STUDIES ON THE FLEECE FIBRES OF BRITISH BREEDS OF SHEEP.

By

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C O N T E N T S.

PART I.

PART II.

BREED DESCRIPTIONS.

I N T R O D U C T I O N.

In connection with a sheep hybridising experiment which is being carried out by the Animal Breeding Research Department, a microscopical analysis of the fleece of the parental breeds involved (viz. Southdown and Blackface Mountain) was undertaken. It was hoped in this way to make a complete survey of all British breeds, describing in the first place those which are most frequently used for crossing on account of their greater value in the study of the inheritance of fleece characters. However, this study had not long been commenced, when it became evident that if the original method of examining each breed separately and thoroughly in sequence were adhered to, while useful data would be collected in large numbers, much of the significance of such information would only be exposed at the end of the investigation, or indeed some points would be entirely lost sight of if they were not accentuated until some breed towards the middle of the series was reached. Moreover, the time required to carry out the work on such a scale would stretch over many years.

Accordingly, the position was reconsidered and it was decided that the quickest way to optimum

results lay in first carrying out a breed survey on the smallest scale compatible with reasonable accuracy in general and basic results. Such a study would at least present a bird's eye view of the situation and would, in all probability, show or suggest more specific lines of research which might be followed with advantage.

The work was carried out at the Animal Breeding Research Department, the University, Edinburgh, and my best thanks are due to Dr F. A. E. Crew, Director, for the facilities and opportunities afforded to me during the course of this investigation. I am very deeply indebted to Professor Barker, University of Leeds, for his kindness in supplying me with most of the wool necessary for this study.

Material and Method.

The material consisted of a series of samples from British pedigree sheep, there being two samples from each breed marked 'fine' and 'coarse' respectively. Although no information was available as to the part of the body from which these samples were taken, it was considered that an analysis of these would be sufficiently accurate for the present purpose, especially as previous experience had demonstrated that variation in the character of fleeces from the same breed are due to difference in the proportions

of the component fibre types and to slight changes in their average diameter (which would deflect the mode of their diameter frequency curve to one side or the other), rather than to any fundamental structural differences. Other samples of wool and sheep skins, obtained from various sources and not described in the present paper, have also been examined as a means of controlling the accuracy of the results from the first series.

Emphasis has been laid on the classification of the fibres and the examination of their structure; collaterally with this a number of measurements have been taken but these generally possess but little value outwith the sample to which they refer and are not to be looked upon as fleece or breed criteria.

Each sample was examined as a whole before smaller portions were removed for detailed investigation. The fibres were then classified by eye and ranges of fibres separated out. Numerous fibres were mounted both in strands as they were withdrawn from the staple and individually. In all cases they were first washed in ether; then those to be mounted in euparal were stained with picric acid while those mounted dry were previously stained by dipping in an alcoholic solution of eosin and Gentian violet and dried rapidly but carefully over a low flame or other gentle heat.

Both methods of mounting were used for fibres from all samples although the latter was chiefly useful in demonstrating the scale structure in fibres pigmented or with a broad medulla as the scales are generally masked by the presence of such conditions. Further, in these cases it was often found necessary to use reflected light instead of, or in addition to, the transmitted light which in general was quite sufficient. The technique used in cutting sections was that developed by J. A. F. Roberts.

The method whereby the most consistent measurements could be obtained presented some difficulty on account of certain general variation in the series of samples. Some were obviously taken from first clip fleeces which are in general longer than those of subsequent clips; moreover taking into account the lamb's wool part would affect the average diameter of the fibre. Again, it has been previously found that fibres show a tendency to be finer proximally than distally; if, however, the clipping is deferred till after the usual season, a thicker part again intervenes between the fine portion and the skin. Finally it was decided to attempt no correction so far as the length measurements are concerned, but to take the diameter in the three regions on the fibre defined as follows: (1) The most uniformly thick

portion of the 'lamb's wool part. (This measurement was only taken where this part could be clearly defined). (2) The most uniformly thick region of the distal (but non-lamb's wool) portion of the fibre. (3) The most uniformly fine proximal region. In the tables of measurements these three regions are referred to as A, B, and C respectively.

In measuring individual fibres the full extended length was taken. The staples were measured in their natural position, for many of them were inelastic and could not be extended without breaking and confusing the fibres.

Photographs were taken at a magnification of 400 by transmitted light, so that the fibres appear in optical section but at the same time exhibit a clear picture of their scale structure. In each case the photographs were taken of the thickest region of the fibre and an attempt has been made to expose as far as possible the range of variation which may be met with in each breed. Unfortunately, all fibres do not photograph equally well and occasionally some figures are not as good as might be expected from their appearance under the microscope. Sometimes the cuticular structure on the other side of the fibre shows through the shaft, giving a misleading appearance. The coarser fibres of the Lustre breeds appear to be most easily

photographed, while some from the Mountain Short Wools (especially Cheviot) were the most difficult.

On each plate the figures are marked according to the class of fibres which they represent, thus:

K = Kemp.

I = Type I, the coarse type of fibres where more than one main type is found.

II = Type II, the finer type of fibres where more than one main type is found, or the main type where only one is present. This also includes the small group of very fine fibres where such occur.

Terminology.

In order that breed descriptions might be made as concise as possible, it seemed necessary to introduce some preliminary classification of fibre structure, such as Hausman's method of grouping according to the configuration of cuticular scales and medulle. However, the graduality with which these strata of the fibres varies and in some cases their irregularity, have made it difficult to adhere closely to Hausman's scheme, though the general idea has been followed.

Cuticular structures appear to vary around or between two main types whose characteristics are most clearly brought out by comparison. The first, known

as the wool type, is in its simplest form of the coronal pattern, that is each scale encircles the shaft of the fibre and rests in the cup formed by the scale beneath it; its ectal edge is convexly curved, faintly and irregularly serrate and points distally. Such a type occurs only in very fine fibres, and as they become thicker more than one scale to the circumference can be seen, which tend to be broad and shallow and are either convexly curved or their free edges trace out a wave-shaped line around the fibre shaft. This tracing, which is most frequently found where more than one scale per diameter occur, presents a very different aspect according to which part of the line is visible: thus a convex, concave, or diagonal line may be exhibited. It can also be observed that the waves so formed tend to run equidistantly from one another, and where the scales are shallow this characteristic parallelism is very marked. In many cases, however, they are not quite continuous at their lowest (i.e. most concave) point and a narrow piece of the slightly deeper scale breaks the regularity here.

The other variety of scale structure, known as the reticulate or hair type, presents the appearance of a rather taut net stretched across the surface of the fibre. The scales although actually slightly curved appear to be straight and smooth-sided in

comparison with those of the previous type. They meet three or four at a point and are frequently irregular in size and shape. However, in some fibres the majority of scales may be long and narrow, in others squarer or broader and more shallow. The last variety approaches the kemp type of cuticular structure to which special reference will be made later. Their ectal edges form notches along the sides of the fibres but are, except in a few cases not so distinct or regular as in the wool type, this being probably due to the fact that whereas in the latter case all the scales have their free edges directed quite definitely distally, in the former they often show a very marked lateral as well as distal orientation. It has been mentioned above that in this type scales characteristically appear to meet three or four at a point. The cause for such an appearance can be more clearly detected in some of the fibres. Namely, the line of fusion between two scales usually starts from beneath an angle or a point of the more proximal scale (below); the scales, however, are so thin and so closely applied to the fibre shaft that the difference in depth of focus may often pass unnoticed and the structure appears as an endless network rather than as an irregular slating which it really is. As was expected, tabulation of the number of scales per unit of fibre

length yielded an indication of difference in scale size between the two types, but while the results are in agreement with the suggestion that the cells of the reticulate type are in general larger in surface area than those of the wool type, the irregularity in scale shape robs them of much of their significance.

Medullae, on the other hand, appear all to be modifications of one main type and vary from an extremely wide continuous type which takes up practically the entire fibre shaft partly at the expense of the cortex, and in which the structure can be clearly seen, to a very fine type which is indistinct in structure. The wide medulla always takes the form of a reticulum in which meshes lie both vertically and horizontally to the length of the fibre and are apparently the shrunken keratinised cells and cell walls of the medulla which, in the follicles of the growing fibre before keratinisation can be distinguished from the surrounding cortical cells by theirround or square shape as compared with the spindle shape of the latter.

As the medulla in the fibres becomes progressively finer the reticulum is still present although it is much narrower, until the finest grade is reached, in which the medulla consists of a single row of cell spaces often apparently of irregular size. In all

cases the spaces are filled with a gas, presumably air, and this, unless expelled by some clearing agent, masks the structure especially in the fine fibres where its expulsion is most difficult.

Medulla which occurs throughout the fibre (with the exception of the tip and root of a shed fibre where it is never present) has been termed continuous medulla, while that which is interrupted at fairly long intervals is designated discontinuous. Since the great majority of medullae come into the last category, it has been found convenient to speak of portion of the medulla as being continuous. Very fine, much and irregularly interrupted medulla is known as fragmentary. Medulla of which the width is less than half that of the entire fibre shaft is referred to as rod-medulla, since its appearance when examined by transmitted light under the microscope is not unlike a black rod. That which is wider is termed reticulate medulla since the network can usually be seen outlined by reason of the gas which fills the spaces.

The word <u>kemp</u> as used in this paper designates a fibre which is, in all but the long-woolled mountain breeds distinct from all others on account of its coarseness and because it is usually found lying loose in the fleece (if this is examined towards

shearing time); it possesses a complete tip and root, from which it is concluded that it is shed at least once a year. In medullary structure it does not differ materially from the other types (vide infra) but the structure of its cuticular layer is rather characteristic. Kemps possess in the medial region, (i.e. their thickest portion) a very definitely reticular scale structure in which the meshes are penta- or hexagonal, the sides being straight and the angles between clear cut. In general they are fairly uniform in size and roughly regular. Travelling towards the extremities of the fibre it is found that the scales become progressively broader and also slightly shallower, the apex angle of the scale becomes more and more obtuse until at last it disappears altogether when the ectal edge is represented by a single firm smooth continuous line. At first sight the scales now appear to be like large wool scales. However they have a tendency to possess straighter sides and take the form of long narrow rectangles while the wool type exhibits a faintly ragged edge and curves down to meet the superimposed scales without forming definite angles. Finer kemps are occasionally clothed throughout by broad shallow scales and have no reticulate markings.

The terms 'hair' and 'wool' have been avoided as

far as possible in the description although it has occasionally been found necessary to use 'wool' in its more general sense to describe collectively all the fibres of the fleece. 'Staple' has been used exclusively to denote the small tufts or locks into which the fibres naturally group themselves in the fleece. In order to obviate the necessity of introducing more figures, it has been decided to use the terms 'wave' and 'crimp' in contradistinction to one another, that is, staples and fibres in which more than 1 wave per centimeter occur are described as 'waved,' while where the waving is finer it is called 'crimping.'

In the following descriptions it has been found convenient to group the breeds into four classes, viz., Mountain Longwool, Lustre, Down and Mountain Short Wool Breeds.

MOUNTAIN LONGWOOL BREEDS.

SWALEDALE.

Coarse Sample. This is very similar to medium quality Blackface wool. The longest type of fibre (27.5 - 35 cm.) are very strong and hairy and fall into free locks for the distal half of their length; these are waved after the manner of the lustre wool staples, though only very lightly and faintly so. Proximally the staples are bunched together into larger clumps by the second type of fibre which forms a thick and fuzzy undercoat, and scattered through this there are found many kemps showing up brightly white against the cream or faintly brown colour of the other fibres.

As has been said, the longest type of fibres vary a little in length; their diameter also shows some variation and in general the finer fibres are shorter. Nearly all show a thin region (2 - 3 cm.) at a distance of 3 or 4 cm. from the proximal end and above this a deep looping or doubling on themselves. In contradistinction to the loose wave which this type possesses and which is more marked in individual fibres, the other main type of fibres is crimped finely and fairly deeply although in its coarser members

somewhat irregularly. This curling causes it to appear much shorter in the staple than the type just described, but the extended length of its component fibres varies from 17 - 24 cm. The proximal part of the fibre is finer than the rest of the shaft and the diameter, while it is on the average smaller than in the long type, appears to vary fairly regularly with the fibre length. The range of variation of the diameter merges into that of an extremely small group of fibres, 26 - 29 cm. long, which is apparently intermediate in every respect between the two main classes. It exhibits a curling which, while distinctly finer and closer than that of the first type, is yet not so fine as in the second.

A small number of fibres are present which have been excluded from the second class solely on account of their length. Some of these possess tips and are 4 - 6 cm. long, others are very fine and blunt distally and have a length of 8 - 9 cm. A very few pigmented fibres of all types occur.

Kemps are 10 - 14 cm. long, thick and very numerous. They show many breaks or flattened bends; also in many a tendency to simulate the short stiff crimping often found in typical hair is observable. As a rule the fibres are fairly uniform throughout their length, only thinning off abruptly for a very short

distance at their tip and root; in some, however, the proximal thinning is much attenuated and may occupy a considerable part of the fibre length.

Under the microscope kemp is seen to possess a reticulate medulla taking up the entire fibre shaft with the exception of a very fine layer of cortex and cuticle which cover it throughout its length and of which the former replaces it for a short portion at the extremities of the fibre. Surface markings are reticulate except at the two ends where the roughly square shaped meshes are replaced by broad shallow scales, these in turning running into the apparently wool type scales which clothe the finer parts.

In the long type of fibres scales are throughout reticular, except on the thin regions in one or two of the finer fibres where wool type scales, either typically coronal or slightly modified, occur. In the other main type and in all the finer fibres wool markings are found, although in a few of the coarser fibres of this type there is a tendency to slight reticulation for a short distance in the thickest parts; in these, however, the scales are small and exhibit somewhat irregularly serrated edges, which show some indications of parallelism.

The fibres intermediate with respect to characters visible to the naked eye also occupy this position with

regard to scale structure. Both types of surface markings may be discerned; the wool markings, usually somewhat modified, occur in the proximal half of the fibre, while a reticulate surface structure is exhibited distally.

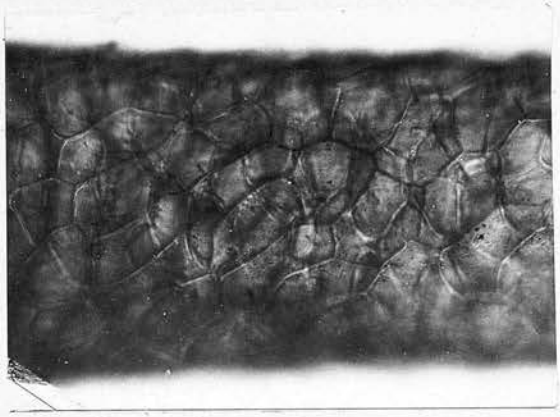
In the fine parts of the long fibres medulla is usually absent or only occurs in the form of short fine widely spaced rods. There are however one or two exceptional fibres, thick and kemp-like in appearance, in which the customary finer portion is absent. They possess a very wide reticulate medulla similar to that of the kemp type, which, however, at one or two points on their length, suddenly thins down and disappears for intervals of varying lengths: in one case it may be as short as 0.5 cm., in another several centimeters long. This disappearance of the medulla is accompanied by an equally sudden and great reduction in fibre diameter, the shaft in the fine region being about the size normally found in the root part of a complete fibre (it is also covered by scales of the corresponding type).

In the remaining fibres medulla varies in width from continuous reticular three-cells broad one found in the thickest distal part of the fibre, to a fine apparently structureless rod which is continuous distally but becomes discontinuous medially and is found to be more and more fragmentary as we travel toward the

fine proximal part, where it often disappears. Generally, it re-appears again, though less well defined, immediately at the proximal end. This latter type of medulla is also found in the fibres of the intermediate group.

In the shorter of the main types of fibres, the coarser members also possess a rod medulla but in general this is only continuous for a short distance in their thickest part. In the rest of the distal region it occurs only fragmentary and is entirely absent proximally.

Fine Sample. This is very different from the coarse sample. Practically all the long hairy outer fibres have disappeared, leaving the finer woolly ones exposed as the most obvious constituents of the fleece; consequently it is of much softer texture. Such long fibres as occur here are much finer than in the previous sample and merge almost unnoticeably into the fine woolly under coat which is again well crimped; the crimping is irregular in its direction giving a fuzzy appearance to the staples. The latter are 24 - 27 cm. long, the long fibres measure 28 - 33 cm., while those from the under coat measure 18 - 23 cm. While all fibres are finer proximally, there is no tender part in the long fibres as was the case in the previous sample. No short pointed fibres are found but



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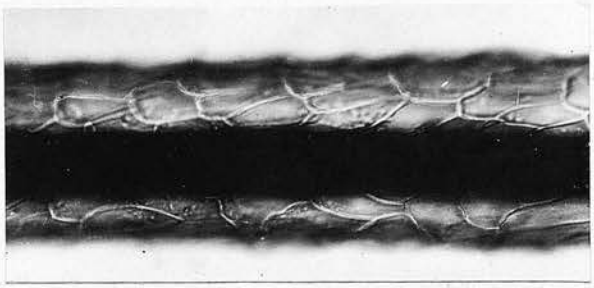

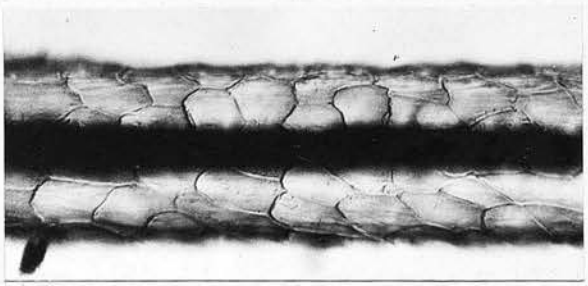

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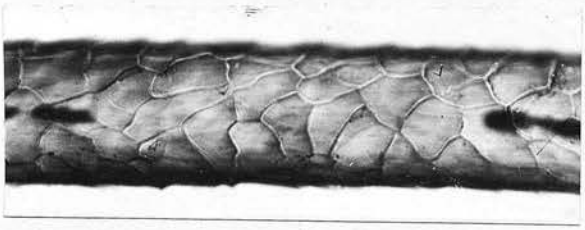
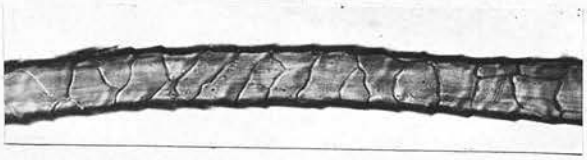




II

SWALEDALE

occasionally there are present very fine untipped ones about 13 cm. long. Scale structure is much as in the previous sample, but medulla is much finer and less frequent in the long fibres and is absent in the fibres of the finer and intermediate types.

LONK.

Coarse Sample. In this sample the staple (18 - 19 cm. long) is soft and lustrous proximally but its distal end is coarser, drier and dull; it is waved similarly to the Border Leicester or Romney Marsh, though not so firmly. Apart from the few kemp fibres 1 - 3 cm. long which are found scattered in the proximal part of the staple, two more or less definite classes of fibres may be distinguished. One, the smaller, comprises coarse fibres 20 - 27 cm. long, straight in their distal part but with irregular short waves proximally. These fibres also show a fine part near the proximal end. Their average diameter varies fairly regularly with the length and the thinnest of this type are not very different from the coarsest of the second type which forms the largest part of the fleece. Fibres of this class, while not showing a large variation in diameter, are finely crimped throughout their length which ranges from 9 - 20 cm.

Pigmented black fibres do not occur as often as

might be expected from a naked eye inspection. The wool has apparently been grown in a mining district and is extremely dirty. Many fibres are almost devoid of cuticular scales distally and numerous particles of dust which have rubbed into the surface of the fibre remain in it after the wool has been subjected to the usual cleaning processes.

In the kemp fibres medulla appears to vary somewhat in diameter, more or less corresponding to the difference in the width of the fibre. In the coarsest it is of the reticulate type with wide clearly marked meshes; in the finer it also forms a network which is proportionally narrower with its threads closer and somewhat confused. In the latter the scales are of the broad shallow type, while in the former they are reticulate centrally with broad shallow scales on either side. One or two of these fibres also possess an elongated fine root portion similar to that found in some of the Swaledale kemp fibres.

The sample further resembles a Swaledale in that occasionally a long fibre is found with a kempy part, that is, distally it has the structure of kemp with a very wide reticulate medulla and reticular surface markings, while proximally it is generally much finer with only a thin rod medulla.

The other long fibres, while non-medullated in

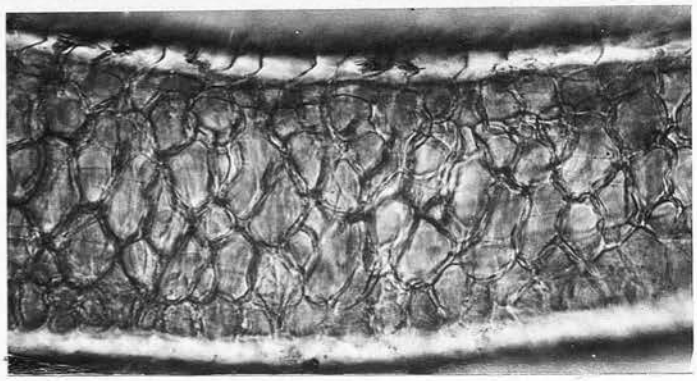
their fine parts, possess a medulla distally and usually for a very short distance at the extreme proximal end. It varies slightly with the diameter of the fibre from a moderately thick two-cells wide medulla to one taking the form of a series of very fine discontinuous rods. Scale markings are as a rule reticulate. Amongst the fibres just on the border line between these two classes in which the medulla is very discontinuous the scales are proximally of the wool type while distally they are apparently reticular.

A large number of the fine fibres show medulla which is continuous only for a short distance in the thickest distal region and gradually becomes discontinuous until it reaches the proximal region where it disappears entirely; it is of the fine rod type. In the finer fibres it is altogether absent or occurs only as isolated particles.

Several fibres in both classes are much flattened and twisted and in cross-section show up among the others, which are roughly rounded, as being somewhat kidney-shaped.

Fine Sample. In this sample which has a staple 15 cm. long the outer end is not so markedly coarse and distinct from the finer under coat. Among the individual fibres too the change from long and coarse to fine and short is so gradual that no division into

two separate groups is possible. The long fibres range from 14 - 24 cm. and, as is the case in the previous sample, have no pointed tips. A few non-medullated fibres 3 - 4 cm. long, with pointed tips and heavily pigmented in their distal portion occur. Kemps are also found though less frequently.



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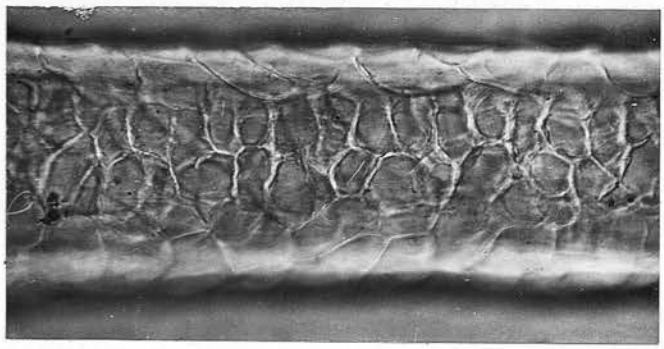

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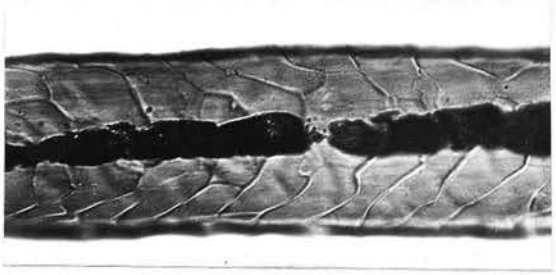
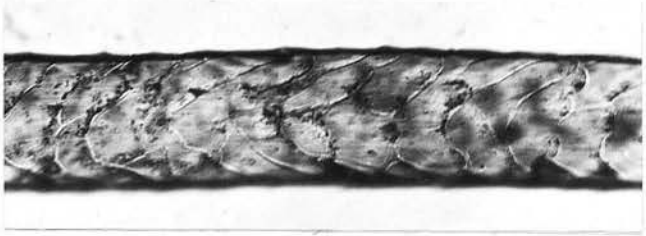




II

LONK

LUSTRE BREEDS.

LINCOLN.

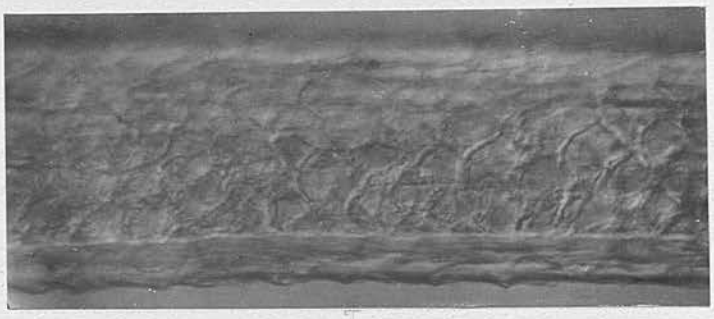
Coarse sample. This is composed of long (25 cm.) staples with deep regular and non-extensile waves. Along the lateral edges of the staple straighter fibres run through among the waved ones; they are in any given length of the staple shorter than the others and, being caught in the yolk, appear to assist in preserving the shape of the staple. A few straight fibres are also seen lying along the outside of the staple, but these are looser and apparently do not play the same part as the former.

There are three distinct types of fibres: (1) Kemp, thick and usually short (1 cm.) though occasionally fibres as long as 6 cm. are found. (2) Long straight fibres of which the fleece is mainly composed; they show very considerable variation in waviness and in length (21 - 31 cm.) and also to a lesser extent in diameter. (3) Very short fine fibres about one third of the length of the long ones (8 - 9 cm.) and very finely crimped, so that 10 to 15 curls of the former are equal to one wave length of the latter. These fibres compose a very small part of the sample, possibly less than one %.

The kemps possess a very broad medulla; the surface markings are centrally reticulate and distally broad and shallow. Of the long fibres roughly half have no medulla, in others it occurs intermittently in minute rods in the thickest parts with occasionally a continuous piece. One or two fibres have for the greater part of their length a continuous and slightly larger medulla. An unusual feature of the medulla in this sample is that in a few cases it is split longitudinally and runs for a short distances as two lines of black rods lying parallel to one another and to the hair shaft. When the medulla is single it is occasionally placed very eccentrically in the fibre. The surface markings are very distinct, generally reticulate with meshes drawn longitudinally. The jagged free edge of a scale is seen always to run to meet the line of fusion of the two scale immediately above it.

As was expected, no medulla is seen in the third type of fibres. The scales differ little from typical wool and in most cases each completely encircles the fibre shaft. No pointed tips are found in either of the last two classes of fibres.

Fine sample. This is much like the coarse sample in appearance, but finer and softer to handle. There are again three types of fibres but the finest type is very scarce. The few kemps found are about 2 cm. long.



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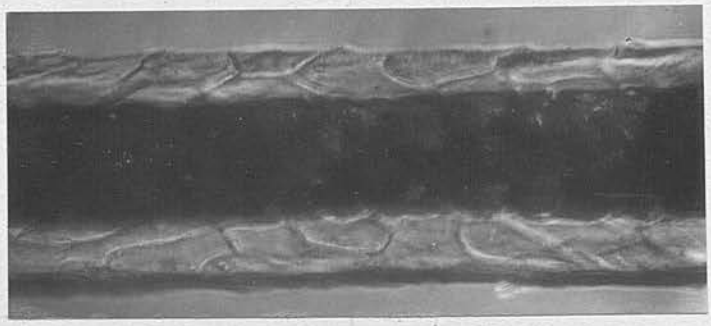

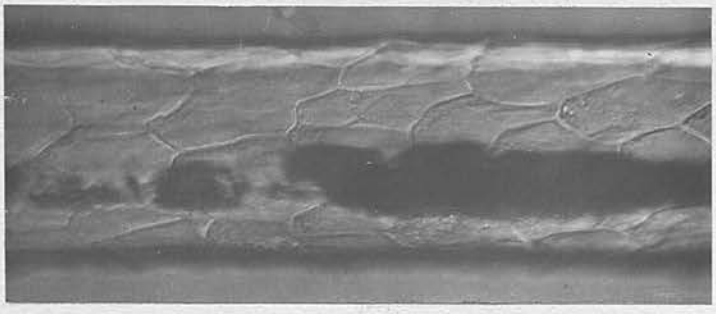

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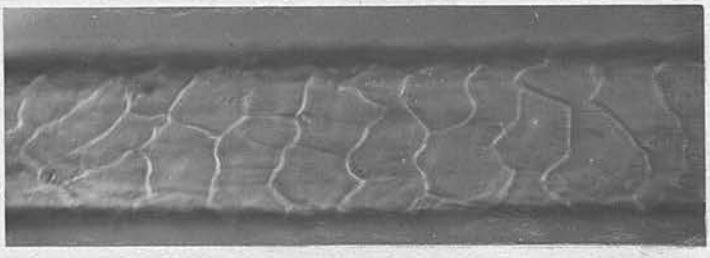

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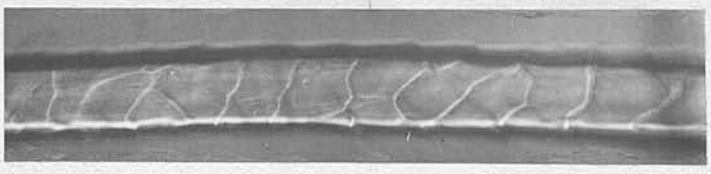


LINCOLN

There appears, however, to be a greater variation in the diameter of the long fibres, one or two being very coarse and hair-like. Some straighter ones are found at the staple edges and a few others, almost quite straight, are scattered throughout the staple, which is again inelastic being run on the straighter fibres and to some extent fixed to them by the yolk in the fleece. It is about 23 cm. long.

With the exception of a few very coarse fibres which possess throughout their length a medulla exhibiting at its widest part definite reticulate structure, the long fibres have either no medulla at all or else have short discontinuous pieces medially and distally.

The long fibres are about 26 - 31 cm., the very fine ones about 9 cm. in length.

LEICESTER.

Coarse sample. The unextended staple measures 22 cm., and is curled more closely than is usual in this breed; the wool resembles slightly Oxford or Romney and is also rather dry and brittle. The staple is fairly inextensile; when pulled out there is a tender point at which the fibres break readily about 8 cm. from the tip. Many kemps are present and are of

two types: the more usual being very thick about 2 cm. long and with a short finely tapering root and tip; the other has the usual tip and thick part which is followed by a long fine portion which merges into the root part. This latter type of fibre is about 7 cm. long and even in its thickest part is somewhat finer than the former. Both types occur at all points along the length of the staple from the cut to the distal end.

Among the other fibres two types can be identified, one long and coarse, about 28 cm. in length, the other shorter and finer, difficult to measure owing to the brittleness of the fibres making it difficult to tell whether they were short or merely broken. Possibly the shortest are about 10 cm. long. In both types variation in average diameter occurs between individual fibres but, on the whole, is not very great. A large number of both long and short fibres possess tips. The 'lamb's wool' part of the fibres tends to be more dead white than the rest, which generally is of a more pearly colour. All fibres show at their proximal end a very fine curly portion about 2 cm. long. The long fibres exhibit a certain degree of waviness; in some, as is expected in firm staples, there are straight portions.

As regards structure, the short kemp exhibits that

typical of a thick kemp fibre. There is a large reticulate medulla, which occupies the greatest part of the shaft of the fibre, and is surrounded by very fine layers of cortex and cuticle. The latter shows over the thickest part a reticulate structure, while above and below the wide 'rectangular' cells are seen merging at the extremities into an apparently wool type of scale.

The long kemp resembles in its distal part the above type; proximally, the medulla is fine and fragmentary and in parts disappears altogether. The cuticle here consists of long narrow scales forming a reticulum which lies diagonally across the fibre.

The medulla found in the distal part of the long fibres varies in width from one two cell-spaces in diameter and showing a reticulate structure to one which shows only as a fine more or less discontinuous rod. In the central portions of the majority of the fibres there is no medulla (as was the case in the proximal region); it is, however, present in some fibres as a fragmentary rod. Microscopically a short portion at the extreme proximal end of the fibre appears slightly thicker than the rest and shows a small piece of a medullary rod.

The cuticle of these fibres generally shows reticulate markings and in these the type of scale

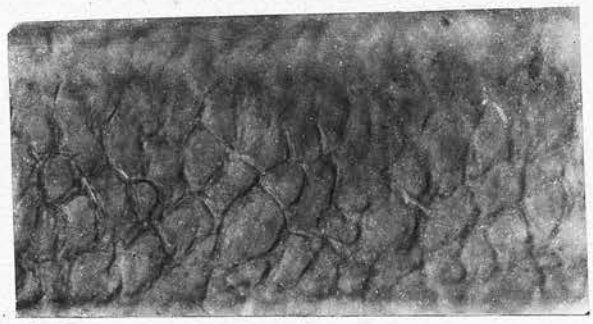
which predominates is long and narrow, lying with its longer axis more or less parallel to the length of the fibre. Such scales are observed both on medullated and non-medullated parts of the fibre. Shorter squarer scales also occur and these are occasionally misleading in their appearance, in that a piece of a fibre may be found which seems to be covered by scales of the wool type with very deeply serrated edges. However, on extremely careful focussing, a fine line of junction running down between the teeth of the scale edge may be discerned, which indicates that these are not scales of the wool type but actually rows of scales forming a net-work. This type of marking is generally found in the finer parts of the fibres.

In the shorter fibres no medulla is present. The scale markings vary from typical wool structure in the finest parts to a kind of modified reticular marking which appears to be not unlike that described above; however, no concealed cell fusions could be detected and accordingly it was regarded as wool marking.

Fine sample. This consists of long distinct and fairly inelastic staples of about 30 cm. in length (unextended). Most of them are definitely waved though many straighter fibres are likewise found. There are, apart from kemp, two types of fibres: the first measuring about 39 cm., showing slight variation

in length and thickness, and more or less waved; the fibres of the second type are very fine and short and are found only in very small numbers. Some of them are practically straight throughout their length while others are either well curled or possess an extremely curly tip. A complete fine short (1 cm.) kemp is found occasionally.

Most of the fibres run out to a fine tip. One or two have in their distal part traces of rod-type medulla, while a few show here and there short black medullar parts as far down as the medial portion of the fibre, but in the main the fibres are non-medullate. The scale markings are very regular, being of the reticular type with the mesh as a rule slightly drawn out in the direction of the length of the fibre. As in the previous sample, the free edges of the cuticular scales are sometimes so prominent as to appear like very irregularly edged wool scales; on closer inspection they are seen in each case to consist of a row of smaller scales. In the shorter fibres there is no medulla. The scales are much shallower and exhibit the typical wool markings except in the thicker parts of some fibres where there is more than one scale per diameter.



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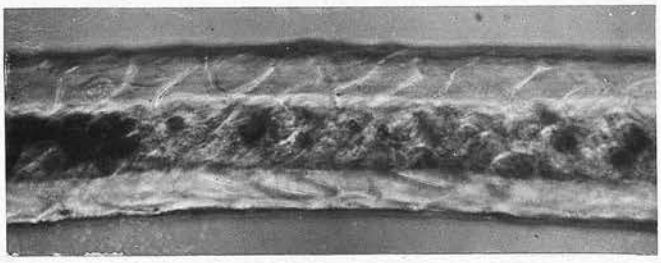

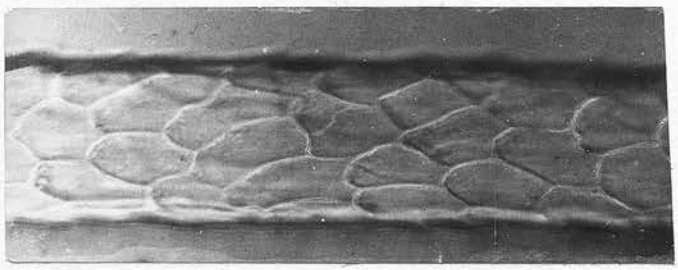

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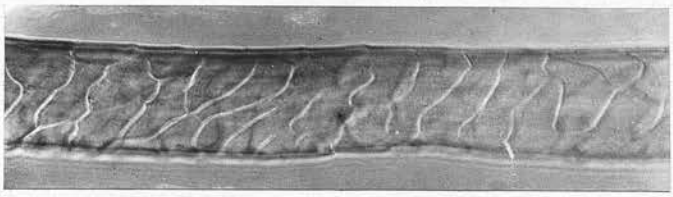


II

LEICESTER

COTSWOLD.

Coarse sample. This is a very long lustrous wool with a staple of about 35 cm. Distally the strands are loosely waved but proximally the waves are shorter and more compressed and numerous straight fibres are seen running through them. These fibres when pulled out are found to belong to the longest class present. This class consists of both straight and of loosely-waved fibres, comparatively uniform in length but varying greatly in diameter, which is on the average intermediate between those of the two other classes.

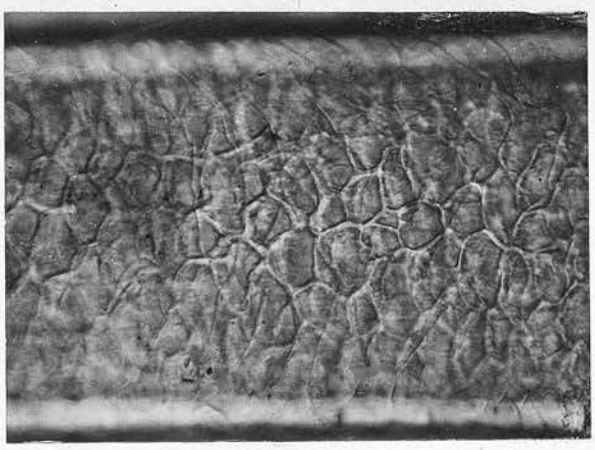
Of the other two types present one, kemp, is represented only by one or two thick short fibres (1 - 2 cm. long), while the other, which is probably equal numerically to the longest class, consists of very fine fibres, 15 - 25 cm. long, somewhat loosely crimped throughout the entire length. A few fibres 8 cm. long are met with, but as they do not differ in any other essential from the preceding class, it was concluded that they were either shorter or broken fibres belonging thereto. In both the long classes many fibres are found to possess pointed tips.

Roughly half of the longest class of fibres show medulla in their distal part; in the coarsest of these it takes the form of a continuous fine rod, becoming

discontinuous in the medial portion and gradually disappearing as one travels down towards the proximal end. Other fibres of this type show at most only minute particles of medulla here and there. The cuticular markings are reticular throughout and show, especially in the thicker parts, a large number of long narrow scales lying more or less along the length of the fibre. These also occur in the finer parts of the fibres, although the tendency for the meshes of the reticulum to be squarer is more marked here.

The finest type of fibres are non-medullated and have typical wool scales.

Fine sample. No great difference is found between this and the previous sample. The wool is finer and softer to touch. The staple is a little shorter (30 - 33 cm.), and the longer and shorter fibres show a corresponding decrease in length. (Long fibres 36 - 40 cm., short, 10 - 18). There is in this case no break in the series of lengths obtained in the finest class of fibres which confirms our suggestion that the shortest fibres in the coarse sample belonged to that group. The longer fibres are on the whole much finer than in the previous sample and not so many have tips, while more of the finer under fibres run out to fine points. No fibres apart from kemp show any more than a few minute particles of medulla.



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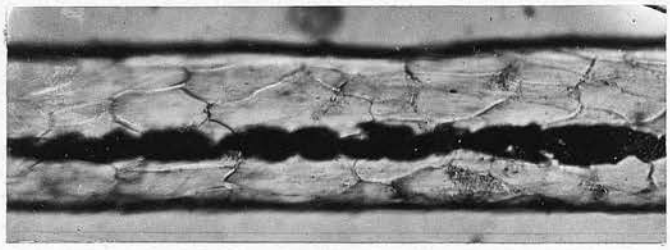
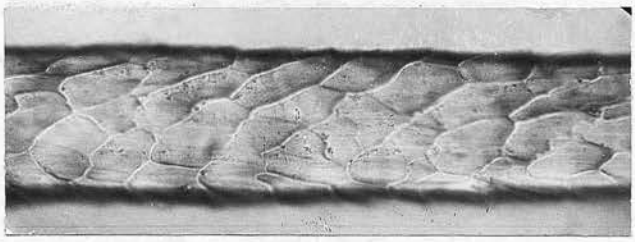
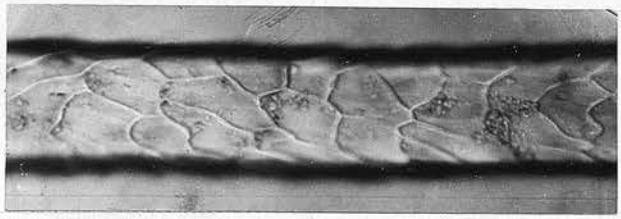






I

II

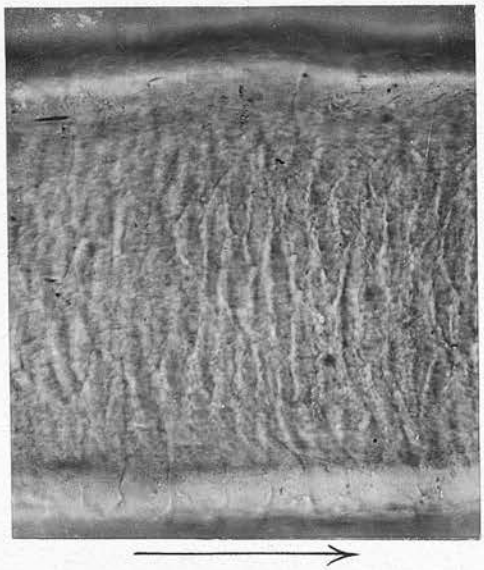
COTSWOLD

SOUTH DEVON.

Coarse sample. The staples are 31 cm. long, inextensile and closely waved. A number of straight fibres runs through each lock. Three types of fibres occur in this fleece: a few kemps, 1 - 2 cm. long, a few very fine fibres which vary from 14 - 22 in length, and long fibres (35 - 43.5 cm.) upon which the character of the fleece depends: these last vary a good deal in diameter. Among the long fibres are classified the straight ones which, when separated out, are seen to be slightly wavy for a short portion at each end. It is worthy of note that these straight fibres are among the longest in this group.

The very fine fibres are either very markedly or very slightly crimped, but never show a tendency to a waved shape, as do the long ones.

The kemps have a wide reticulate medulla and the corresponding surface markings. The meshes of the medulla are very much drawn out transversely. Fine rod medulla is found in the coarser of the long fibres where it is continuous except for a part towards the proximal end, or else discontinuous and occurs only distally. The finer long fibres have no definite medulla and show only minute particles of it here and there. Reticulate markings are seen on all those fibres and are most clearly discernable on their



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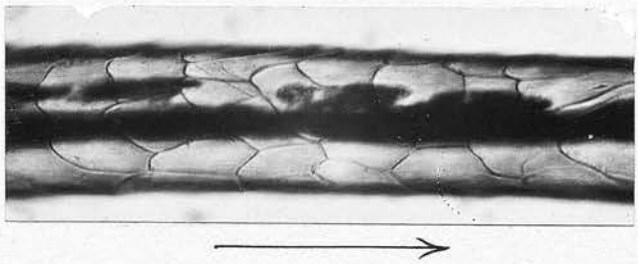

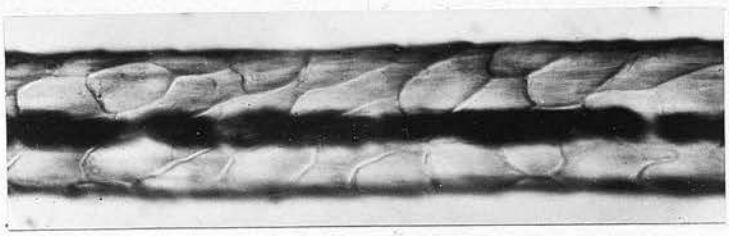

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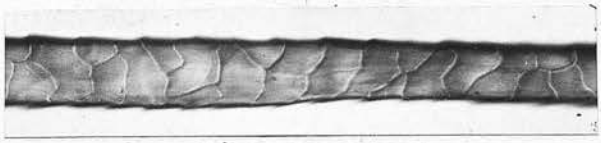


II

SOUTH DEVON

thicker parts, where it is possible to focus down until they are seen to assume a very fine but sharp outline.

In the very fine short class of fibres medulla is absent and the fibres all show distinct wool surface markings.

Fine sample. The staple is much about the same length and shape as in the previous sample. It is a little more lustrous and also softer to handle. The same three types of fibres can be identified; the finest fibres occur a little more frequently than before but are still inconspicuous in the fleece as a whole, and range in length from 17 - 24 cm. The long fibres (36 - 40 cm. long) appear to have as wide a variation in diameter but are on the average thinner than in the previous sample.

The structure of the fibres does not differ in any way from the coarse sample.

BORDER LEICESTER.

Coarse sample. The staple is 22 cm. long, well defined, lustrous and has deep short waves which are somewhat firmly fixed by many straight fibres running through it; these latter, however, are not obvious unless the staple is pulled taut. A few short thick kemps (1 - 2 cm. long) are found scattered in the

bottom of the sample. They show up opaquely white against the translucent lustre of the other fibres which can be divided into two types. The coarser type ranges in length from 15 - 32 cm. and is waved correspondingly to the staple itself, being a little straighter at the distal end where the pointed staple also becomes straight. At the tip these fibres are dull white in colour but elsewhere they are brightly lustrous and in the proximal part in general noticeably finer. Individually they vary a good deal in diameter.

The other type of fibres is numerically about equal to the first, though much less in bulk. The fibres are fine throughout and their undulations do not correspond to those of the staple but take the form of a slight irregular though quite obvious crimping, perhaps best described as crinkly. They also vary in length (12 - 22) but not noticeably in diameter. With this class were classified one or two other fibres which resembled it in diameter and curl, although they measured only 3 - 4 cm. in length. As they were very carefully removed from the staple, it seems unlikely that they were broken fibres, especially as several had tips.

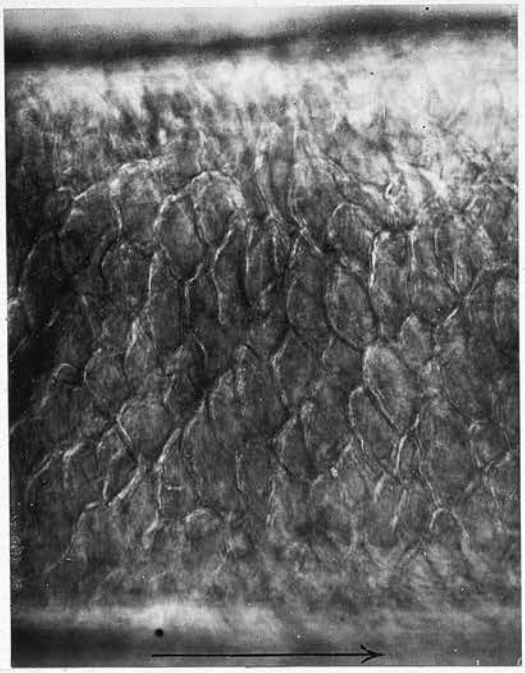
The varying length of the fibres of the main types present along with the fact that a very large number in both types had pointed tips leads to the

conclusion that the sample was taken from an animal clipped for the first time.

In structure the kemps present a picture usual when almost the entire fibre shaft is composed of reticulate medulla with air-filled spaces. Tips and roots are always complete.

Of the long group, the coarser fibres show in a number of cases (almost half the total) a continuous piece of rod medulla immediately behind the tip, which although usually much worn exhibits clearly in most cases a tapering point. The medulla soon becomes discontinuous and in only one or two of the thickest fibres it persists as far as the medial portion, though even in these it is very fine and much interrupted. All the fibres are non-medullate proximally. The scale structure throughout the thicker fibres and in the medial and distal parts of the finer ones is very definitely reticulate, long narrow scales with straight edges predominating. In the finer proximal parts the markings are still reticulate but a greater irregularity in size and shape is seen; pseudo-wool scales are also sometimes met with.

In the finer group of fibres wool markings are the general rule, as might be expected. No medulla is present. In the thickest part of one or two fibres, however, the scales might be called reticulate,



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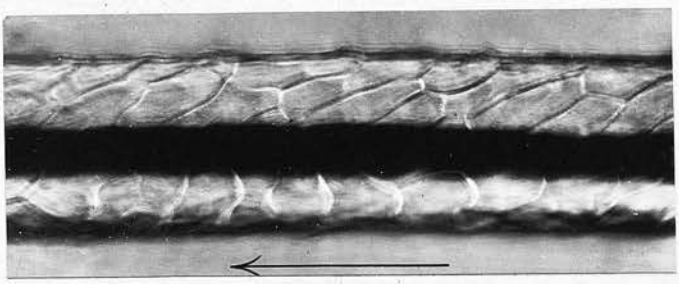
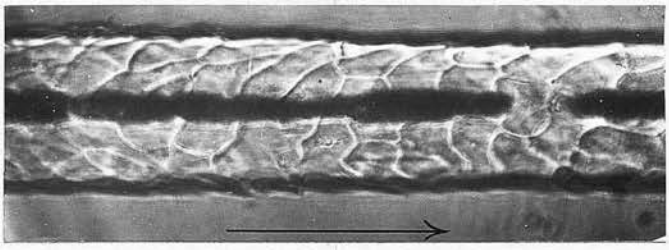
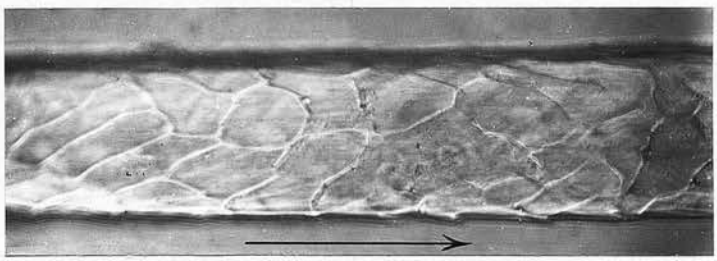
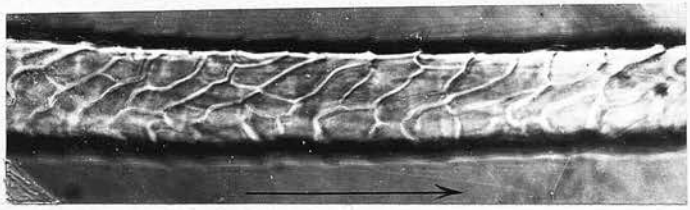








I

II

BORDER LEICESTER

but they are broad, shallow and have rounded edges. They do not meet in sharp straight lines and angles as do these of the coarser fibres. The extremely short fibres are identical with typical wool.

Fine sample. In this the staple, 19 cm. long, is elastic and is not fixed to any extent. In other words the fibres constituting the staple are all more or less equally well waved. The fibre types are the same as in the previous sample, although the proportion of the two main types is somewhat different. The coarser fibres, having a length of 22.5 - 30.5 cm., are much greater in number than the finer which vary from 12 - 26 cm. in length. The very short fibres and the kemps are again present occasionally. Structurally there is little difference, the fibre diameter is not noticeably smaller, but medulla is almost entirely absent.

ROMNEY MARSH.

Coarse sample. These staples are 16 cm. long and rather dull white in colour; distally they are almost straight, medially well waved and proximally have a finer crimp. In some cases what appears distally to be one solid staple is found proximally to have split into several well crimped strands. The staple is not fixed and is slightly elastic, all the fibres being

waved though somewhat irregularly as the staple is not clean cut.

Variation in fibre diameter is great but gradual. All fibres show a distinctly finer and more closely waved proximal part which is roughly a third of the unextended or half the extended length. A few short thick complete kemps are present. The length of other fibres varies a good deal, being in the majority 17 - 27.5 cm. (the strongest fibres are the longest), while the very fine fibres which are not numerous measure on the average 12 - 15 cm. The strongest fibres are distally not unlike fine Blackface 'hair.' No pointed tips are found. One or two of the coarsest fibres possess a medulla throughout; others have it in their distal portion only and in the majority of these it is very fine and discontinuous. The finer fibres are entirely without medulla.

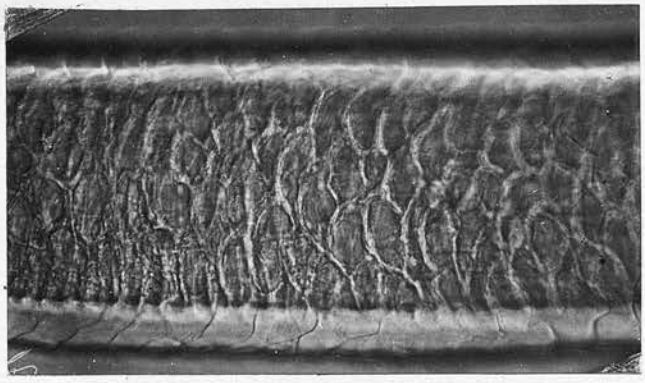
The kemp has a broad medulla and surface markings of the corresponding type, as in the Lincoln and Leicester. The medullary cell spaces are drawn out to an unusual extent in the direction of the breadth of the fibre. Reticulate surface markings are found along the greater length of the long fibres but in the proximal part of some, especially the finer ones, they are modified in the direction of wool markings. The coarsest medulla, not more than three cells deep, is

present in the distal part of the long fibres only and occurs very infrequently.

The short as well as one or two of the long fine fibres show wool markings with only very little modification in their thicker parts.

Fine sample. This is much finer than the previous sample and more uniform in fibre diameter. The whole staple, as well as the individual fibres, are well crimped from end to end, but slightly more so proximally, in which region the fibres tend to be noticeably finer. A few kemps 1 - 1.5 cm. long are present. The staple is not at all rigid and may be pulled out till the fibres are almost straight; when released, it springs back to its previous length (16 - 17 cm.) but the fibres scatter as it does so. The very fine fibres are not so much shorter than the coarse ones (19.5 - 27.5 cm.) and in general difference between the two types in this sample is not so marked.

The micrological structure of the fibres is much the same as in the coarse sample except that medulla occurs less frequently and in all but one or two very coarse fibres is finer and very discontinuous.



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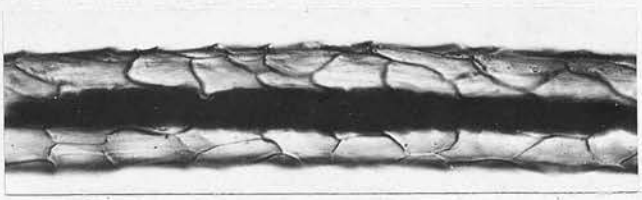

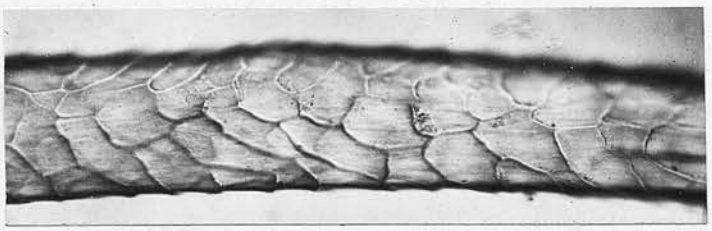

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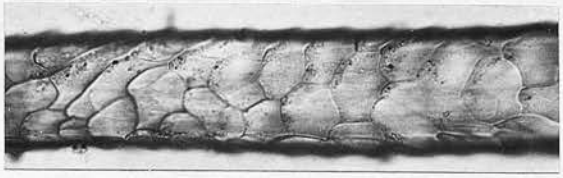
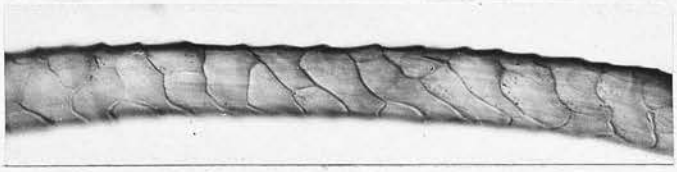




II

ROMNEY MARSH

DOWN BREEDS.

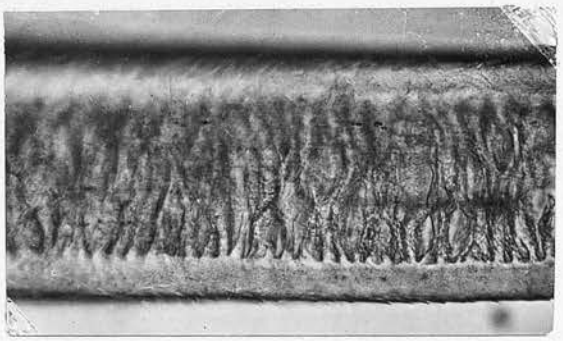
SOUTHDOWN.

Coarse Sample. This is finer and softer than any of the other samples examined, though it nevertheless possesses a slight harshness. The staples are about 8 cm. long and although the fibres are well crimped this is not mirrored in the staples which are not well defined so that it is difficult to pull them apart without breaking and disordering many of their marginal fibres. In separating the component fibres it is found that they are even more closely bound together and the greatest care has to be taken in order to obtain them unbroken.

Fibres are found to be for the most part of one type which shows a noticeable variation in diameter and in length ranges from 10 - 14 cm. The coarser fibres which in this case constitute a very small portion of the fleece are finely waved proximally and distally show a slight tendency to become straighter and a little thicker. Finer fibres are to some extent increasingly more curled and although no finer proximal part can be distinguished in these, the curl becomes so fine and light as to become quite indiscernable by the naked eye, so that at first sight the fibre appears almost straight.

After careful searching a few kemps can be found, measuring about 5 cm. in length and varying to a great extent in diameter. They also vary structurally some having a fine, others a very wide reticulate medulla. The tendency of the reticula to be drawn out transversally is also very strong. Scale markings are reticulate for the greater part of the fibre length, with the meshes somewhat drawn transversely, but not to anything like the same extent as those of the medulla. Towards both ends, and in the finer kemps throughout the fibre, these merge into rectangular markings.

In this case there is no difficulty in deciding that the scale markings of the long fibres are of the wool type. A tendency to form a pseudo-reticulate type of markings is only seen on one or two very thick fibres and is apparently caused by the scales having their lateral edges in a rough line one above the other, as on focussing through to the other side of the fibre the usual parallel lines of scale edges are seen. In this breed they seem a little closer to one another than in others, though they still have the faintly irregular outline met with in other Down breeds. No medulla is present in these fibres but here and there small pieces of fibre are seen where the cortex has become loosened and the air, having



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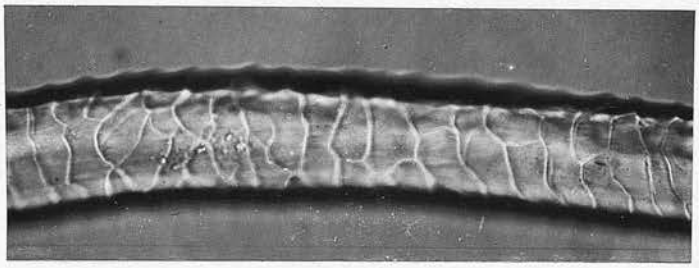

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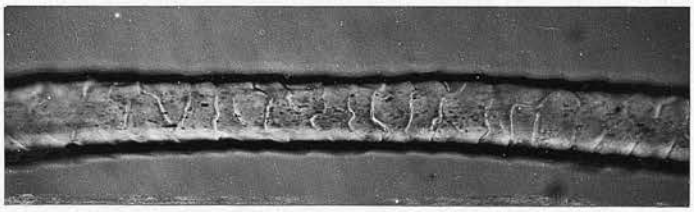


SOUTHDOWN

found its way between the cortical cells, roughly outlines them. An alternation in diameter together with an extensive proximal thinning is seen clearly in fibres of all thickness. Thick fibres however often exhibit many irregularities as though flattened and twisted to a great extent. Several of the shorter fibres possess tips; they are thickest in their medial portion and thin down very gradually towards the tip.

Fine Sample. This sample is considerably longer than the previous. The staples measure 10.5 cm., are curled from root to tip and run out to pointed curly ends. This, together with the fact that many of the fibres had tips, points to the conclusion that this sample differs from the previous in being first clip wool. The same type of fibres are found although the diameter variation is less obvious, as is also variation in curl within individual fibres.

SHROPSHIRE DOWN.

Coarse sample. This is short and rather harsh. The staple, 8 cm. long, is not clearly defined, shows no distinct curling and is quite elastic. The fibres themselves, however, are well but irregularly curled. There is a noticeable variation in the diameter of the fibres which are finer and more closely curled at the

proximal end. Besides the kemps which are found rather frequently at the base of the sample and in complete fibres measuring 1 - 1.5 cm. the sample appears to consist of only one other type of fibres not varying much in length which ranges from 10 - 12 cm. Pigmented fibres are frequently met with, both isolated and in small groups of two or three. All the kemps except one short broken piece are heavily pigmented and look almost black against the dark brown of the other coloured fibres.

Kemp varies greatly in diameter and their medulla also varies from the broad reticulate type filling almost the entire fibre shaft, through a fine rod type, to an apparently complete absence of medulla in the case of a fine kemp. All these fibres are of much the same length and possess pointed tips and finer complete root parts with the usual brush-like termination of cortical cells. Only the thickest fibres, however, show definite reticulate scale markings in their medial portion. In others the markings are either flat reticular or broad shallow rectangular ones. The pigment is confined to the cortex and medulla, leaving the cuticle clear. In the cortex it consists of fine grains diffusely scattered but with a certain tendency to alignation parallel to the length of the cortical cells; short strings of larger

granules are also found here and there throughout the length of the shaft. In the medulla diffuse pigment and large granules are also present but the latter occur separately and not in strings.

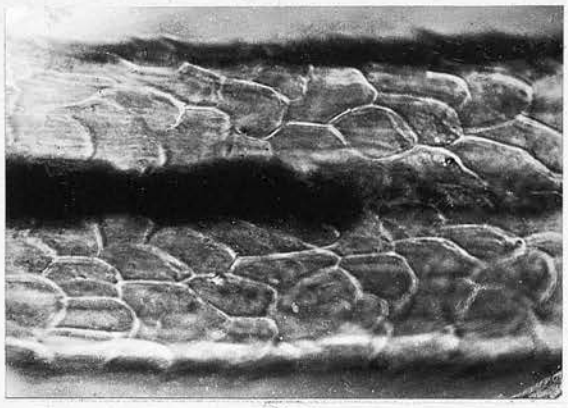
Even after the most careful searching no medulla has been found in the other and main type of fibres. Pigmented fibres seem to occur among the thicker members of this class and the distribution of the pigment is similar to that in the cortex of the kemps, which gives the fibres a streaky appearance. Scale structure is of a very definite wool type, quite characteristic in the finer fibres; in the thicker ones, while the scales do not in some case altogether encircle the fibre, they are very broad and extremely shallow and their edges running parallel to those of the scales above the below, trace out wave-shaped lines around the fibre. Scale edges are in all cases slightly and irregularly serrated. Further it has to be noted that the difference in scale size - particularly in depth - is more illusory than actual and is chiefly due to the fact that whereas in the fine fibres only a small portion of the scale is in focus at a time, in the thick fibres the whole width of the scale is exposed more or less in one plane.

An alternating thickening and thinning of the fibres with every crimp is noticeable especially when

the crimps are fine; and in the thicker regions further undulations, but much shorter and finer ones, are seen which under the microscope appear like wrinkles on the fibres. All fibres have the usual fine proximal part which is, as a rule, quite distinct, the change to the thicker part being slow and gradual.

Fine sample. Much finer than the above sample, this one is a little longer (8.5 cm.) and more evenly crimped, the crimp being this time exhibited in the staples which are extensile and clearly separated in their distal parts. The same types of fibre occur as in the previous sample, although kemps and other pigmented fibres are less frequent. Kemps are thick and 1.5 cm. long. The main fibre type is 10 - 12.5 cm. in length and shows noticeable variation in diameter between individual fibres. In general the curliness of the fibres appears to vary in direct proportion to the diameter, extremely fine fibres being very well crimped and coarse ones rather more openly and irregularly. Tips are found only very occasionally and although the majority of fibres thin a little at this extremity they terminate in blunt cut ends.

In cross-section the fibres from these two samples are not so regular as those from the lustre wools. The sections are rounded or oval in shape but often have flattened parts in their outline



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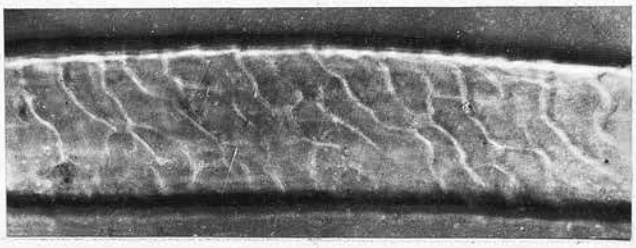
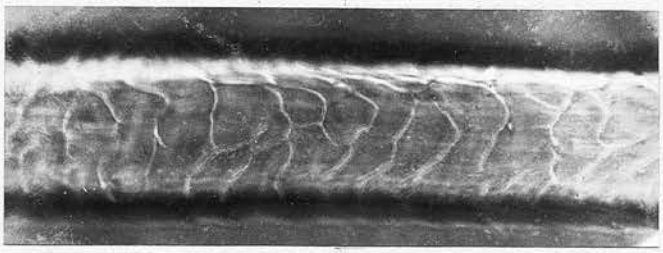




II

SHROPSHIRE

besides occasionally exhibiting a blunt point which may be regarded as a ridge in the fibre.

HAMPSHIRE DOWN.

Coarse sample. The fibres are loosely and irregularly crimped, but since they lie parallel to one another only in general direction and not in respect to their individual crimps, the staple, which is about 10 cm. long and only vaguely defined, does not mirror this curling. The sample is greasy but somewhat harsh to touch. As in the Shropshire, the fleece is composed chiefly of one type of fibres which vary noticeably in diameter and in length range from 12 - 17.5 cm. Fibres become progressively more finely crimped as they get finer; one or two are found which are extremely fine and very curly and measure 4 - 6 cm. The sample is bright but becomes dull as one travels distally into a more or less clearly defined part at the distal end which is probably the lamb's wool growth or remains thereof. Many kemps are found not only in the region near the proximal end but also in the most distal, i.e., probable lamb's wool part, the medial portion of the staples being practically free from them. As is to be expected, the kemps are of the very short type, measuring 1 - 1.5 cm.

The majority of the fibres end in pointed tips

and show, with the exception of one or two of the very fine ones, a small deposit of pigment immediately behind it.

In the kemps the pigment, laid down in the same manner as in the Shropshire fibres, is however so dense that it masks almost completely the structure of the medulla and cuticle. The density of pigment seems to be due largely to the great increase in the number of strings of large granules. Medulla can only be seen if it is air-filled, when by transmitted light it appears as a thick dark rod running down the centre of the fibre apparently differing little in colour from the large pigment granules. By reflected light, however, it shows up light and silvery, while the latter remains dark. The scale structure is predominately of rectangular type.

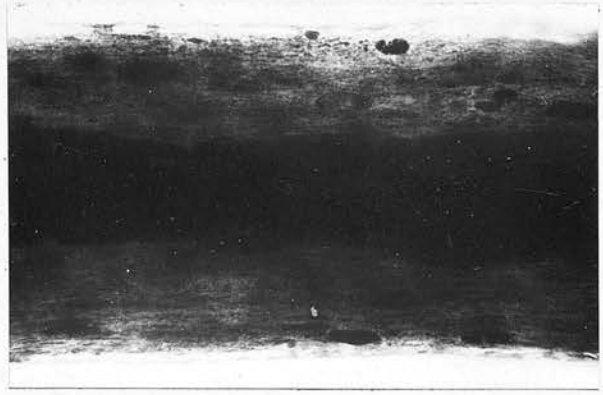
At a distance of 4 - 5 cm. from the distal end fibres of the main type, show a thinning down and have a tendency to break. Further distally the majority have a medulla reaching in the coarsest fibres a thickness of 2 cells in diameter, while in the finest it takes the form of a number of widely spaced particles; the majority of these fibres carry a fine rod medulla one cell thick. Travelling proximally the medulla disappears for a short distance and reappears only in a few of the coarsest fibres as a fine much

interrupted rod. Other fibres have no medulla in their medial portion and none possess it in their proximal third.

As regards scale structure, the wool type is seen clearly to occur in the proximal and medial regions of all fibres and throughout the finer and non-medullated ones. In the coarsest lamb's wool parts, however, the type is sometimes more difficult to define, the more so as many fibres here are much worn down by attrition. The scales seem deeper and the edges more wide apart, but they still run fairly parallel even in places where the scales are irregular in size. It has been finally concluded that the markings were of a modified wool type. The scale edges are again irregularly and finely serrated.

The few very fine short fibres have no medulla and are typically wool-marked throughout.

Fibres of the intermediate (main) type show a distinct series of thicker and thinner parts throughout the greatest part of their length, which is superimposed on the usual variation in diameter along the length of the fibre. The cross-sections, while rounded in their general outline, are of a flattened oval shape or else have the appearance of an arc of a circle with its angles much flattened. These two facts lead to the conclusion that the fibres are not only finely



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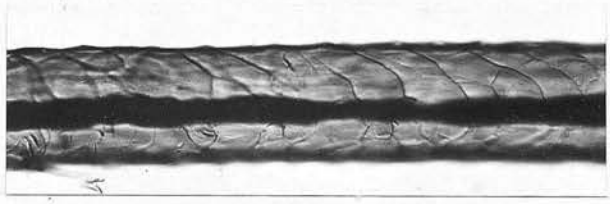
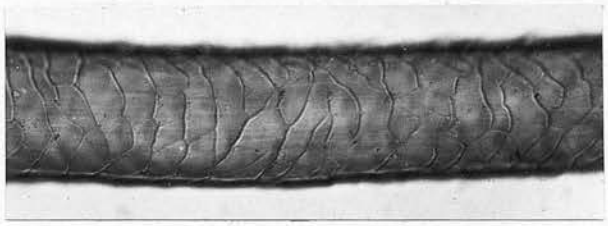




II

HAMPSHIRE

thick as the medial region. Many fibres are pointed, but some of these are much worn at the tip.

SUFFOLK DOWN.

Coarse sample. This wool is very greasy, the staple is ill defined and crimped widely and loosely; distally it thins down to a point and is here straighter and harsher to touch. The chief type of fibres present is that which determines the character of the staple; it is 10 - 17 cm. long, somewhat coarsely crimped and generally shows a practically straight piece at the extreme distal end. Noticeable variation in diameter between one fibre and another occurs, but differences within individual fibres are not visible to the naked eye. The general appearance is dull white but one or two fibres are faintly pigmented while others have a small deposit of brown pigment at the tip. Occasional brighter fibres are found, well crimped throughout their whole length which varies from 8 - 9 cm. They are subsequently found to approach in diameter the finest of the longer type.

Kemps in this sample are somewhat unusual. In addition to a number of short thick kemps about 1.5 cm. long, complete at both ends, darkly pigmented and occurring both in the proximal and in the rather vaguely defined lamb's wool region of the sample, there

is also in the latter region a fairly large number of dark brown fibres, a little finer and less brittle than the rest, measuring 2.5 - 3.5 cm. and likewise possessing complete tip and root. Structurally the kemps possess a broad reticulate medulla and the recticular and rectangular surface markings usually associated therewith. The longer pigmented fibres, however, are extremely interesting in that they possess a median thick rod medulla and on the surface beautiful typical reticulate scales, a little longer than they are broad, closely resembling those on the main type of lustre wool fibres.

Those fibres which form the bulk of the fleece are clearly wool marked in all parts except in a few of the coarsest fibres in the lamb's wool part, where here and there the scale approach very near to the reticulate type; they differ however, in that their edges are rough and serrated and also that in some parts they run irregularly parallel to one another round the fibre. Elsewhere in the broader parts of the fibres the surface markings take the form of wavy lines running closely and parallel, as described in Shropshire and Hampshire breeds. In the finest parts and fibres the scales tend completely to encircle the fibre.

In a few fibres the medulla persists more or

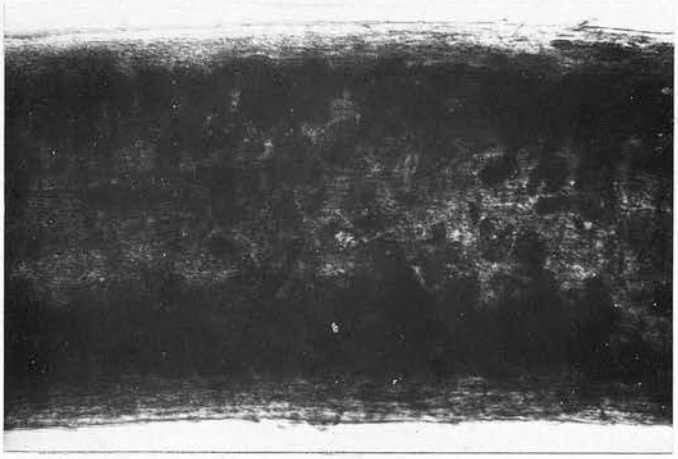
less throughout their whole length. It is thick in the lamb's wool part and in general thins down or disappears entirely for a short distance between this and the medial part. Travelling medially and proximally it is very discontinuous or fragmentary. Many other fibres have a discontinuous rod medulla only in the lamb's wool part, the rest being entirely without it or, in one or two cases, showing a few fragments in the medial portion. Finer and shorter fibres which like those just described, in the majority of cases are completely tipped, often do not reach beyond the rough line of demarcation between the lamb's wool and the medical region of the staple. It is further observed on examining complete strands of fibres under the microscope, that in this case there are many fibres which lie in the lamb's wool part and have been shed somewhere about its junction with the medial region. However, they had not been shed simultaneously, as some occur above and other below this point. They do not possess the crimp of the main fibre type, appear straight or slightly and stiffly waved, and have a thin and rather irregular rod medulla. Scales are arranged in a reticulum which in some parts is not a very typical one, and are smaller than usual. Their edges are straight and smooth but in one or two areas tend to imitate those of the wool type forming

wavy lines. A very small quantity of diffused pigment is present throughout the length of the fibres but in general is not sufficient to colour it visibly.

The few short crinkly fibres referred to above have no medulla and are typically wool marked. On microscopical examination it is found that both this and the main type of fibres show a considerable length at the proximal end much finer than the rest of the fibre, the medial region generally being the thickest.

Variation in diameter at the bends of the crimps, while it does occur, is not at all obvious, and the general impression is that of a fibre gradually changing in diameter, which is further supported by the fact that cross-sections are round or oval. It may be worth mentioning, however, that in the thick parts of the coarser fibres short series of very brief variations of diameter occur without any relation to their position in the crimp.

Fine sample. The staples here are firmer, more closely waved, and are more clearly marked off from one another. The staple is softer and although pointed shows no definite lamb's wool area at the distal end, but the crimp becomes a little more open here. The fibres can be classified into the same groups as in the previous case. No loose fibres occur in the



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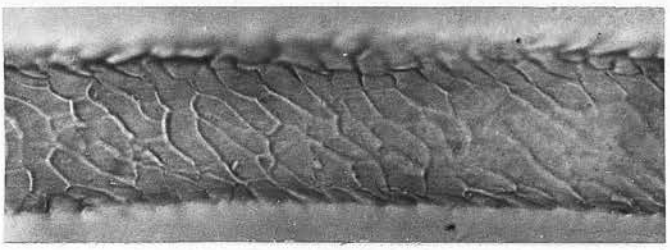


II

SUFFOLK

lamb's wool region except for those which in the coarse sample described together with kemp; here, however, both these types while still heavily pigmented are finer and smaller. The former and occasionally the latter are entirely without medulla. Scale markings are somewhat masked by pigment, but appear to cross the fibre at right angles and parallelly; their edges show as a series of deep and regular serrations distally directed along the sides of the fibre, so that but for the straightness of their ectal edges which is not typical of the wool type, they might be either wool or rectangular scales.

OXFORD DOWN.

Coarse sample. In this sample the staples (12 cm. long) show a faint and moderately fine crimping and are fairly easily separated from one another. It is rather coarse in appearance but does not handle so harshly as one might expect. Numerous clusters of pigmented dark brown fibres occur among the main type. Kemps which are found fairly frequently, are fine, about 0.5 - 1 cm. long and occur more or less all along the staple. In many cases they are heavily pigmented. Other fibres vary considerably both as regards length and diameter. The coarser fibres show

a crimping which is fine in their proximal third and coarser distally, where the fibres themselves are also thicker. The finer fibres are finely crimped throughout. As regards length the former class ranges from 10 - 16 cm. and thus includes the latter, for although some of the finer fibres are found to be as short as the coarser ones none of them exceed 14 cm. in length. The pigmented fibres appear to belong chiefly to the coarser class, though fibres with pigmented tips are found in both classes. Complete tips, however, occur only very infrequently, and it would appear that it is only in such that a pigmented distal end is found.

Kemps have a medulla of large reticulate cell spaces and citucular markings form a network medially and merge into rectangular scales on either side. While pigment is laid down in the same manner, the strings of large granules are fewer and the component granules finer than in the Shropshire.

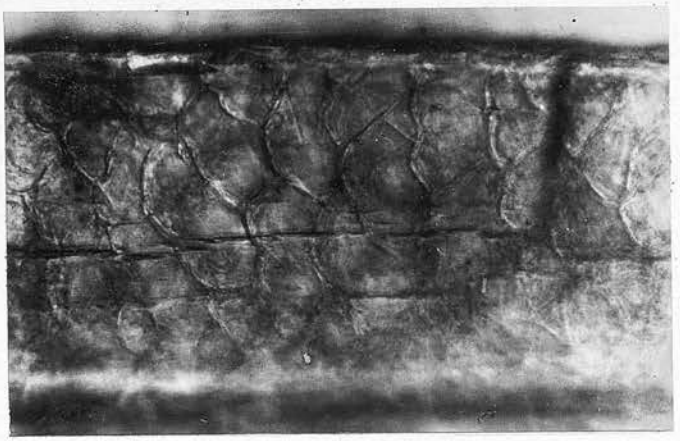
In the larger fibres there are, as has already been mentioned, very few tips and medulla is practically absent occurring only in one or two of the thicker fibres in their distal half as three or four short and thin fragments situated far apart. The cuticular scales are in general of the wool type with the usual modifications in thicker and thinner fibres. In the finer ones it is noticed that their edges seem more

widely spaced than in the Suffolk wool, while the coarser markings, though showing in some cases marked parallelism, run in waves which are higher in proportion to their width than in the former breed. In parts of these coarse fibres a few places are observed where they give a picture very closely approximating to the reticulate type, though there are one or two minor difference. The scales have an irregular edge similar to those of the definite wool type and, while of different shape, some being long and narrow and other short and square, do not have their lines of junction rising from an angle of the scale beneath. Further, their edges stand out much more freely from the fibre shaft than in the characteristic reticulate type of scales. The fibres which are fine throughout have no medulla and possess cuticle scales encircling fairly completely the shaft.

Both these types although they do not exhibit the alternating changes in diameter seen in the Hampshire, show in addition to a long and well marked finer proximal portion a certain amount of unevenness which usually takes the form of short and sudden swelling in the fibre. Cross-sections are oval in shape and twisting does not appear to occur.

Fine sample. In this sample the wool separates more naturally into staples, 11 - 12 cm. long, which

are a little more firmly and finely crimped than in the previous sample, while the fibres are similar in form and structure. Long fibres vary from 10 - 20 cm. and kemps, which are again fairly frequent, from 1 - 1.5 cm. Two very short tipped fibres 2.5 cm. long which are at least equal in firmness to the finest of the longer fibres are also found; they have typical wool structure.



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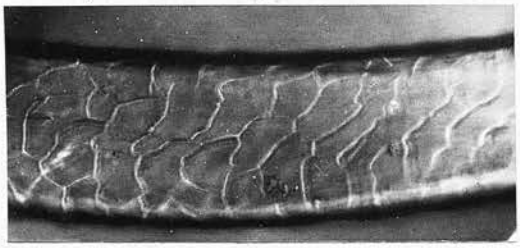

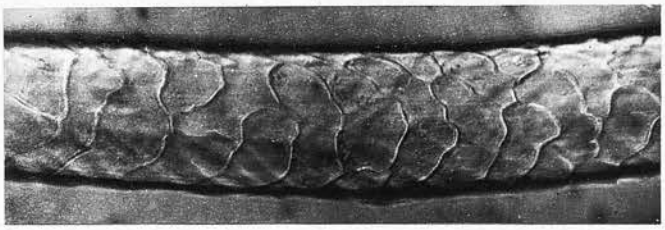

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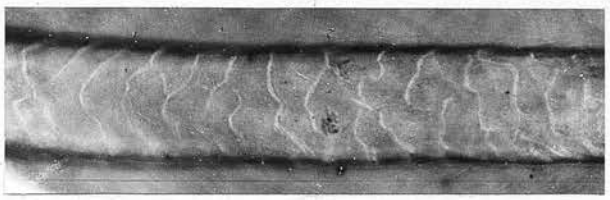


OXFORD

MOUNTAIN SHORT WOOL BREEDS.

EXMOOR.

Coarse sample. This sample is very coarse in texture and appearance. The staple, 14 cm. long, shows only medially faint traces of a rather coarse crimping and 2 cm. from the proximal end it exhibits a thin or tender part, which may be due to some factor influencing the general health of the animal but more probably is a seasonal variation similar to that noted in other breeds. If this is the case then it would appear that this fleece had been cut very late in the season.

On separating out the fibres a wide variation in diameter is at once noticeable. The coarser fibres are coarse and hair-like in their distal half and finer proximally; in the latter region some are very fine, only thickening very slightly and gradually towards the cut end, while in others there is a short extremely fine tender portion running abruptly into the thicker proximal region, which appears to be as thick as the distal. In these fibres the fine parts are very finely crimped, the coarser widely but still deeply crimped while one or two are almost straight in their thick part.

On working through the series to the finest fibres it is found that the difference between thick and thin parts of the fibres becomes less and less marked until a point is reached where no variation can be detected by the naked eye. Roughly 25% of the fibres have this appearance, but in actual bulk they account for only a very small part of the sample since they are so fine in comparison with the others. As regards length they fall into a finely graduated series ranging from 8 - 15 cm. and merging into the coarser class in which the variation is from 14 - 19 cm. Apart from these there is a considerable number of thick kemp fibres which are 0.5 - 2 cm. in length and are distributed chiefly in the region above the thin part of the staple. A few very short and tipped fibres are found which reach only to the tender portion; they are mostly fine though an occasional straight one is found. Assuming that this 'tender' portion of the staple is the usual seasonal break in the fleece, it has been concluded that these are new fibres and need not, therefore, be taken into account.

The kemps are found to belong to the type with an extremely thick medulla. They exhibit a scale structure intermediate between rectangular and typical reticulate types except in the medial region of the fibre where there appears a reticulate scale structure with broad shallow meshes.

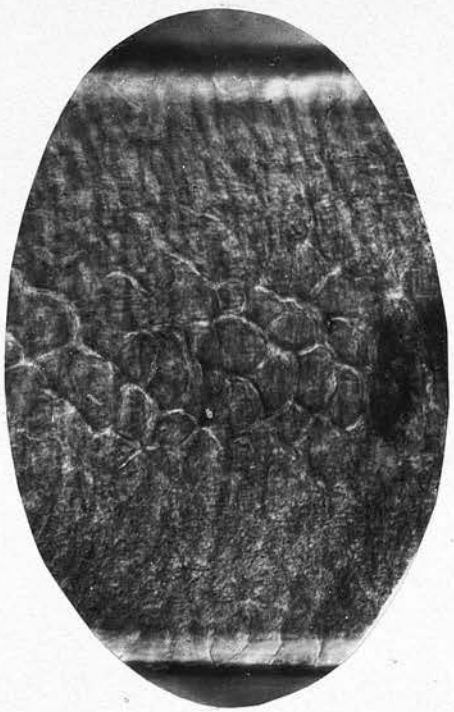
Among the other types of fibres none can be found which are entirely without medulla; even the finest fibres show in their thickest part a few short discontinuous pieces, others exhibit a discontinuous medulla for the whole of their length with the exception of a small piece at the finest part (corresponding to the tender region of the staple), where there is either no medulla or only a few fragments. In one or two fibres only the finest proximal part is as thickly medullated as the distal; elsewhere it exhibits a series of medullary fragments following one another in close proximity. At its thickest the medulla attains a width of two cell spaces, the most general type is only one cell wide and further appears to vary in very close relation to the width of the whole fibre shaft.

The fine fibres exhibit fairly typical wool markings and on the majority of the coarser ones the scale are found to be capable of classification in that group, although in all fibres there is evident a distinct irregularity in scale size, not so much in adjacent cells as between groups of cells in different areas or between the corresponding areas of different fibres. Such variation does occur in other breeds but not to the same extent. In some parts, for example, scale markings run closely parallel, while in others

they are much wider apart without any relation to the thickness of the fibre. Pseudo-reticulate markings, however, are only found on the thickest parts of one or two coarse fibres.

It has been mentioned above that not all coarse fibres exhibit the wool type of surface markings. The exception in this respect are apparently those fibres which, on naked-eye inspection, differ from the others only in that they lack crimpiness. At no part of their length do these fibres show wool markings of the type where individual scales encircle the shaft of the fibre. Further, their scales present an appearance midway between the pseudo-reticulate cuticle in thick fibres from some Down wools and the typical reticulate markings of the lustre breeds. The scales are intermediate in size between these two and, while not so rough-edged as wool type, do not as a rule have the smooth outlines of the reticulate type.

Fine sample. The crimp is finer and more regular in this staple which is a little shorter than the last (12.5 cm.), but it also has a tender part two or three cm. from the cut end. The texture is softer and very coarse fibres occur much less frequently. Kemps are present in considerable numbers and vary from 1 - 3 cm. in length. The longer fibres have blunt tips while the finer shorter ones run out



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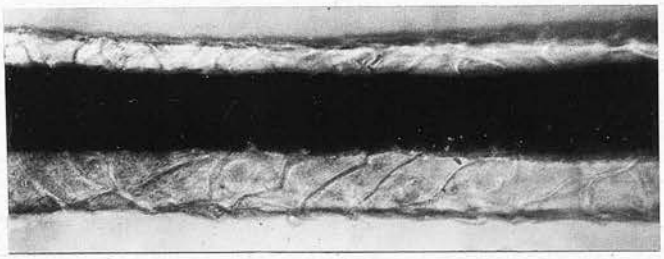


II

EXMOOR

to a fine point. It is seen on microscopical examination that the former also thin down gradually towards the distal end, but the extreme tips are missing: possibly owing to the rather brittle nature of the fibres they have been rubbed off.

As is to be expected, there is much less medulla present in the fibres than in the last case. One or two very thick fibres possess at their greatest width a narrow reticulate medulla and are reticulately marked through their length. Their medulla also persists in the proximal half but is very fragmentary. In the other fibres medulla is fine and discontinuous; there is invariably a break between the medial and the lamb's wool parts of the fibre, and no medulla or only a few particles occur proximally. Thick fibres show a tendency to be flattened and twisted distally.

CHEVIOT.

Coarse sample. This wool falls into thin rather well defined staples, 11 - 13 cm. long, which are distinctly and regularly crimped in their medial part and run out to fine points where the crimping is more open and not so marked. Proximally the crimping becomes more irregular and the staples cling fairly closely to one another. Fibres are in the main of one type, the length of which varies from 9 - 18 cm. It might be

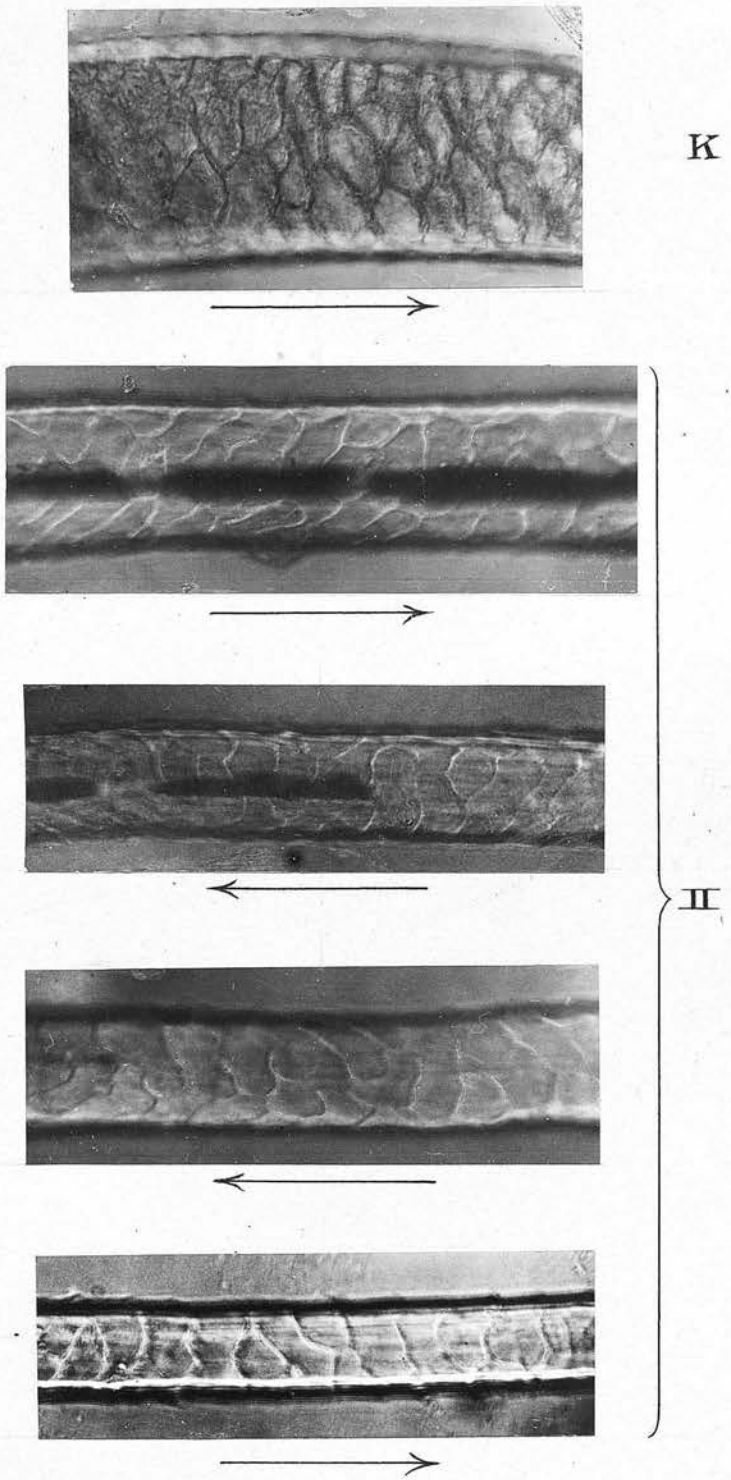
possible to subdivide this class according to length and diameter (as the latter also varies a good deal and apparently in direct proportion to the former), but the change is so gradual that it would be difficult to make any clear cut division. All fibres are found to be crimped more or less regularly in their medial part and less so elsewhere. Proximally, all show a very marked fine portion which is more finely crimped. In the coarser fibres it extends to about 3 cm. in length, in the very fine ones to 1 cm. As has been observed in other breeds, the fibres show most variation in thickness in their medial and distal regions. The majority of fibres have pointed tips. Kemps 1 - 2 cm. long are found but seem rather fine and are difficult to see when examining the sample as a whole. Also they possess a somewhat irregular stiff crimp the bends of which show under the microscope as finer portions of the fibre. In structure they exhibit a wide reticulate medulla, not quite extreme in type, for a small band of cortex can be distinguished in optical section running down the lateral edges of the fibre shaft between the medulla and the cuticle. The latter is a little irregular and appears to be composed of wide shallow scales, rectangular in the narrower parts of the fibres and on the thicker parts deepening to form reticulate markings in which the meshes are still broad and rather shallow.

In the main class the majority of fibres show medulla but in very varying degrees. Among the coarsest fibres which constitute only a small percentage of the fleece, one or two have a continuous thick rod medulla, beginning from just behind the pointed tip and running continuously to near the proximal end where it becomes very fragmentary or disappears entirely. Others show a tendency to have a discontinuous medullary portion between the lamb's wool and the medial region. In medium fibres the medulla becomes more discontinuous and fragmentary with only short continuous pieces in the lamb's wool or the medial or in both those regions. As the fibres become progressively finer, it recedes further and further from the proximal end; many of the finest ones have no medulla and others possess only small particles here and there in the medial and distal regions. In working through the series from the thickest to the finest fibres, while it is noticeable that the proximal part is always the first to become non-medullated, there appears to be no difference with this respect between the distal and the medial regions.

The scale structure show a fairly close resemblance to that of the fibres of the corresponding diameter and disposition in the Suffolk and Oxford Downs, but there is here a tendency for the scales to be

deeper with their edges more widely apart; these latter are again slightly irregular in their outline; in the wider fibres the impression of parallelism is much less marked which is perhaps due to some extent to the wide spacing of the markings. As was also the case in the breeds just referred to, the thickest fibres possess small portions where the markings appear to imitate the reticulate type; in this case they are always situated over a medullary part of the fibre which makes it impossible to obtain a clear view of the cuticular structure.

Fine sample. This is much finer than the previous sample and is exceedingly soft, softer indeed than any of the Down samples and it also possesses a slippery texture foreign to these. The staple which is 13 cm. long is crimped in the same manner as the previous one, but the medial crimping is closer and firmer. The fibres composing the main type vary very little in diameter either from one another or individually, and only in a few of the thicker ones can a finer part be distinguished proximally. Length varies from 11 - 19 cm. but in this respect the fibres tend to divide themselves chiefly into two groups: one 11 - 13 cm., the other 17 - 19. In the majority of cases they again exhibit pointed tips. As might be expected from naked eye inspection in which the fibres



CHEVIOT

appear more translucent than in the previous sample, very little medulla is found. A few fibres show discontinuous pieces in the lamb's wool part, but only in one or two of the coarsest ones medulla occurs further down the fibre and even then in the form of short fragments very widely spaced; none is found proximally. Scale markings are much as in the previous case except that, even in the thickest parts, they do not tend so much towards the reticulate type.

KERRY HILL.

Coarse sample. In this sample the staples (12 - 13 cm. long) possess a deep but loose crimp which becomes closer and firmer towards the proximal end. The wool is very white but non-lustrous and harsher to touch than it is expected from its appearance. Considerable numbers of kemp fibres are found at all stages from the outer to the cut end of the fleece. These vary in length from 2 - 3 cm., are generally curly and exhibit alternative thickening and thinning at short distances. The remaining fibres pass through a very gradual series of lengths varying between 12 cm. and 21.5 cm. Variation in diameter and in the degree of crimping is very wide and is proportionate to the fibre length. A few pigmented fibres occur. Unlike other coloured fibres examined the distribution of

pigment is uneven, e.g. a short portion shows up dark brown the pigment being thickly deposited there; on travelling along the fibre this is seen gradually to merge into a length with no pigment and this is again followed by a pigmented part; the entire pattern may be repeated several times.

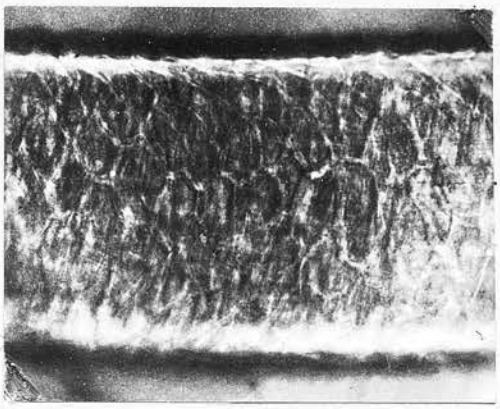
In the kemp fibres medulla varies in length. In some it is reticulate but of medium size, while in others it has the appearance of a fine black rod. In fibres of this latter type the wide apparently homogenous cortex forms an excellent background on which to examine the cuticular markings; these stand out clearly as a reticulum composed of rough squares and hexagons of uniform size. In the broader kemp fibres the stiff broad shallow scales tend to predominate.

In the main type of fibres only the very finest ones present typical wool markings, while other slightly coarser ones possess proximally scales of the coronal type but distally where the fibre widens the scales are smaller and tend to form an irregular network in which the scale edges are faintly jagged. Parallelism of scale rims does not occur to so marked a degree as in the Down breeds but what little is exhibited can be readily detected when comparing with one or two other fibres in which the scales form a

network throughout, apparently differing from the surface reticula of the long lustre wool fibres only in the size of the meshes which are a little smaller in the present instance. The edges of the scales are comparatively smooth and their shape long and rather narrow. No medulla can be found in any of these fibres.

The finer proximal portion is as a rule long and distinct and in addition there are at intervals all along the fibre sharp notches or 'breaks,' as if the fibre had been bent and on being released the flattened part at the bend had not resumed its former shape.

Fine sample. While in appearance this is as coarse as the previous sample it has a much softer texture. The staples are slightly longer (13 - 14 cm.) and show a tender part 1 - 2 cm. from the proximal end; they are straighter and do not exhibit so definite a crimping. Fibres of the main type vary in length from 12 - 19 cm. and in all but the finest a very thin region near the proximal end is visible, which corresponds to the fine part of the staple. They possess on the whole straighter distal ends than do those of the coarse sample. A few very short fibres (4 - 6 cm.) are also present, which have no corresponding type in the coarse sample; they possess pointed tips and reach only as far as the fine portion



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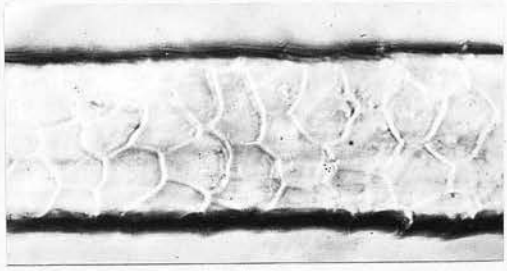

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II

KERRY HILL

of the staple. They are regarded as a new growth of fibres and are not included in the classification.

Other samples of Kerry Hill wool which have been examined all possess a certain amount of medulla in their coarser fibres and in this respect the present samples would appear to be somewhat atypical.

DISCUSSION.

During the last century, Nathusius, Böhm, Löbner, and others made notable contributions to the literature relating to the structure of the fleece fibres of the sheep, both of a general nature and dealing with a particular breed. However, micrological technique has improved since their days, and, moreover, as it is known that there have occurred distinct changes in the fleece types of many breeds, it seems outwith the scope of this paper to discuss their work. Mention must be made, nevertheless, of the credit due to Nathusius for suggesting, first that the medulla of a fibre contained air, and secondly, that curling in a fibre is caused by the curvature of the follicle.

Of the more recent writers, Bowman and Kronacher appear to be the only ones whose work impinges directly upon the present investigation. With the former I find myself in agreement in so far as his description of the particular breeds goes, but differing totally as regards the structure of kemp; this, however, will be discussed later. It would also appear that he considers medulla to be composed of rounded nucleated cells. While these are clearly visible near the base of a growing medullated fibre, in my experience the cell walls always become keratinised and the cell

contents, owing possibly to a lack of nourishment caused by the imperviability of the cell walls, disappear before the fibre part in question reaches the mouth of the follicle.

Kronacher in the course of his comprehensive paper, 'Neues über Haar und Wolle' gives short descriptions of the wool from Cotswold and Leicester sheep. The latter were imported animals while the former had been bred in the country for some time. His microscopical description of the fibres appears to agree with the present, but no classification into types was carried out and measurements were taken only of the average diameter. In the Leicester breed he makes no mention of fibres shorter than 16 cm., and since in some of my samples fibres of type II were very infrequent, it is just possible that they may not have occurred at all in Kronacher's material. In the Cotswold he is greatly troubled by the variation in length and diameter of the fibres which is no doubt partly due to the presence of the two different types.

It is evident that the four classes into which the breed samples have been grouped in the foregoing description, namely, Mountain Longwools, Lustre, Down Wools, and Mountain Short Wools, are definable by more than their general appearance. The first and second groups differ from the other two in that they have two

types of fibres while the others have only one. The first and last groups differ from the second and third respectively in that there is more medulla present in the main types of their component fibres, although between the two Short Wool groups the distinction is not so well marked. Within a group where only one main type occurs, the structure and disposition of the fibres are similar and there is no doubt that they are homologous throughout; likewise, where there are a coarser and a finer type, the analogy in each of these classes throughout the group of breeds leads to the same conclusion.

The difference between the two types in a sample or within a group of breeds would appear to depend primarily on cuticular structure and on crimping. There seems to be some more or less definite degree of the latter which is correlated with each of the two types of scale structure; fibres possessing a wider crimping tend to possess the reticulate type of scales, and those with a finer crimping - the wool type; thus the coarser type always exhibits a wider crimping than the finer. The average length and diameter of fibres of the two types, although they vary from breed to breed, are also constantly distinct, the finer being always the shorter. The proportional lengths of the two types vary without apparent relation to their breed groups: however, the tables of

diameter measurements suggest that the range of fibre variations in type II is greatest in the Short Wool breeds, and further that this increase occurs at the coarser end of the series, the finer being more or less the same in all breeds. Type I, as would be expected, shows the greater range of variation in the mountain wools where the additional variations also take place at the coarser end of the series.

Medulla appears to bear no definite relation to fibre type and is very variable even within a breed.

It is not intended to postulate that the differences in scale structure and crimp are the fundamental distinctions between the two fibre types, but rather that they are the most constant manifestations of these distinctions, and any aberrations which are found to occur seem to be capable of reasonable explanation.

It has been indicated in the foregoing description that where thinning occurs in the proximal part it is usually short in the first type of fibres and longer and less abrupt in the second, although in neither is its length at all regular. This seasonal thinning especially in the former type would appear to occur at the same time as the periodical shedding of the hair in the primitive breeds of sheep and since it is concluded (<u>vide infra</u>) that these fibre types are

homologous it seems reasonable to argue that the thin portion in the former corresponds to the fine root and tip regions in the latter. This suggestion receives further support from the fact that some breeds with a strong outer coat (i.e. of type I fibres) occasionally tend to shed their fleece at this period. In such a case not all the fibres are shed, however, - many snap at their fine part on account of the strain placed on them by the weight of the fleece.

It will also be recollected that in all fibres the tip and root parts invariably exhibit coronal markings which are similar in external appearance to wool markings; moreover, there is no evidence to suggest whether these are actually the same, or whether there may be some undetectable difference in this category of cuticular structures in the various types. Nevertheless, this analogy between the fibre types in the fleece of the present day and the primitive breeds partially explains why one finds occasionally on the short fine portions of the fibres of type I aberrations from the cuticular structure typical of that group. The explanation of the occurrence of the atypical fibres in type II is less clear but as these are the coarsest and straightest, it is possible that they have been wrongly classified. However these as well as the intermediate fibres which are classed

in a few cases between the two main groups are so few in number that it does not affect the hypothesis if they are placed in either group.

From the tables of scale lengths little can be gleaned but it would appear that the reticulate scales are fairly constantly larger than the wool type. Further, they suggest that the latter are shortest in the Down breeds and longest in the Lustre group.

As regards the relation between the groups of breeds, it is clear that the Longwools differ from the Short wool group in possessing an extra type of fibre. The coarse type in the former differs (intra se) only in respect of the amount of medulla present. (A variation in the amount and definiteness of waving is also noticeable but as it has been observed throughout that fibres possessing medulla are straighter than others of the same size but non-medullate, it is presumed that this is a secondary modification). Close similarity is also seen between the finer types (again not taking medulla into consideration), and between these and the main fibre types in the Short Wool Mountain wools on the one hand the Down wools on the other. There is the closest resemblance between the fine type in the Lustre breeds and the Down main type, a distinct variation in length occurring in both these groups.

The coarse fibre types appear to be more closely allied to one another than the finer ones. Again difference between breeds within a group are chiefly those of length and average diameter (dependent on varying fibre diameters and the proportion of each fibre type present). While breeds may be arranged in a certain series with respect to these characters, it is known that the latter frequently varies greatly within the breed and it seems probable that in breeds in which the fleece is most similar (e.g. in Hampshire and Shropshire, or in Lincoln and South Devon), differences are due to the different hereditary constitutions of the parental breeds.

All these facts together with the erratic variability of the medulla point to the conclusion that within each fibre type the fibres are homologous in all breeds in which they occur. This finds some further support in the evidence relating to the effect of environment on wool. It is frequently stated that coarse-woolled mountain sheep brought down to a more favourable climate produce a finer fleece, while the fine wool of Down breeds becomes coarser under less favourable climatic conditions. The few samples of such wool which I have been able to examine have lent support to this statement in that those of the former possessed less medulla (in both fibre types), while

those of the latter exhibited more medulla than was usual. To what extent this is due to climate alone and to what extent to differences in feeding and general management there is no evidence to show.

Two cases are known to me which appear to be in direct opposition to the above remarks and which should be mentioned here. Both refer to the Blackface Mountain breed, which would be classed with the Mountain Longwools. First, sheep in certain parts of the West Highlands possess a much finer fleece than on the mountains elsewhere. The contradiction is not so great as it would appear at first, for the thinness referred to above is due to modification in both main types of fibres, whereas in this case it would seem to be due only to the shedding of the coarse outer type. Secondly, the fashionable show sheep which are usually more carefully looked after possess the coarsest type of fleece. But breeders of such animals have been consistently selecting for a coarser type, which depends for this character mainly on the coarser fibre type, and, when one considers the obvious effect which this fashion for strong wool has had on the breed, it seems probable that genetic factors affecting amongst other things the medulla are also involved here.

If one returns now to the various breeds

described in the present paper and considers the environment as typified by climate, feeding and management, it will be noted that they fall roughly into the previous groups each of which is related to a certain type of farming - the greatest differences in management are between the mountain and the non-mountain classes, and it is suggested that the differences in amount of medulla in otherwise analogous types of fibres are not totally due to hereditary characters capable of selection, but in some measure due to this difference in environment. This contention is further supported by the fact that, if fine and coarse samples are considered separately, it is seen that the line of demarcation between the Short Wool groups must be moved so as to include some of the fine samples from the mountain wools in the Down wool group. That such similarity between the Short Wools and Down wools is not a chance happening in these particular samples is borne out by the fact that wool from mountain Short Wool flocks, kept under more favourable conditions than the average is sometimes classed as Down wool on account of its fineness. Again it is necessary to point out that cortex like medulla appears to vary with environment, but its modifications are not so pronounced as those of the latter while in some cases they seem to be dependent on it. But until some

knowledge of the mode of their variation is obtained and the limits of variation measured, the exact genetic relation between the corresponding fibre types in the various breeds must remain obscure.

In suggesting a possible mechanism for such changes, it is necessary to consider the situation of the fibres in the skin. It has previously been stated that follicles in different types of fibres penetrate to different depths in the skin; this is confirmed by the examination of a small range of sections from the skins of a number of pure breeds and crosses. Thus, it has been found that the follicles of thickly medullated kemp penetrate furthest into the skin, while the fine wool follicles are somewhat shorter than those of the other fibres. It only seems necessary to postulate some response of the skin to environment whereby in unfavourable conditions the follicles may be widened and deepened, so that the medullary cells may be proliferated into the fibre shaft; or, on the other hand, in more favourable surroundings they may contract and raise the follicle so that only cortex thickness may perhaps occur in a similar manner but it must be noted that this apparently varies in each of the two main fibre types within more or less definite limits. This would stipulate two limited ranges of depth in which the follicles move.

The seasonal variation in fibre thickness might also be put down to similar responses of the skin to varying environment induced by the climatic conditions at the different seasons of the year.

Kemps.

Although in the samples described kemps are in nearly all cases distinct from other fibre groups, yet their variation especially in length and in medulla size (with its concurrent effect on diameter) may arouse some doubt as to their being homologous. The results of the present investigation tend to suggest that fine kemps occur in the finer fleeced breeds; for although in these kemp with thick medullae also occur they are not so exaggerated as in the coarser breeds. There appears to be no break in the sequence of gradations of the width of the medulla and while kemps occurring in Mountain Longwools are on the whole much longer, yet in structure they are analogous with the coarsely medullated kemp fibres occurring in the other breeds and differing from other kemps in the same sample in only one respect, namely, in that the latter possess a finer medulla. It seems quite justifiable therefore to regard them as one homologous type.

Duerden in describing kemps in the South African Merino defines them as possessing "...a thick central

medulla with hollow inter-spaces containing air." Further he mentions another type of fibre called 'dog-hair' or gare, possessing a finer type of medulla but it is not clear whether this is quite analogous with the kemps with fine medulla described in the present paper and it seems possible that in length and disposition it more closely resembles the wool fibres of the fleece. That short fine kemps with little or no medulla do occur, however, we know, for they have been found in a few coarse pieces of Merino wool which I had the opportunity to examine.

Bowman appears to be the only writer with whom I find myself at variance with regard to the structure of kemp. He divides kemps into two classes: true kemp and 'flat kemp.' The latter he described as portions of ordinary fibres where one long ring-like scale encircles the shaft; but neither in his description nor in his figures is there anything in opposition to the simpler explanation that in the portions in question the cuticular scales have been rubbed off, leaving the smooth cortical layer exposed. True kemp he defines as a fibre without internal structure and he depicts kemp from a Highland sheep as a solid structureless fibre possessing a cross-section which has the appearance of three solid rounded fibres joined laterally to each other. This is quite contrary to

all other descriptions. Not only do the fleeces of mountain sheep generally contain kemp fibres with extremely thick medullas but even among the flat and twisted kemps exhibiting many breaks in their length and which are occasionally found among the ordinary rounded ones I have never come across such which did not exhibit both in longitudinal and in cross section some remnants of a reticulate medullary structure.

Pigmented Fibres.

While pigmented fibres have been found in a large number of cases it is not considered justifiable to draw any conclusions from their occurrence in the present range of samples. It is perhaps worthy of note, however, that in all but one breed these were either wholly pigmented or pigmented at the tip only. In the exceptional case (the Kerry Hill) the fibres possessed alternating pigmented and non-pigmented regions. From the analysis of the Down breeds it would also appear that kemps tend to become pigmented more readily than other fibres.

Origin.

The question of the origin of the various fibres has given rise to a good deal of discussion. It is generally accepted that kemp is homologous with the

hair of the primitive breeds and the similarity is certainly remarkable in the coarser of the kemp fibres found in the present series of samples. Since in this investigation the conclusion has been reached that the coarse and the fine kemps are homologous, there would appear to be nothing in my findings to disagree with the prevailing opinion.

As regards the very fine fibres found in a few of the samples and composing the second small subsidiary group (this does not include the fibres which were considered to be a new growth), these in structure and disposition are analogous to the primitive wool and would seem to be homologous with it. It must be noted, however, that among these fibres complete roots were found only very occasionally, which suggests that like the more intermediate main fibre types they tend to grow continuously; on the other hand there is a possibility that they are shed at a period later than the normal clipping time.

It is more difficult to come to a definite decision regarding the other types of fibre. It is obvious, however, that of the two main types of fibres one tends to resemble more closely the hair, the other the wool of the primitive breeds, or rather they approach in structure the two intermediate types which have been found in some primitive breeds. The chief

difference is that of length: both present day types have outgrown their primitive analogues, though it should be noted that in the former, as is also the case in the latter hair-like fibres are the longer and in them medulla occurs in larger amounts as in the primitive hair.

Ewart has suggested that the fundamental difference between hair and wool is the presence of medulla in the former and its absence in the latter. This distinction certainly does hold to a very high degree in the primitive breeds but when one comes to consider the present range of samples it must be admitted that in attempting to classify fibres in accordance with this criterion, one would in many cases separate into different classes fibres which are the same in every other respect, while fibres markedly different apart from the occurrence of medulla would be grouped together. Further, it would frequently occur that samples from the same breed might be at one time classified as all hair, and at another as all wool, according to the amount of medulla present. (This follows from evidence given above, which leads to the conclusion that environment has a marked effect upon the amount of medulla in the fibres).

Again, while the two main fibre types described are for the most part fairly distinct from one

another, medulla varies greatly in both, and its presence or absence does not appear to be associated with any other clear cut differences in the fibre type. In some breeds, particularly the mountain Longwools, there is no very definite line of demarcation between the two types although the number of transitional fibres is small and the great bulk of both types are clearly distinguishable from one another. In most lustre breeds also the two types are quite distinct. It seems most probable that the two types are not variations of one original type but rather two separate ones tending to some extent to be modified in converging directions and further that they are also homologous with the primitive hair (coarse type) and wool (fine type), for each type in its extreme form is analogous in structure to its presumed ancestral prototype and their modifications are only such as might be expected when the change in fibre size is taken into consideration.

Thus, I am of opinion that the hair and wool of the primitive breeds each possess two homologues in the fleeces of modern breeds. Kemp occurs in all breeds and it seems probable that so does the other class most similar to the ancestral type, e.g. the very fine wool fibres; in all breeds the finest fibres are very similar in diameter and in structure

do not differ from the finest members of type II, so that the two groups merge into one another (i.e. the series of lengths and diameters in the two groups is without a break), so that it is not possible to draw a sharp line of demarcation. It is for this reason that no distinction has been made between the two groups in photographs or tables and they have been classed together as type II.

It has been seen that the two main types are not always present together. In the Short Wools it would appear that only type II is present or at most that type I is only represented by an occasional greatly modified fibre in the mountain breeds of this group. It is also possible that in some of the lustre wools type II may be absent, but there being no definite difference between this and the very fine class of fibres it is impossible to determine when this occurs.

The relation between kemp and type I does not appear quite clear. They resemble one another most closely in the coarsest mountain breeds (e.g. Swaledale, Blackface), when occasionally it may be difficult to decide to which type a particular fibre belongs. Elsewhere they appear to be modified in diverging directions. The significance of the so-called rectangular scales of the kemp fibres could not be determined. In some fibres they merge on one side into

the coronal markings characteristic of the root and tip regions, and on the other into typical reticulate markings. Again it may be difficult to find any material difference between them and wool type scales, although one always has an impression of stiffness from the former which is not present in the latter. This is probably due to the sharp rigidly pointing ectal edges which possess a longer free portion than do wool scales.

As was anticipated, the material used for the present investigation proved to be insufficient for the purpose of exposing the differences between the various breeds. The short and long wools are seen to be quite distinct from one another but it is difficult to find clear cut distinctions between their component breed groups. While a definite range of variation in length, diameter and crimp for each fibre types may be obtained for the different breeds in many of the more nearly related breeds these overlap to a greater or lesser extent. Scale size has also been put forward as a breed criterion but the present data concerning this are not sufficient to give a definite answer, though they seem to indicate that in this case too there will be overlapping.

It will be observed that several breeds, including a few well-known ones, have been omitted from the

description. While samples of these have not been examined in such detail as those described in the present paper, I am satisfied that they supply no evidence which disagrees with the conclusions arrived at here.

The results of the present investigation seem to have some bearing on the analysis of cross-bred wools as well as those from hybridising experiments. Undoubtedly, the wide range of variation in the fleece fibres of the so-called pure breeds accounts for many of the difficulties arising in this connection; this, it has been suggested, is due to environmental as well as hereditary factors. Moreover, it is noted that most of such examinations have been carried out on crosses between a long and a short-woolled breed, where one parental breed carried two main types of fibre and the other only one; it is obvious that failure to consider the two types separately must have complicated the results.

Many other points have arisen in the course of the present investigation which it would be of interest and importance to follow up. The question of lustre might be mentioned. Is this characteristic of the Lustre breeds due to the reticulate cuticular structure of type I fibres which are the predominating class in the fleeces of the more typical breeds of

this group? If this is so, then is the non-lustrous appearance of mountain Longwools to be accounted for by the greater amount of medulla carried by their fibres? This appears possible for finer samples of the latter wools sometimes exhibit a typical lustre appearance in their type I fibres.

The fibres of type II also show a greater degree of opaqueness when medulla is present but the most important variable in this class is that of 'handle'. In the Mountain Longwools type II is often notable for its soft and silky feel, while in the Short Wools it is frequently somewhat harsher to touch. That such differences may occur within the same breed may be seen by referring to the Cheviot sample described in the present series. One would expect variations of this kind to be dependent on the cuticular layer of the fibre, but whether they are due to differences in the angle between its scales and the fibre shaft or to differences in their shape or resistance is not yet known.

The brittleness of type I fibres in the Mountain Longwools and of heavily medullated kemp as compared with the strength of the former in the lustre wools is undoubtedly due to the large amounts of medulla present; in some cases the solid part of the fibre is a mere shell rendered inelastic by the inclusion of

air. This lends support to the often quoted remark that "good wool has no medulla."

Lastly, the formation of staples must be mentioned. It has been stated that they depend for their disposition on the arrangement of the follicles in the skin. Thus it is necessary to make a histological examination of the skin in order to find an explanation of the variation in staple form in the different breeds and especially of the inelastic staples which are typical of some lustre breeds. The examination of sections of skin would further be of interest in disclosing the inter-relationship between the two main fibre types in the fleece.

The object put forward at the outset of the investigation, namely, to obtain a general survey of the situation, has, I think, been achieved and this together with the many suggestive points which have been briefly mentioned would appear to justify the rather long period of time spent on the microscopical analysis.

S U M M A R Y.

1. Two main types of fibres occur in British breeds of sheep. Type I is proportionally the longer and coarser and exhibits characteristic scale markings. It appears to occur only in the Lustre and the Mountain Longwool groups of breeds. Type II is shorter and finer and possesses a coronal type of scale marking; it occurs in all breed groups. It constitutes the main type in the Short Wools, is present in varying proportion in the Mountain Longwools and the Lustres. In some samples of the latter group, however, its component fibres are very few in number.

2. Two small subsidiary classes of fibres are also found. Kemp, the coarsest type, is present in all breeds. It is shorter than the main types and is shed periodically, being usually found lying loosely in the fleece with a complete tip and root. The other small group consists of very fine short fibres similar in structure to the finest members of type II. They were only identified in a few of the samples, but it is possible that they were present in all breeds but were not separable from type II.

3. Type I and kemp are considered to be homologous with the hair of the primitive breeds of sheep, while the primitive wool is represented in modern breeds by type II and the small group of fine fibres.

4. Medulla varies greatly even within individual breeds. It has a greater tendency to appear in the homologues of primitive hair than those of wool, and occurs more frequently in the Mountain than in the Non-mountain wools. It is suggested that this variability is not wholly due to hereditary influences but is in some measure caused by environment.

Regarded tables. Origin – Hand-work. Time place
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Summary
Bibliography
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TABLES SHOWING THE RANGE OF VARIATION IN FIBRE DIAMETERS AND THE NUMBER OF SCALES PER CM. OF FIBRE LENGTH IN THE VARIOUS BREEDS.

KEY TO LETTERING (SEE INTRODUCTION p.)

A. = Lamb's wool portion.

B. = Distal (non-lamb's wool) portion.

C. = Proximal portion.

SWALEDALE

Coarse Sample

	Fibre Diameters cm.			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.01634			440	
Kempy distally	.01333	.00473	.00602	440	730	525
Type I		.00645	.00387		470	670
		.00645	.00387		470	620
		.00645	.00516		500	660
		.00559	.00387		525	790
		.00387	.00215		700	900
	.00387	.00473	.00258	525	620	990
Type II	.00301	.00365	.00172	670	670	850
	.00387	.00473	.00279	550	525	820
	.	.00258	.00193		875	900

Fine Sample

	Fibre Diameters (cm)			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp	[illegible]	.01204			410	
		.00688	.00387		410	850
Type I	.00473	.00645	.00387		470	670
	.00387	.00473	.00301	670	670	900
	.00473	.00645	.00387		525	580
		.00645	.00473		470	580
	.00473	.00602	.0043	525	470	640
	.00473	.00602	.00387		410	580
Type II	.00279	.00387	.00236	820	700	700
	.00387	.00473	.00301	640	670	820
	.00215	.00301	.00215	790	820	700
	.00258	.00258	.00172	790	760	820
	.00344	.00387	.00258	700	670	875

LONK.

Coarse Sample

	Fibre diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.0125		B.	C.
	.0086		670	
	.00774	.00387	470	640
	.00645	.00387	525	700
Type I	.00602	.00387	440	670
	.00559	.00365	470	500
	.00516	.00301	670	525
	.0043	.00256	580	850
Type II	.00344	.00215	410	730
	.00387	.00150	640	790

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B	C	B.	C.
Kemp	.01075	.	640	
	.0086	.00516	440	610
	.00645	.0039	525	670
Type I	.00495	.0026	550	670
	.00473	.0030	670	700
	.00430	.0026	610	820
Type II	.00390	.0026	700	700
	.00322	.0024	846	760

LINCOLN

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.00966		640	
Type I	.00774	.00516	410	440
	.00688	.00559	380	380
	.00580	.00494	380	525
	.00537	.00451	410	500
	.00516	.00473	-	470
Type II	.0043	.00365	410	525
	.00408	.00258	670	790

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.00860	.	640	
Type I	.00774	.00516	290	500
	.00645	.00473	410	470
	.00645	.0045	380	470
	.00602	.00387	500	550
	.00516	.0043	380	610
Type II	.00365	.00279	550	500

LEICESTER

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01075		700	
Long Kemp	.00731	.0043	700	640
Type I	.00612	.00473	500	610
	.00494	.00559	470	580
	.00516	.0043	470	525
	.00473	.0043	580	525
	.0043	.00344	325	500
Type II	.00365	.00258	670	640
	.00301	.00172	760	730

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.0086		700	
Type I	.00602	.00559	410	380
	.0537	.00473	320	350
	.00516	.00516	350	350
	.00387	.00301	470	500
	.00387	.00387	320	525
	.00387	.00365	500	440
Type II	.00258	.00301	730	610

COTSWOLD

Coarse Sample

	Fibre Diameters cm.			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.00376			670	
Type I	.00516	.00602	.0043	470	380	580
	.00559	.00559	.00516	380	410	525
	.0043	.00516	.00473	380	646	500
	.00516	.00516	.00301	640	850	760
	.00344	.00387	.00344	380	580	580
Type II	.00322	.00365	.00258	525	550	760
	.	.00344	.00172		580	760
	.00258	.00344	.00301	730	820	620
		.00322	.00215		-	875
		.00301	.00193		700	700
		.00215	.00215		550	700
		.00193	100193		700	730

Fine Sample

	Fibre Diameters (cm)			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.01376			610	
Type I	.00387	.00516	.0043	560	525	640
	.00279	.00516	.00473	500	410	470
	.00387	.00473	.00473	380	500	525
		.0043	.00387		550	760
	.00322	.00387	.00344	640	500	640
Type II	.00301	.00387	.00258	700	640	850
	.00258	.00344	.00215	670	500	790
		100301	.00215		580	640
	.00215	.00279	.00215	760	610	760

SOUTH DEVON

Coarse Sample

	Fibre Diameters cm.			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.0172			730	
		.0093			700	
Type I	.00473	.00602	.00387			
	.00408	.00516	.0043	380	440	440
	.00387	.00473	.0043	470	380	580
	.00301	.00387	.00301	580	440	610
Type II	.00301	.00387	.00301	670	525	550
	.00344	.00344	.00172	580	500	790
	.00215	.00322	.00193	640	580	730
	.00215	.00322	.00193	670	640	790

Fine Sample

	Fibre Diameters (cm)			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.01634				
Type I	.0043	.00559	.00408	-	380	440
	.00451	.00559	.00408	380	380	440
	.0043	.00559	.0043	410	380	470
	.00451	.00516	.00387	380	380	525
	.00322	.00387	.00322	580	470	610
Type II	.00322	.00387	.00258	580	525	610
	.00379	.00387	.00258	550	550	670
	.00258	.00322	.00258	640	500	610

BORDER LEICESTER.

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01634		730	
Type I	.00559	.00408	580	580
	.00387	.00344	640	580
	.00516	.00365	550	640
	.00387	.00301	500	670
	.00344	.00215	610	790
Type II	.00344	.00172	760	760
	.0344	.00215	930	930
	.00279	.00193	820	990

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01677		-	
Type I	.00580	.0043	470	440
	.00559	.0043	525	580
	.00473	.0043	610	580
	.00408	.00301	470	610
	.0043	.00279	550	640
Type II	.00301	.00256	640	610
	.00301	.00236	760	900

ROMNEY MARSH

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01161			
Type I	.00602	.00387	410	525
	.00516	.00387	410	550
	.00516	.00322	550	850
	.00516	.00468	470	500
	.00387	.00258	525	700
Type II	.00344	.00215	550	760
	.00301	.00150	670	875
	.00258	.00193	820	990

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	-			
Type I	.00645	.0043	380	640
	.00662	.0043	380	700
	.00559	.00387	500	730
	.00537	.00344	410	580
	.00516	.00301	410	580
Type II	.00516	.00322	610	710
	.00473	.00344	500	640
	.00451	.00344	760	790
	.00387	.00258	550	700
	.00258	.00215	700	730

SOUTH DOWN

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.0138		790	
Type II	.00559	.00344	670	900
	.00473	.00258	730	900
	.00344	.00236	900	875
	.00344	.00215	930	1080
	.00301	.00215	790	1110
	.00301	.00215	730	875
	.00301	.00215	820	820

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	-		-	
Type II	.00451	.00322	730	1080
	.00408	.00322	820	930
	.00473	.00301	820	960
	.0043	.00301	820	850
	.00387	.00301	700	990
	.00322	.00236	900	850
	.00301	.00258	875	900
	.00301	.00215	900	990

SHROPSHIRE.

Coarse Sample

	Fibre diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.00688		960	
	.01075		525	
Type II	.00559	.00344	790	930
	.00473	.00344	930	960
	.00473	.00215	875	850
	.00387	.00279	875	790
	.00387	.00279	790	1020
	.00387	.00172	960	1050
	.00344	.00236	1020	960
	.00301	.00258	760	960

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01182		730	
Type II	.00473	.00258	930	1050
	.0043	.00258	990	930
	.0043	.00258	990	930
	.00387	.00322	875	900
	.00387	.00215	930	820
	.00322	.00215	875	790
	.00301	.00172	990	875
	.00301	.00150	930	850

HAMPSHIRE

Coarse Sample

	Fibre Diameters cm.			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.0146			787	
		.0086			729	
Type II	.00559	.00645	.00516	760	850	820
	.00580	.00623	.00516	640	900	900
	.00473	.00602	.00367	640	760	1080
	.004515	.00559	.00387	670	960	1080
	.00387	.004575	.00344	700	875	900
	.00473	.00473	.00301	730	790	990
	.004083	.004515	.00344	620	850	960
	.00430	.00430	.00344	670	990	930
	.00387	.00387	.00387	820	1020	990
	.00258	.00301	.00258	820	820	875
	.00430	.00430	.00344	790	875	820
	.00322	.00387	.00301	850	850	900
	.00258	.00301	.00344	990	820	1110
	.00365	.00279	.00322	820	730	930

Fine Sample

	Fibre Diameters (cm)			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.01032			610	
Type II	.0043	.00516	.00387	820	960	875
	.00301	.00387	.00258	730	900	930
	.0043	.00344	.004085	640	790	875
	.00258	.00301	.00215	790	962	790
	.00322	.00322	.00258	850	820	820
	.00301	.00430	.00301	930	820	760
	.00258	.00387	.00258	580	900	850
	.00258	.00344	.00258	820	900	875
	.00215	.00236	.00150	820	875	930

SUFFOLK

Coarse Sample

	Fibre Diameters cm.			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.01075			700	
Type II		.00516	.00516		700	875
	.00387	.0043	.00215	580	820	990
	.00387	.00387	.00279	730	1020	850
	.00387	.00430	.00256	640	990	990
	.00279	.00344	.00215	930	900	900
	.00301	.00322	.00172	-	930	930
	.00236	.00279	.00172	960	930	990

Fine Sample

	Fibre Diameters (cm)			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.00989			760	
Type II	.00301	.00516	.00344	760	930	930
	.00301	.00473	.00359	730	990	1050
	.00344	.00473	.00301	900	1050	875
	.00344	.00430	.00258	820	1020	960
	.00301	.00408	.00279	820	990	990
	.00301	.00344	.00258	820	1020	960
	.00258	.00344	.00215	990	930	990

OXFORD

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01376		-	
Type II	.00473	.00387	670	820
	.00473	.00301	580	760
	.00430	.00322	670	875
	.00344	.00258	700	670
	.00322	.00258	760	730
	.00301	.00236	670	875
	.00258	.00215	730	900

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01333		525	
Type II	.00537	.00387	690	610
	.00516	.00365	760	850
	.00473	.00322	700	700
	.00408	.00236	730	820
	.00344	.00215	790	820
	.00279	.00215	790	990

EXMOOR

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.01935		730	
	.00580	.00344	610	640
Type II	.00559	.00301	470	640
	.00494	.00258	670	990
	.00473	.00301	640	825
	.00387	.00279	730	900
	.00344	.00172	850	875
	.00322	.00193	930	990
	.00322	.00150	875	930
	.00322	.00150	850	1020

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.00946		610	
	.00580	.00387	580	700
Type II	.00559	.00387	410	550
	.00559	.00301	670	820
	.00516	.00258	525	790
	.00473	.00301	670	790
	.00387	.00215	730	875
	.00344	.00172	760	930
	.00344	.00279	700	930
	.00301	.00258	670	900

CHEVIOT

Coarse Sample

	Fibre Diameters cm.			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.00796			875	
Type II		,00559	.00344		550	730
		.00537	.00301		525	646
	.00387	.00387	.00215	440	580	760
	.00387	.0043	.00322	550	640	730
	.00365	.00473	.00301	-	760	500
	.00365	.00387	.00279	525	550	500
	.00344	.00344	.00193	730	640	760
	.00279	.00279	.00172	730	790	820

Fine Sample

	Fibre Diameters (cm)			Scales / cm.		
	A.	B.	C.	A.	B.	C.
Kemp		.00946			670	
Type II	.00365	.00365	.00365	640	580	580
	.00365	.00387	.00301	-	640	610
	.00344	.00344	.00258	550	820	670
	.00301	.00302	.00215	610	580	670
	.00322	.00344	.00215	700	670	610
	.00258	.00301	.00150	670	730	730
		.00365	.00215		730	580

KERRY HILL

Coarse Sample

	Fibre Diameters cm.		Scales / cm.	
	B.	C.	B.	C.
Kemp	.00516	.00301	610	760
Type II	.00473	.00344	580	440
	.00387	.00279	470	730
	.00387	.00215	610	820
	.00387	.00215	820	930
	.00344	.00172	790	930
	.00322	.00172	700	760

Fine Sample

	Fibre Diameters (cm)		Scales / cm.	
	B.	C.	B.	C.
Kemp	.00516	.00344	470	760
	.00451	.00344	875	790
	.00430	.00344	580	640
	.00387	.00344	730	730
	.00387	.00215	790	730
	.00301	.00215	790	900
	.00279	.00150	760	900
	.00236	.00172	850	960