.	cm.	
Back of neck ..	.. 16 to 25	19·93	6
Shoulder ..	.. 15 to 21	18·53	9
Fore leg ..	.. 12 to 20	16·04	10
Middle of back	.. 14 to 23	18·69	7
Side	.. 17 to 25	20·66	11
Belly	.. 11 to 20	16·37	8
Upper britch ..	.. 15 to 21	18·88	12
Middle britch ..	.. 14 to 22	18·55	13
Lower britch ..	.. 15 to 23	18·66	14

Following the selection of fibres and the grouping of them into tens, these subgroups were all washed and weighed, the total weight of each being recorded. It was found that there was no correspondence between total length of the subgroups and their weights. From these facts the relation between length and weight was worked out—that is, the number of centimetres of wool fibres which weigh 1 milligram for each group. Here the variation was even greater.

An examination of Table 15 will make this very much clearer, as it shows the lengths, in centimetres, of the individual fibres in each of the ten bundles of ten fibres, and the weight-length ratio calculated from these measurements. This table represents only the measurements relative to a single sample of wool—that of Sample No. 1.

TABLE 15.

Sample No. 1.	Sub-sample Nos.									
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Lengths in centimetres	21·0 18·5 21·0 16·0 21·5 20·0 21·0 19·0 20·5 19·5	20·5 18·5 18·0 18·0 19·0 19·0 19·5 24·0 23·5 21·0	20·0 22·5 18·0 19·0 19·0 22·5 19·0 19·0 20·5 22·0	21·5 16·0 19·0 16·0 19·0 18·5 19·0 19·0 21·0 20·0	19·0 21·0 18·5 20·0 18·5 19·5 19·5 20·5 19·0 18·0	18·5 19·0 20·0 19·0 20·5 22·0 19·0 20·0 20·0 18·0	17·5 21·0 20·5 19·0 19·5 20·0 20·0 21·0 17·0 18·0	20·0 17·0 21·5 19·0 20·5 20·5 19·5 18·0 20·0 20·0	18·0 18·5 19·0 22·5 20·5 19·0 19·5 18·5 17·0 16·5	19·0 18·5 20·0 20·5 21·0 21·5 20·0 21·0 19·0 20·5
Total lengths ..	198·0	200·0	201·5	189·0	197·5	196·0	193·5	196·0	189·0	201·0
Number of centimetres per milligram	84·2	76·9	71·96	84·0	79·0	78·4	87·95	81·67	96·92	77·31

From this will be seen the tremendous variation in the value of 1 milligram of wool fibre, for an examination of the last line of figures shows a range from 71·96 cm. to the milligram up to 96·92 cm. to the milligram ; and these samples have all been taken from the same sample of wool, all the fibres being grown within an area of about 2 square inches of the sheeps' back. This surprising variation may be due to a variety of causes. In the first place, the wool fibre is very hygroscopic, and it is certain that the samples could not possibly have been measured and weighed under the same conditions, as they would alter very considerably with the varying humidity of the atmosphere. Further, no diameter measurements have yet been made, and till this is done little more can be said, as these measurements should throw a considerable amount of light on this variation, as the presence in one group of a large number of medullated fibres and the absence of the condition in another may cause certain marked differences in the weight-length ratios of the groups in question.

However, the position is quite different when these weight-length ratios are worked out as the arithmetic average of each of the samples instead of weight-length ratios of each subgroup. Table 16 following gives the weight-length ratio for each subgroup in the above nine samples :—

TABLE 16.

Number of Centimetres of Fibre per Milligram.

Sample No.	Subgroups.										Arithmetic Average.
	1	2.	3.	4.	5.	6.	7.	8.	9.	10.	
1	84·2	76·9	71·96	84·0	79·0	78·4	87·95	81·67	96·92	77·31	81·83
2	73·0	66·79	71·15	66·96	74·79	68·65	72·80	74·35	72·45	71·49	71·24
3	86·61	85·26	78·25	68·26	83·30	82·90	90·88	80·52	80·26	84·05	82·06
4	62·25	88·44	95·79	92·25	88·75	81·52	90·48	80·00	73·40	89·27	84·22
5	66·83	58·26	59·43	54·59	52·00	57·11	57·36	60·00	63·28	56·57	58·54
6	70·20	78·25	91·43	82·56	90·00	80·79	68·13	81·11	87·65	85·28	81·54
7	53·18	53·03	55·47	54·41	51·35	58·45	50·86	60·16	58·73	56·91	52·26
8	47·50	50·26	49·20	55·00	48·21	47·43	59·83	48·46	49·73	51·55	50·72
9	57·59	49·86	49·31	48·45	41·28	43·33	47·05	45·48	45·78	43·18	47·13

It must be quite obvious that the greater the length of fibre to unit weight (1 milligram in this case) the finer the fibre. These sample numbers 1 to 9 inclusive refer to samples of wool selected from the back of the neck (sample No. 1), shoulder (sample No. 2), fore leg (sample No. 5), middle of the back (sample No. 4), side (sample No. 8), belly (sample No. 7), upper britch (sample No. 3), middle britch (sample No. 6), and lower britch (sample No. 9). As stated above, the very fine wool is shown in samples Nos. 1, 4, and 7 ; fine wool in samples Nos. 2, 5, and 8 ; and the coarse wool in samples Nos. 3, 6, and 9. These stated with their weight-length ratios are as follows :—

	Centimetres per Milligram.
Very fine wool :—	
Back of the neck (sample No. 1)	81·83
Middle of the back (sample No. 4)	84·22
Belly (sample No. 7)	81·54
Fine wool :—	
Fore leg (sample No. 5)	82·22
Shoulder (sample No. 2)	71·24
Side (sample No. 8)	58·54
Coarse wool :—	
Upper britch (sample No. 3)	55·25
Middle britch (sample No. 6)	50·71
Lower britch (sample No. 9)	47·13

Hence these numbers, representing the weight-length ratio, support the original statement of the quality of wool at the various localities on the fleece, and make the very fine and the coarse groups stand out with marked clearness.

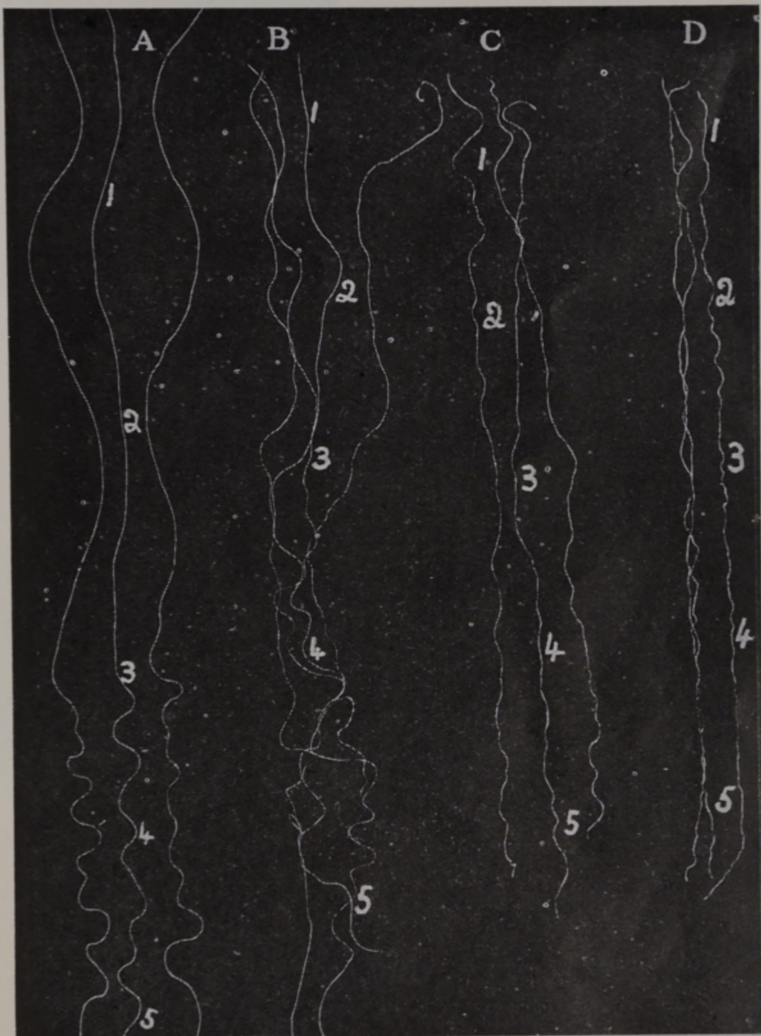

Plate I.—Selected fibres showing varying degree of thickening. A shows long thickened tip and thickened base; B shows very much less thickening at the tip; C is thickened only at the tip, the rest of the fibre being fairly fine; D is fine wool from the tip to the base.

Plate II.—Staple of wool spread out to show the dense matted condition due to cotting.

PLATE III.—Staple showing a small degree of cotting at *a*.

PLATE IV.—Staple of fine wool showing crimp extending from the base to the tip.

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