A BIOLOGICAL AND STATISTICAL STUDY OF THE DEVELOPMENT OF THE FLEECE OF THE SCOTTISH MOUNTAIN BLACKFACED BREED OF SHEEP FROM BIRTH TO MATURITY

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C O N T E N T S.

LIST OF ILLUSTRATIONS.

I. INTRODUCTION.

General Description of the Blackfaced Fleece.

The fleece of the Scottish Mountain Blackfaced sheep consists of an admixture of fibres which differ amongst themselves in respect of physical characterisation. The concensus of opinion amongst producers and users of Blackfaced wool is that the fleece should consist of hair-like fibres, grouped into long, tapering staples which fall to either side of the body with a "part" along the dorsal line, forming a long, smooth, outer coat, whilst beneath this there should be an abundant growth of fine, shorter fibres called, in contradistinction to the fibres of the outer coat, wool. Ideally, each staple should taper to a tip not less than the size of an ordinary lead pencil. Within the breed there is a great variation in fleece quality and quantity. Usually it is long and coarse and contains considerable numbers of white, opaque, pointed, hair-like fibres which will not take up dyes at all readily, which differ in their structure from the other constituents of the fleece, and which are known as kemp. In many animals a proportion of pigmented fibres can be found. Lying entangled amidst the growing fibres are to be found kemp fibres that have been shed.

A detailed account of each of the types of fibre constituting the Blackface fleece follows. (see pages 45-60).

It is reasonable to assume that the outer coat of this fleece mainly serves to protect the inner coat and skin from wet and injury, whilst the inner coat, in virtue of its physical properties, conserves bodily heat. Thus, the ideal type of fleece from the point of view of the breeder is one which provides adequate protection for the sheep in that it protects the body from cold, wind, rain and injury.

Manufacturing Uses of Blackfaced Wool.

The wool of the Blackfaced sheep is a unique product, and is to a large extent used for carpet manufacture. According to Robert M'Millan (17) and a report of the Scottish Wool Growers, Ltd., it is also used in Italy for the purpose of making mattresses. The type required for this market is the very strong deep fleece free from grey and black fibres. The ordinary average type of Blackfaced fleece is used extensively in New York, Boston and Philadelphia, in the United States of America, for the making of carpets. Limited quantities are used for the same purpose in Germany, at Lodz in Poland, Moscow in Russia, and Vienna in Austria. A considerable quantity is also consumed in England, particularly in Kidderminster, Carlisle, Halifax and Heckmondwike. A certain amount is absorbed in Scotland, in the cities of Glasgow, Aberdeen and Ayr, etc. The shorter/

shorter fine type of Blackfaced fleece is used in the home market for the purpose of making "Harris Tweeds", (for golfing and shooting wear), notably in Harris, Lewis and other Hebrides. It is also occasionally used for ladies' dress goods, when the fashion demands rough but light cloths. (Oliver (20)).

In the spinning processes, where the fibres are put into perfectly parallel relationship by the gill box instead of by combing processes, a wastage of about 7½ % of kemp and fine short wool takes place, which from the manufacturer's point of view is a serious loss. The kemp is wasted on account of its defective spinning properties and a proportion of the fine wool is lost in consequence of its deficient length; it cannot be manipulated by the fixed setting of the top rollers in the drawing and spinning processes.

Blackfaced wool is blended with about 10% "bred" wool; i.e., Irish wool or some other variety similar to "half-bred" wool; this effects a stronger yarn by uniting the coarse and fine Blackfaced fibres. This strengthening of the Blackfaced wool yarn is necessary since it is used to provide the strong warp threads in carpet weaving. The weft threads are usually made from Jute.

The/

The wool has been comparatively little subjected to market fluctuations in the past when comparing it with other types of commercial wool. (See Wool Chart on page 5). On a basis of breed merit this type of wool yields a greater profit than any other when considering it as a commodity of secondary importance.

The Blackfaced breed consequently serves a very useful function in the hands of the breeder by providing wool which may be used for a variety of different purposes.

The Evolution of the Blackfaced Fleece.

As is well known, the fleece of the Blackface is essentially composed of fibres which to some extent fall into three main classes:

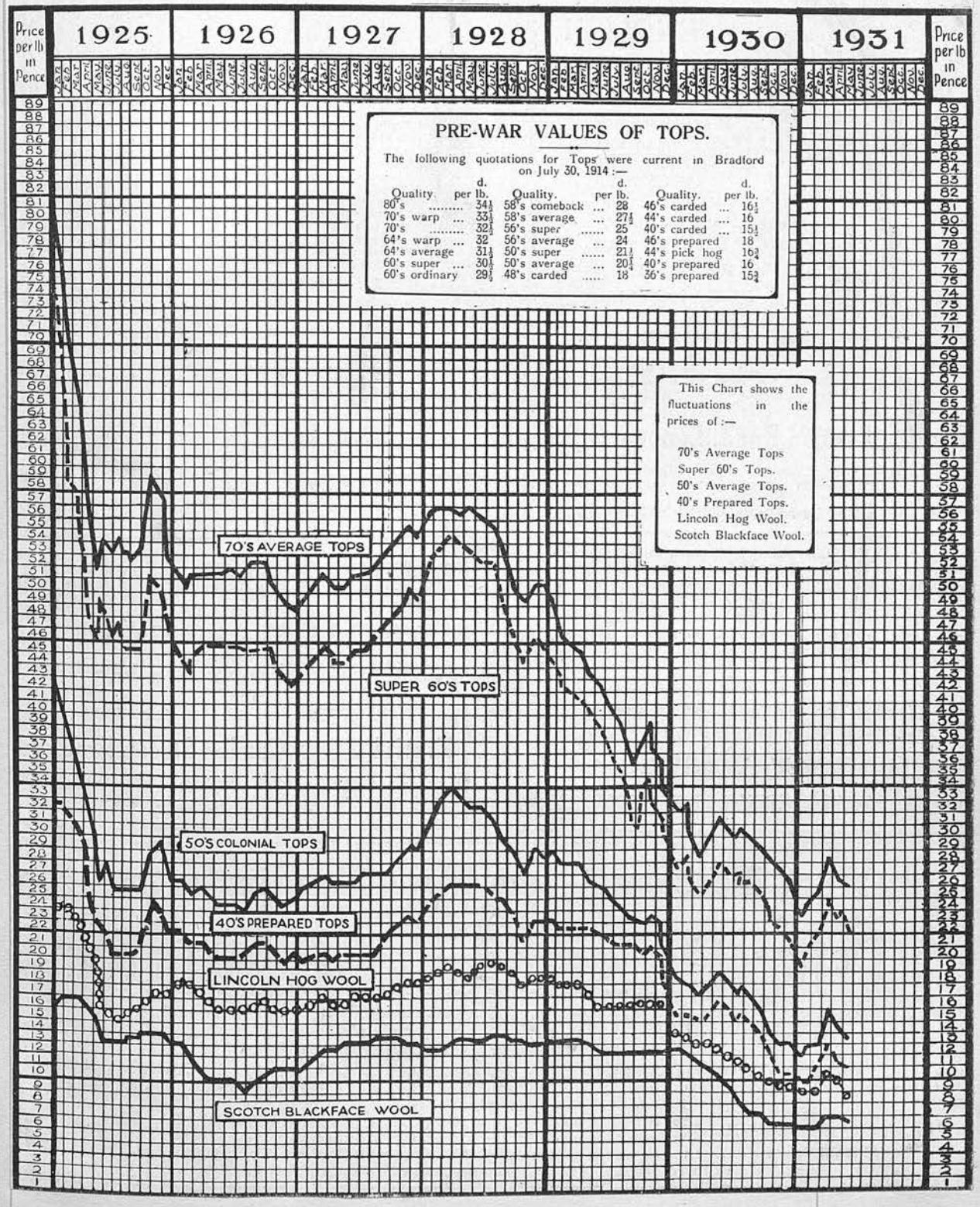
(1) Wool fibres, some of which are non-medullated and some of which are partially-medullated, are soft, irregularly crimped and intermediate in length between kemp and hairy fibres;

(2) Long hairy or Heterotype fibres: these represent a type of fibre intermediate between kemp and wool in structure, being coarse and medullated in their upper parts and fine and wavy below, the portion between the two phases showing much variation;

(3)/

FLUCTUATIONS IN PRICES OF TOPS.

The lowest curve of the chart shows the fluctuation of market values of the ordinary type of Scottish Blackfaced wool best known throughout the trade.



(3) Kemp fibres, which are the shortest and thickest fibres, medullated except for a short fine tip, and, when shed naturally, for a portion of their proximal ends, they possess typically a fairly regular wave in one plane only, are extremely brittle and have an "opaque" white appearance.

It is manifest that in the course of the evolution of the Blackfaced breed the primitive coat has been modified to a great extent. It will be advisable briefly to discuss each of the fibre types separately from the point of view of their origin.

(1) Kemp. In the process of evolution the coarser outer coat of kemp of the primitive sheep has undergone no important modification in that its periodic phenomenon of shedding is still in evidence in the Blackfaced breed of to-day. These fibres still maintain their ancestral significance in this respect. They have, however, decreased in number as well as in diameter.

(2) Long hair or Heterotype. A speculative hypothesis may be propounded that these fibres are modifications of the coarser wool fibres which are shed annually. The Heterotype, however, does not shed, but presents a woolly phase at the time of shedding; occasionally a few are shed with the rest of the fleece, while the majority/

majority continue to grow and repeat the hairy phase in the new season's growth.

(3) Wool. These fibres have increased considerably in diameter in the Blackfaced sheep (when comparing them as compared with the wool of the Urial, Ovis vignei, Moufflon, Ovis musimon and Argali, Ovis amnon.

The fleece of the modern Blackface probably originated mainly through a series of modifications of the fine wool of the primitive sheep. Firstly, the fine wool was transformed to a coarser type and is represented by the wool fraction of the present-day Blackfaced fleece; the next stage was a secondary modification of this coarser portion to such an extent that long hairy fibres were obtained; these derivatives of wool fibres practically never shed and the nearest attempt is a fining down in diameter.

Finally, a unique modification of long-hair can be observed in a new type of fibre, intermediate in structure between kemp and long-hair. This type is termed for convenience, "Hybrid Kemp" and will be discussed later on more fully.

The Heterotype fibres, with one portion belonging functionally to the inner coat and the other portion to the outer coat, are characteristic of some animals which are probably closely related to the primitive/

primitive sheep. In the Blackface these phases of changing structure are only recognizable in Winter when all the component types of fibres either shed, or become fined down proximally, giving the fibre two distinct structures.

When comparing a sample of the wool of Urial sheep, Ovis vignei, with that of a Blackface after the long-hair is removed, a marked similarity is noticed between the two. The undercoat of the Ovis vignei which comprises fibres of an intermediate type b, described by Crew and Blyth (4), and the coarser type of wool in the Blackface sample, correspond to the Intermediate (b) in their thickened, medullated, distal portions. (Figs. 1 and 2).

Pease (21) suggests that the Scottish Mountain Blackfaced breed of sheep has originated mainly from the Urial family of Ovis. He gives a table to illustrate this schematically..

Therefore, it can be assumed as in the case of the Merino sheep, Duerden (11), that the diversity of fibres in the Scottish Blackfaced fleece is derived both ontogenetically and phylogenetically from a coat made up of two diverse types of fibres.

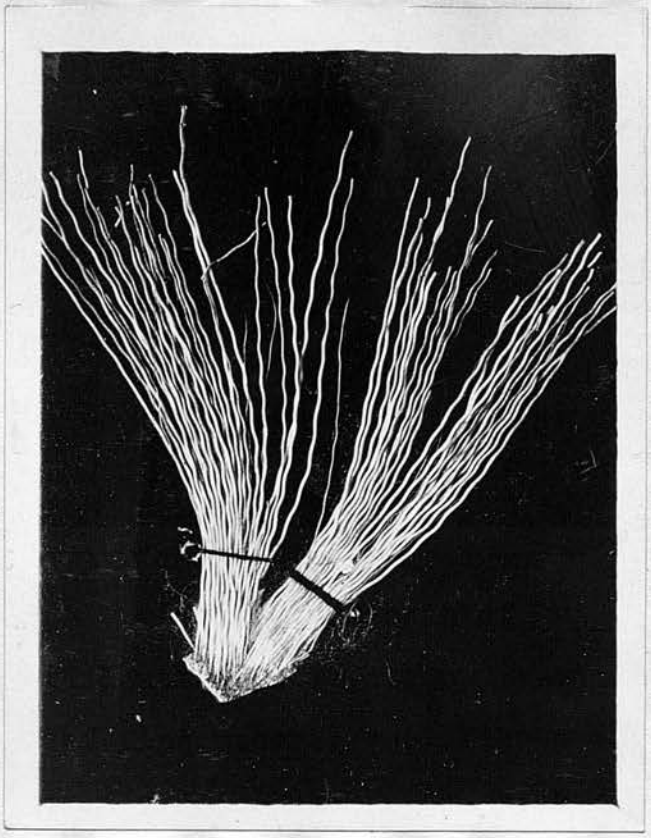


Fig. 1. A portion of the skin of Ovis vignei with the fibres still attached to it; on examination an undercoating of fine, short, wool fibres can be seen near the skin; a smaller number of thick, waved, broken-tipped kemp-like fibres of considerable length forming the outer coat can be easily seen, and a few shorter, finer sharp-tipped intermediate fibres can be seen in the middle of the photograph. These latter are described by Crew and Blyth (4) and are classed as a-type and b-type. (Only a-type are visible in the illustration).

Note the similarity between these intermediate fibres and those in the Blackfaced sample (Fig.2) when compared in each case to the remaining fibres in the sample.

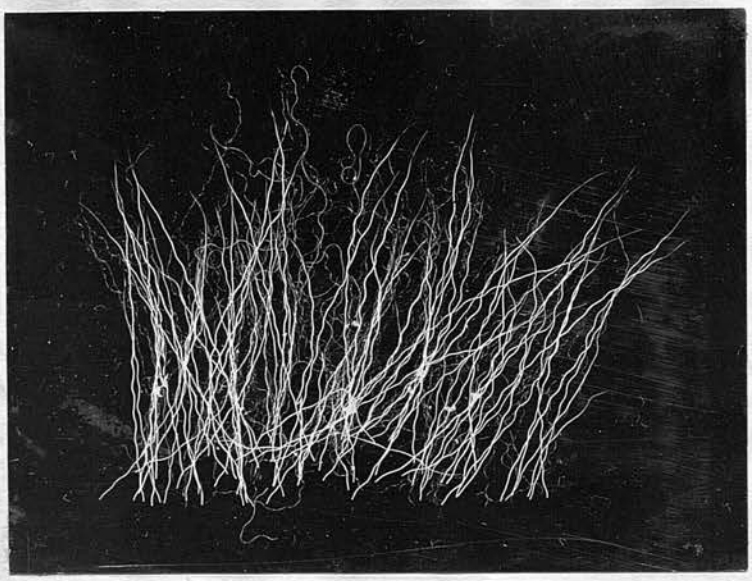


Fig.2. A portion of a Blackfaced staple which has the long-hair and hybrid kemp removed. Three types of fibres are present; fine wool, which corresponds to the fine wool in Fig.1; coarser wool, similar to the intermediate (b) type of the Ovis vignei; and, the long white pointed kemp fibres which are closely related to the long coarse white fibres in the outer coat of the Urial sheep.

General Discussion of the Birth-coat.

In all breeds of sheep the characteristics of the lamb's coat are, within limits, typical for the breed, but in no one instance is the birth-coat composed of the same varieties of fibres as are found in the adult fleece. Certain fibres which are deciduous and others which are immature can always be demonstrated. In most cases the birth-coat approximates to some extent to the type of fleece which is found in the wild sheep of which the Moufflon, Ovis musimon, may be taken as a type, in that it contains varying proportions of strong, coarse, comparatively straight, and usually medullated, fibres, projecting beyond the dense mass of finer fibres which is to be regarded as typical of the adult coat of each of the improved breeds of sheep. That is, in the lamb, there is an anlage of the final adult fleece (viz., a group of fine wool fibres, and a group of long hairy fibres) containing in greater or lesser degree an admixture of fibres derived from the old outer coat of primitive sheep. There is ample evidence that these coarser outer coat fibres are in the lamb completely shed and never replaced by other fibres in those breeds which by selection have been brought to a state of comparative perfection from the point of view of the successful/

successful producer of the higher grades of wool.

In varying degree from this class of sheep a gradual transition can be traced through various breeds back to the primitive type, in which there is not only a large number of coarse fibre types in the birth-coat, but also in the adult coat; these latter being usually called "outer coat fibres". They are not only useless, but highly undesirable from the manufacturers' point of view.

Shedding.

The process of shedding of wool fibres is very significant in the case of sheep, and various stages can be illustrated from complete annual loss of the fleece on the one hand to regular growth during the whole life of the sheep on the other. As instances of these may be mentioned the primitive Shetland breed, which has its entire fleece shed annually, and the Merino, the most improved breed of sheep, in which shedding never occurs during the life of the sheep except under the influence of disease. Duerden (10) states that in this breed the wool fibres grow continuously from a persistent hair germ.

The Scottish Blackface occupies an intermediate position so far as the shedding of its fibres are/

are concerned. The fleece is only partially shed each year. The long outer coat fibres continue to grow during the year, but they exhibit a certain fining down of their thickness and a reduction in growth rate, during that period when the great majority of the fine wool fibres are cast off from their follicles to become felted into a "cot" in the fleece and constitute a certain guide to the owner indicating to him the time to shear.

Just like many other mammals the Scottish Blackface possesses a coat which has a double function in that the outer coat protects the skin from rain and snow and the inner coat serves to conserve body heat. As development proceeds the long outer coat fibres in the lamb's fleece, having increased in length considerably from birth, fall to either side of the middle line of the back forming a long smooth outer coat.

II. PURPOSE OF THE INVESTIGATION.

Only a few investigators, Crew and Blyth (5), Blyth (6), and Duerden (10), have undertaken investigations on the fleece of the Scottish Blackfaced breed of sheep and by none of these workers has any particular attention been paid to the development of the fleece from birth to maturity.

This investigation was carried out in order to determine the periodic changes in the development of the birth-coat of the Scottish Mountain Blackfaced breed of sheep from the age of one week onwards; the experiment began in March-April 1930, eleven lambs being used.

It is exceedingly important to know the stages in the evolution of the fleece from birth to maturity, because if it could be shown that some characteristic or feature in the fleece of the lamb was correlated with a desirable or undesirable character in the adult fleece, a mechanism would be criterion available whereby instead of having to go to the expense of rearing all lambs born to the stage when the characters of the adult fleece are recognisable and then selecting those animals which are to be retained for further breeding, and eliminating through the markets those which are below standard, selection could be/

be made among the lambs. This would be advantageous to sheep breeders from two very important aspects. Firstly, if selection could be practised early, those lambs which should be retained in the flock could be segregated with their mothers and could undergo special methods of rearing calculated to give maximum expression to those genetic characters of which they are potentially capable, while the undesirables could be reared under less extensive and less expensive conditions of management and could be sold much earlier than normal. Secondly, by recognising desirable or undesirable characters as early as possible after the lambs are born, a sheep-owner would be enabled to make his plans for future breeding 6-8 months earlier than otherwise, and could take steps to eliminate or restrict the use of parents which were giving undesirable offspring or could correct them by suitable mating, while those sires (or even dams) which showed a large proportion of desirable types among their offspring could be more extensively used in the next season. Such knowledge is not at present available.

These observations are submitted to indicate the great importance of an accurate knowledge based upon scientific analysis of the progress of the fleece from birth to maturity. The Scottish Mountain Blackface/

Blackfaced breed was utilised for this work because it is one of the breeds in which the birthcoat of the lamb approximates to that of the wild sheep, and undergoes a very pronounced change during growth. Moreover, in this breed it has been found possible to recognise the existence of a far larger number of fibres which are deciduous and succeeded by undesirable kempy fibres, than in other breeds. It is felt that the knowledge acquired by a study of the Blackface will enable a very much more accurate analysis to be made of the fleeces of lambs of other breeds in which the differences in fibre type are less gross and therefore less easily recognisable and demonstrable. From the work in Edinburgh and from parallel work, already in progress by other research workers, using different breeds of sheep, it is quite evident that underlying the progress in development of the fleece from birth to maturity there is a very definite biological law, which, most probably, holds true for all breeds although there may be modifications of this law.

Various other facts concerning the fleece came to light during the course of the experiments. These may be enumerated briefly as follows:

1. The determination of the appearance of each type of fibre at definite time intervals was made.

2. Statistically the periodic ratios of different fibre types to each other from birth onwards were ascertained.

3. Density of fibres per unit area of the skin in relation to live weight was found to be correlated.

III. EXPERIMENTAL PROCEDURE.

On commencing this work it became necessary to devise new methods of approach and attack, since in the Scots Blackfaced breed the evolution of the fleece differs from that of other breeds and had not been studied previously. Consequently, more practical and applied techniques had to be elaborated to secure scientifically accurate samples from the living animal than had been used by other workers.

Weekly samples were taken from a measured area on the right shoulder from each of ten lambs (including a pair that were sampled on the right haunch) and the number of fibres calculated per unit area. When the lambs had reached an age of three months, samples were taken and the observations were carried out at intervals of two weeks instead of weekly. At the approximate age of six months the number of animals was reduced from ten to five.

The individual live weights of the lambs were recorded on each sampling day and from the periodic increase in weight the increase of body surface area was calculated and finally an assumed density figure was obtained.

Triangular/

Triangular Method of Determining Density.

This method was first used by Roberts at this Institute, and has been elaborated further by the staff of the Sheep Section.

Principle. The principle of the method is that of isolating a triangular tuft of wool from the rest of the fleece in such a way that the sides are straight, the angles cleanly defined, and the divisions in the wool are made with as little breaking or tearing of the fibres as is consistent with complete separation of the fibres from each other.

The method depends upon the essential fact that to make a perfectly straight parting in the fleece which shall be of adequate length it is advisable to employ only one dividing agent at a time. The sensory system of the sheep is of such a high degree of sensitivity that the slight cutaneous irritation resulting from the passage across it of any heavy instrument, or of an agent which, used carelessly or roughly, may prick the skin, may readily cause a reflex contraction of the cutaneous muscle, with consequent disturbance of the outlines of the area from which the sample is to be removed. In the method to be described it is believed that the sources of error as outlined are eliminated.

The/

The method is of most use for the long-woolled breeds, where separation of tangled staples of wool is difficult under any conditions and impossible under some. It has been found inadvisable to employ any form of instrument in which the points which must separate the wool are short or thick, for sheep such as the Scottish Mountain Blackfaced breed, and since much of the work in progress at this Institute includes the use of long-woolled breeds, the triangular method has been elaborated primarily for them by Mr. W.C. Miller.

Instruments. The equipment consists of an ordinary steel ruler - preferably graduated in sixteenths of an inch along one edge and having the usual centimentre scale along the opposite edge, a pair of screw dividers, one sharp-pointed steel dissecting needle, one large porcupine quill or knitting-needle, and three pairs of cross-action aural forceps. These latter are not essential, but they facilitate keeping the surrounding wool from the field of operation in the initial stages when the fleece is still comparatively short. A very suitable substitute for these latter instruments is a large clamp with a broad front which is turned upside down to keep the wool parted by its weight. An indelible pencil is most suitable/

suitable for delineating the corners of the triangle, or if the exact area must be permanently marked for future reference, an electric tattooing machine may be used. Rubber bands are a convenience to slip round the isolated tuft of wool, and a series of envelopes serve as handy receptacles for the samples.

Location of Sample. A series of samples were taken from the right shoulder and right haunch respectively and on some individuals the number amounted to thirty-four consecutive samples from the same region. To provide for such a large number it was found necessary to arrange them in definite order on all the animals.

Figure 3 illustrates very clearly the arrangement of the samples on shoulder and britch. It can be explained better by reference to the britch where the circular arrangement of the first series of six triangles is indicated. The position of the following six triangles in the series will be understood by reference to the shoulder diagram, where the triangles are all numbered according to the sequence of taking the samples. The diagram illustrates the left side whereas the samples were taken from the right side. The areas on the shoulder are located an inch or two backwards from the actual point of the shoulder, (bicipital prominence of the humerus) and

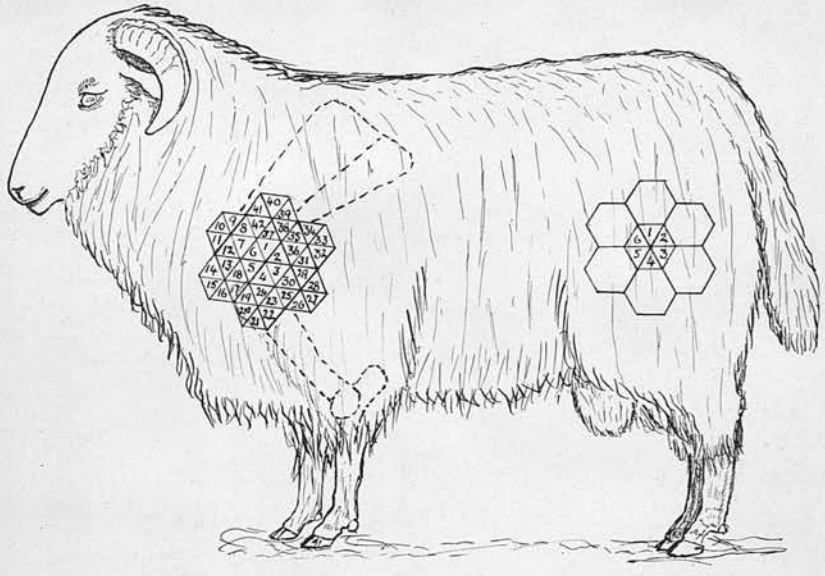


DIAGRAM TO ILLUSTRATE THE ARRANGEMENT OF SAMPLING AREAS ON SHOULDER AND BRITCH.

Fig. 3. A series of triangles is illustrated on the shoulder and britch areas in the diagram. A similar arrangement was adopted for every animal, except, that the shoulder area was placed slightly more posteriorly than is indicated in the diagram.

not strictly according to the illustration. The order of the samples is greatly facilitated by the colouring of every triangle with indelible pencil after the wool is clipped off. This procedure is a great aid in detecting the triangle previously sampled and also it indicates the general trend of the successive areas.

This order of distribution is aimed at as far as possible in practice but one is confronted with the problem of irregular growth of the skin area, which has a slight influence on the areaisation of the triangles.

The smallest-sized triangles used in these series of periodic samples ranges from 1.5 to 2.0 cms. length on each of the three sides and it is suggested that triangles smaller than that should not be used.

Method of Securing Sheep and Outlining the Triangles.

The sheep is secured in the appropriate position, on the table for preference, and should under no circumstances be allowed to move when the measurements of the sides of the triangle are taken. The area from which the sample is to be taken is determined by the site of the previous triangle coloured with indelible pencil and arranged in circular order according to the diagram.

To/

To get the best results an assistant should be employed to keep the animal in position by holding its fore and hind feet. Its head should be kept well down on the table. With these precautions and gentle handling the animals soon become accustomed to the process of sampling and seldom offer resistance.

A large sharp-pointed porcupine quill is inserted horizontally into the fleece until it meets the skin and is then guided along its track with its point pressed lightly but firmly on the surface of the skin in such a manner that a straight course is followed without pricking or irritating the skin. It will be found that the line through the wool will not be straight unless the quill has parted the wool for a distance of an inch or more. After the quill is pressed sufficiently far forward and kept in position on the skin, a dissecting needle is run along its upper surface to complete the separation of the wool which has been commenced by the passage of the quill through the fleece.

With the quill in one hand and the knitting needle in the other the two walls of wool are carefully parted, starting from the deeper part of the fleece and passing to the tips of the staples until finally the distal ends of the separated wool are firmly pressed over to either side. A cross-limbed forceps or/

or a large clamp is slipped on to that wall which is to lie outside the triangle and separated from it, (see Fig. 5) while the inner wall is released to assume its natural position. This serves to preserve the division in the wool already made and prevent entanglement of the fibres which constitute the sample by those outside it.

If the fleece is long and the fibres somewhat entangled the division of the two walls is best effected by raising the quill $\frac{1}{2}$" to 1 inch from the skin surface and the wool divided either with the fingers or by another quill. Care must be exercised not to stretch the skin by having the outside walls of fibres too tightly stretched since it would distort the construction of the succeeding line to be made in the fleece.

The first line being considerably more than the requisite length, the second quill is inserted into the fleece in the same manner an inch or more behind the line of the first one, and in such a direction that it will form an angle of about 60° with it. (See Fig. 4). The reason for constructing longer lines than necessary is that the parting is more correct and easier and there is the additional advantage of better shaped corners of the triangle.

Following the same procedure as is described/

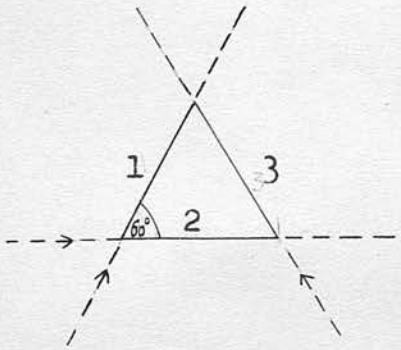


Fig.4. Diagram to illustrate the insertion of each quill at a point about one inch behind the outline of the proposed triangle.

The arrows at the commencement of the dotted lines indicate the points at which the quills enter the fleece.

Fig. 5. Photograph to illustrate the stage at which the first quill has been inserted and the wool divided back; the second quill can be seen in position, but the second side of the triangle has not been demarcated. One pair of cross-limbed forceps has been affixed.

Note: The actual skin line of the part in the fleece made by the first quill cannot be seen because of the natural spring of the wool, which could not be made to remain back out of the line of the camera while the exposure was made.

described previously a second side of the triangle is demarcated, and the wool to the outside of it secured out of the way by a second pair of cross-limbed forceps. In the same way the third side is prepared and the wool outside it also secured by the third pair of forceps. (When the fleece reaches maturity these forceps are unnecessary and it is better to do without them).

It is sometimes necessary to re-construct the sides and angles to get the best results; this is very easily carried out with a little practice. Each point must not be allowed to rise from the skin level by even a fraction of an inch, or a false and irregular line will result. The success of the results obtained depends upon the careful observance of this rule.

A triangular area of wool is now isolated (see Fig. 6). Its angles are approximately of 60° and it is therefore practically equilateral in outline.

Removal of the Wool Sample from the Skin. The primary object is to clip the wool as close to the skin as possible. A pair of strong sharp steel scissors angled on the flat with the blades one and a half inches in length, tapering to a fine point in front and comparatively narrow at the back, is satisfactory.

The sample is clipped off a few fibres at a time/

Fig. 6 shows the triangle demarcated from the surrounding wool. The quills are laid to the outside of the divisions they have made in the fleece. The cross-limbed forceps are in position holding back the outer walls of wool, and a rubber band has been slipped round the isolated triangle of wool which is to constitute the sample.

time as close to the skin as possible by pulling the fibres tightly against the blades of the scissors in which way a double-cut of the same fibres is prevented. It is very necessary to avoid double-cutting the wool since a large number of fragments of fibres present at the proximal end of the staple interfere with subsequent analysis. It is convenient for extreme accuracy to mark with an indelible pencil the exact point of each angle of the triangle before removing the sample so that the actual angles can be better observed. The three sides, between these dotted points, are accordingly measured by the dividers after the sample has been removed (see Fig. 7), and it requires care to ensure that the legs of the animal are stationary during this part of the procedure since it would otherwise alter the measurements and therefore the area of the triangle. During measurement it is important that the surrounding skin should not be stretched by endeavouring to expose the dots to better view. Sometimes it is necessary to repeat the measurements if the animal struggles or the skin is stretched.

During this investigation the lengths of each of the three sides of the triangle were immediately noted on the envelope which also carries the number of the sheep and the date of sampling, together with/

Fig. 7. The triangular tuft of wool has been clip-:ped off and is lying to the right side of the photograph. The triangle of skin is exposed. The dots in each corner cannot well be seen in the photograph since it was not convenient to enlarge them to such a size as would render them visible in the print.

[Note: Débris in the wool should not be mistaken for dots of ink.]

with other particulars of live weight and birth-coat appearances. The common practice was to record the live weights of all the animals before the sampling started. This avoided a loss of weight while other animals were awaiting sampling, which might otherwise have been the case.

If the sides of the triangle are denoted by AB, BC and CA; and if S = half the sum of the sides, the area of the triangle is calculated mathematically from the following formula:-

$$\text{Area} = \sqrt{S(S - AB)(S - BC)(S - CA)}$$

It is suggested for convenience in measuring the sides of the triangle that the metric system is the more satisfactory. The various measurements of the triangles with their calculated areas were kept for reference and in many instances the triangles corresponded to one another in their individual measurements.

Classifying. The samples were analysed in a way similar to the method adopted by Darling (8). They were held in the left hand while the right drew out from the distal end of the staple the longest fibres first, in numbers of ten to twenty, followed by the shorter ones. Every time the fibres were drawn out they were grouped into their appropriate classes and usually laid aside *in toto* on a black velvet covered board.

The different types were found to vary in length which facilitated the grouping to a great extent. The longer heterotype fibres extended to the distal end of the sample while the shorter wool fibres only reached as far as the middle portion of the sample. Having grouped the fibres satisfactorily they were counted to determine the density per square centimetre and the percentages of different fibre types in each area.

Counting. The counting was done by a Hand Tally, which has a quick set back and which records every fifty fibres as one unit.

By analysing the sample twice and by the aid of the instrument, personal error was to a great extent eliminated.

The next step was to calculate the density, the numbers and percentages of the different fibre types per sq. cm. The data were tabulated in the manner shown on page 34. In this way comparison of the different fibre types was facilitated; particulars of size of sampling triangle, live weight of the sheep date of sampling, etc., being recorded on the one table. Additional notes of a general nature on the character of the birth-coat at the different stages are included.

Mounting/

Lamb No. 151 ♀;				Right Shoulder;										Born 8/3/30.
Date of Sampling.	Area of Triangle. (sq.cms.)	Order of Sample.	Age at Sampling. (Days.)	Live-Weight at Sampling.		Gain in Live-Weight.		No. of Kemp Fibres.	%age of Kemp Fibres.	No. of Het."B" Fibres.	%age of Het."B" Fibres.	No. of Het."A" Fibres.	%age of Het."A" Fibres.	No. of Wool Fibres.	%age of Wool Fibres.
				lbs.	ozs.	lbs.	ozs.								
17/3/30	1.5	1st	9	7	10	-	-	-	-	519	25.8	544	27.0	945	47.2
24/3/30	1.2	2nd	16	9	12	2	2	-	-	320	20.3	417	26.5	834	53.2

The above table was used for recording the data obtained on each sampling day.

Mounting. The fibres were mounted on dark grey matt paper in their respective groups, spaced at convenient distances for comparison and appropriately labelled. (see Figs. 8-15). Each mounting bears the number and age of the animal, and serial number of the sample. By this means the different series could be kept for easy reference in a folder. This system of preserving the fibres proved very satisfactory and required comparatively little time, labour or expense.

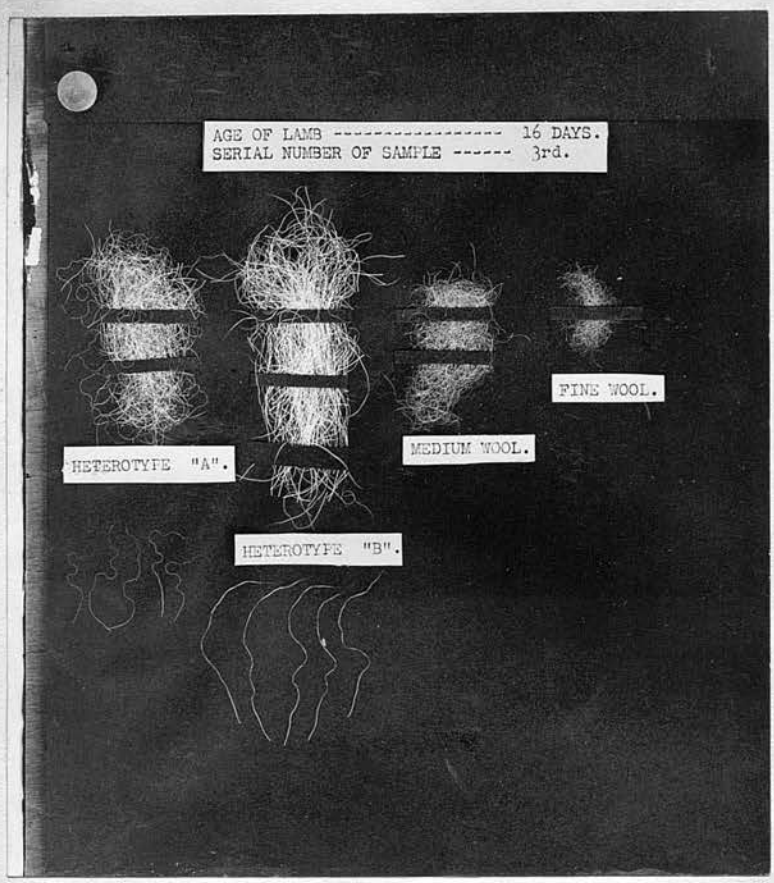


Fig. 8. A few fibres belonging to heterotype "A" and heterotype "B" groups have been separated from their respective classes. The macroscopic structure of these two classes of fibres is very important, since by their different lengths, different distal tips, uniformity and by the class of these, they can be readily differentiated.

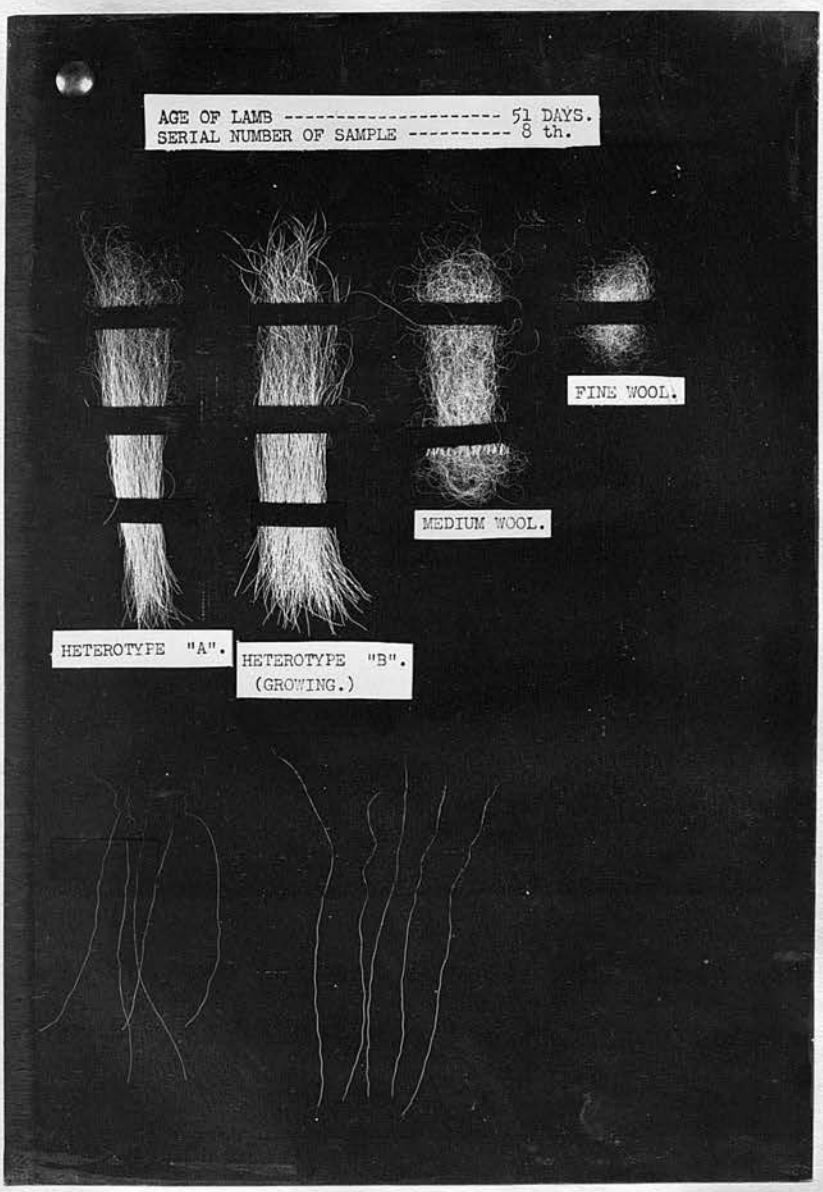


Fig.9. The two longest classes of fibres were again separated to illustrate the relative increase in length of the heterotype "A" class in relation to heterotype "B".

Medium wool and fine wool groups are still increasing in length and number.

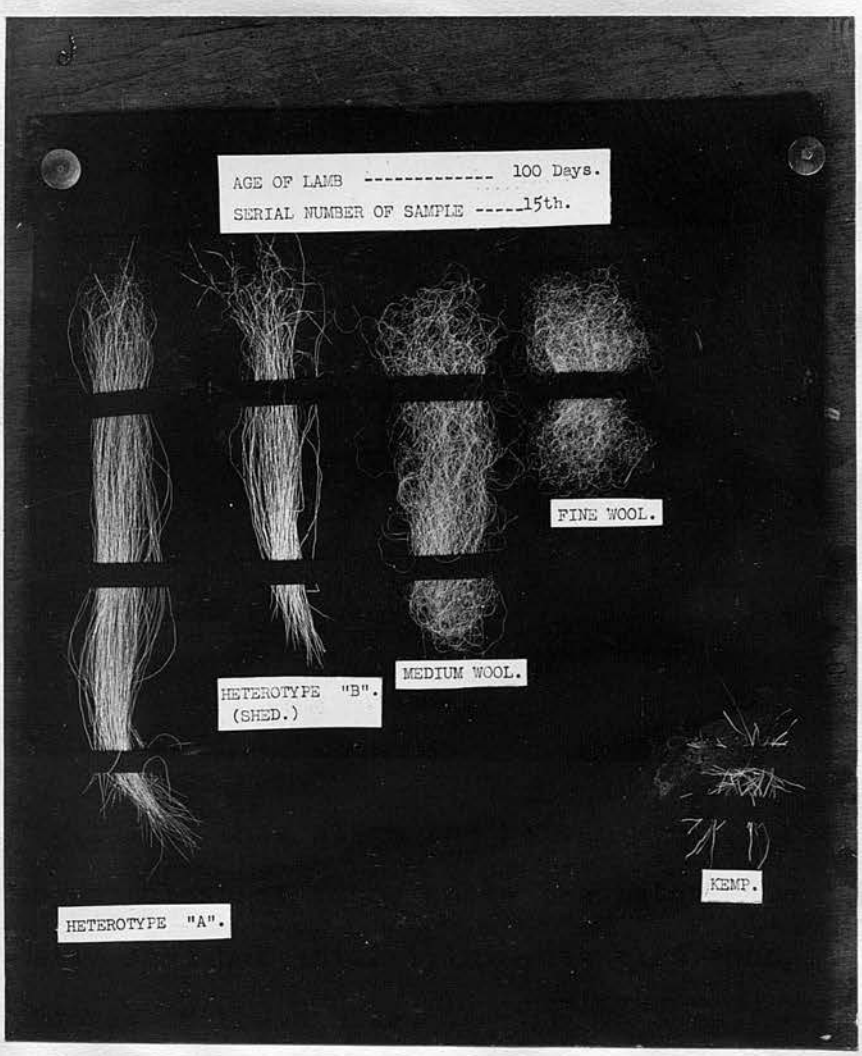


Fig.10. At this stage the heterotype "A" represents the longest class of fibre while the heterotype "B" are mostly shed but still lying entangled among the other fibres of the staple.

Tips of kemp fibres immediately follow the shed fibres and correspond to them in time, number and length.

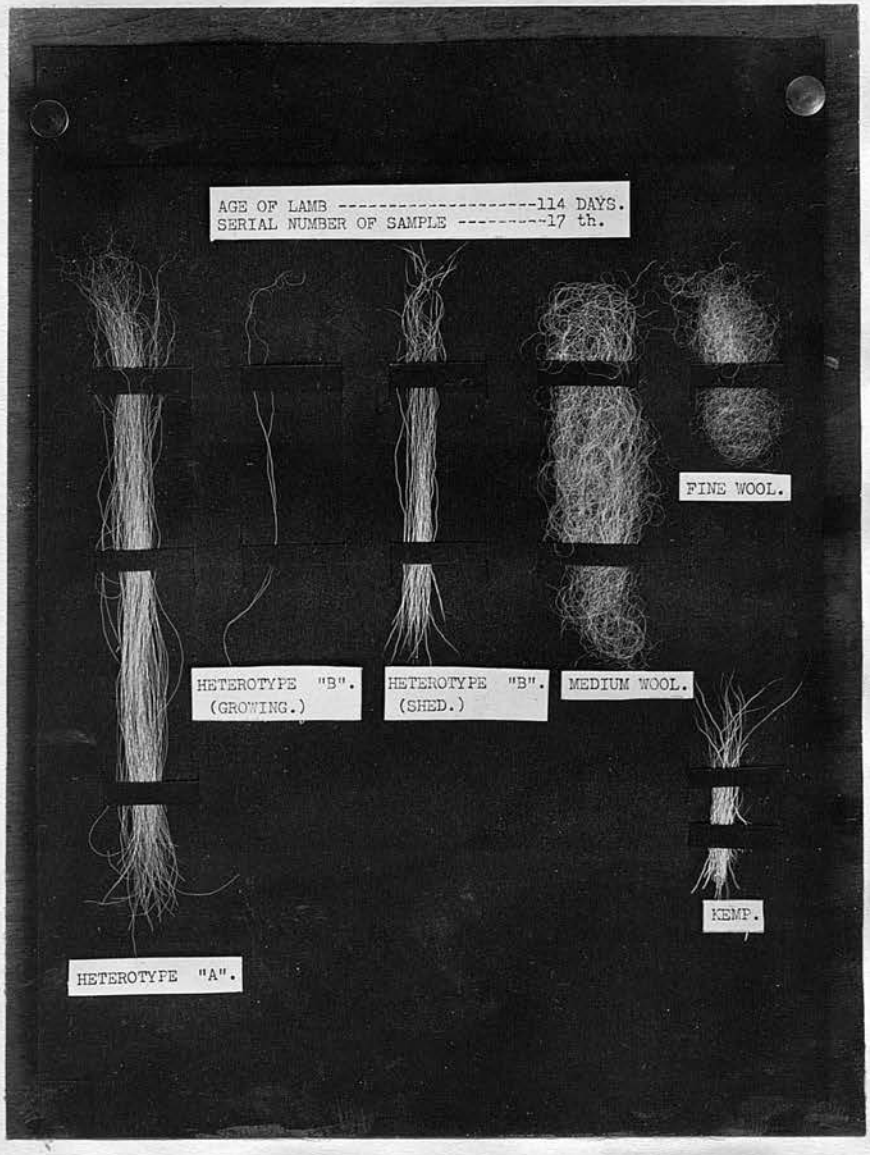


Fig.11. The shed heterotype "B" fibres are decreasing in number while the kemp increases in both number and length.

Medium wool and fine wool are more readily distinguishable at this stage.

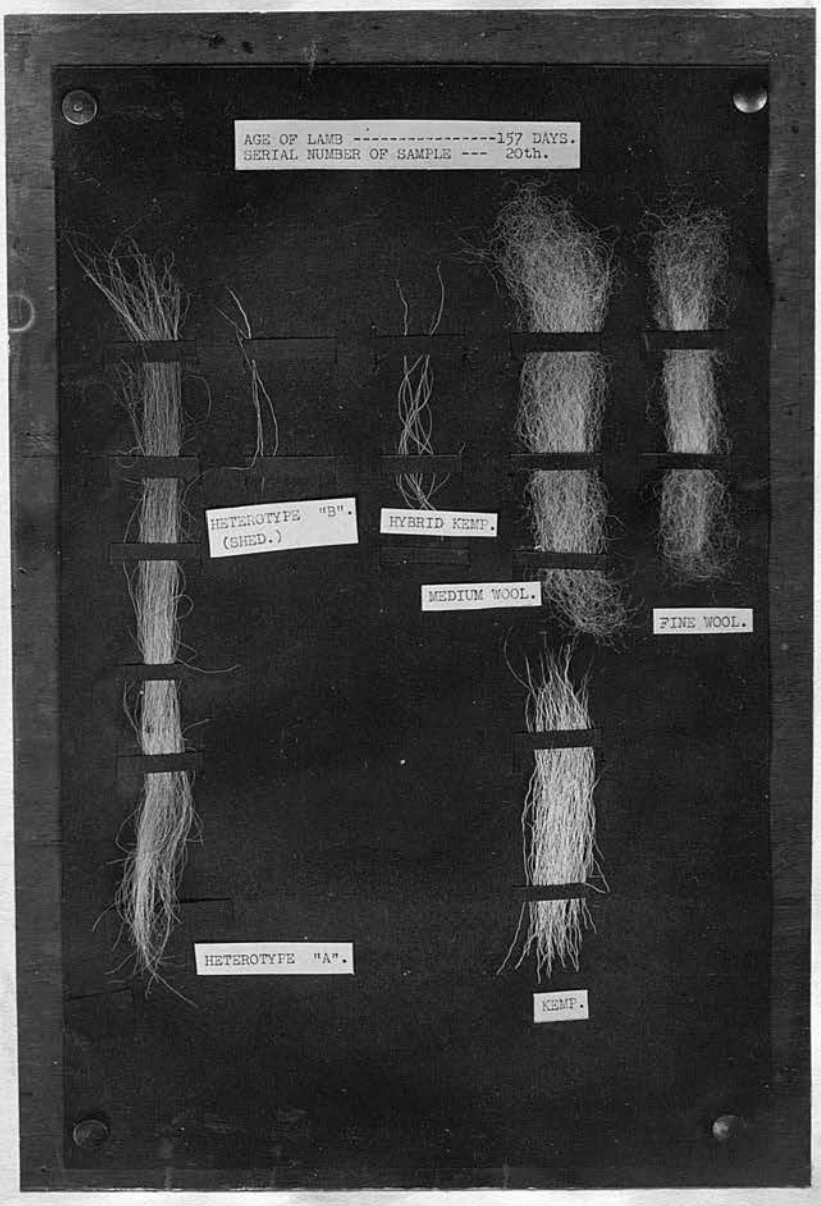


Fig.12. The different fibre types show a further stage of progress in development.

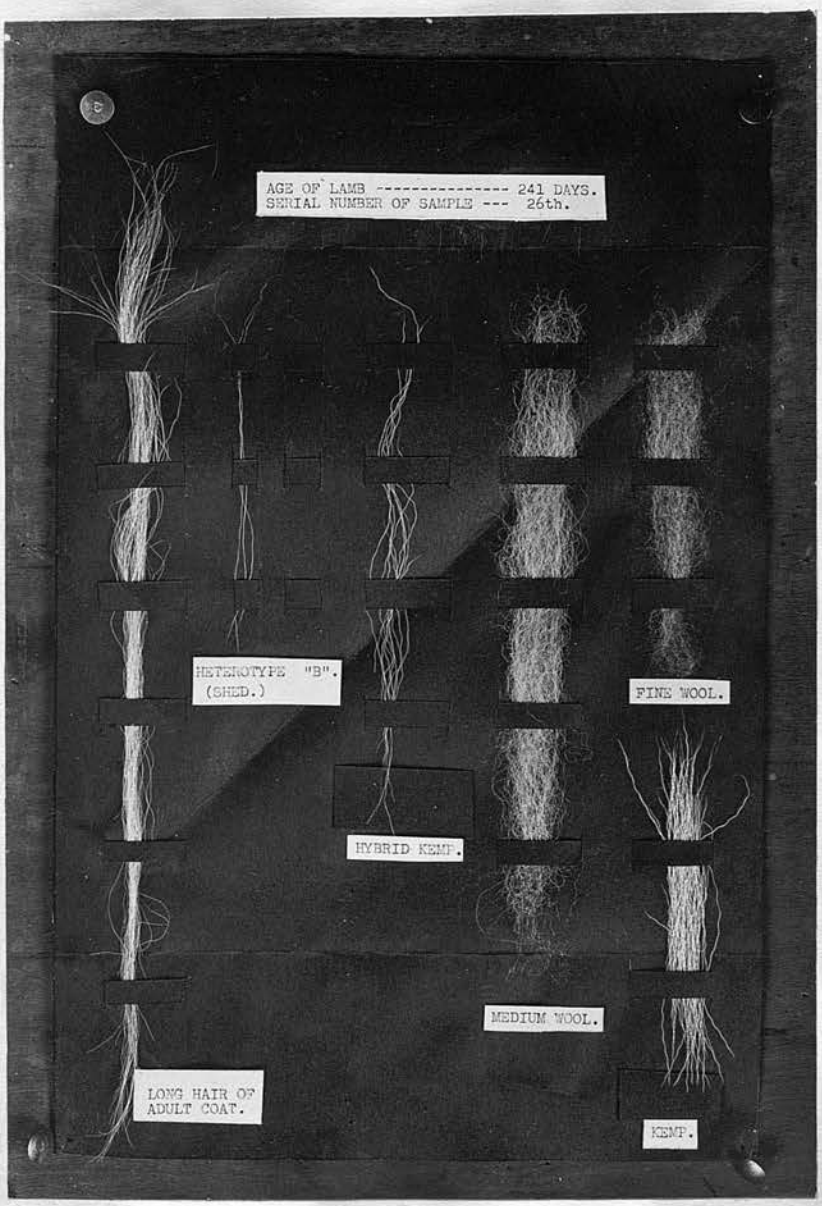


Fig.13. The longest type of fibres are termed long-hair at this stage as represented in the adult coat. Medium wool and fine wool considerably long.

Two types of kemp fibres recognisable as the longer hybrid kemp class and shorter true kemp class can be determined.

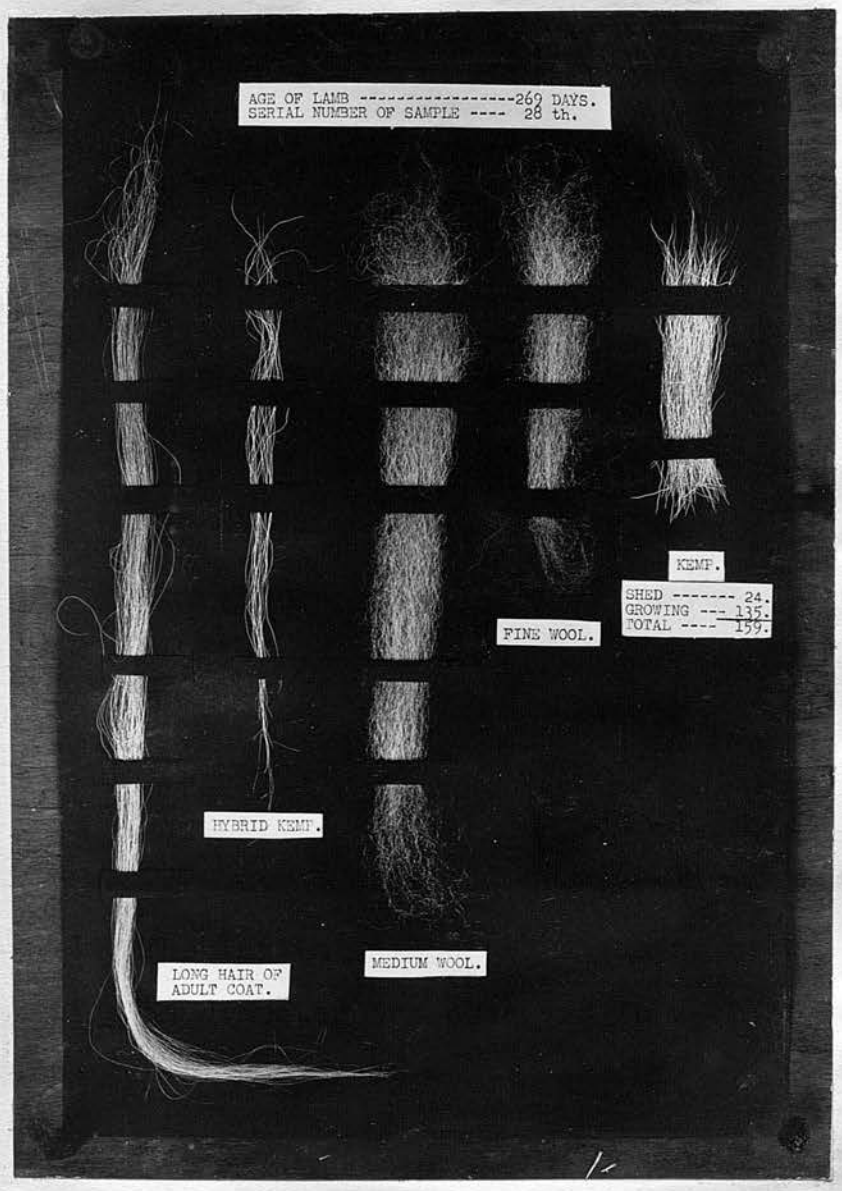


Fig. 14. The initial stages of shedding of kemp and reduction in diameter are observed in each of the various types of fibres.

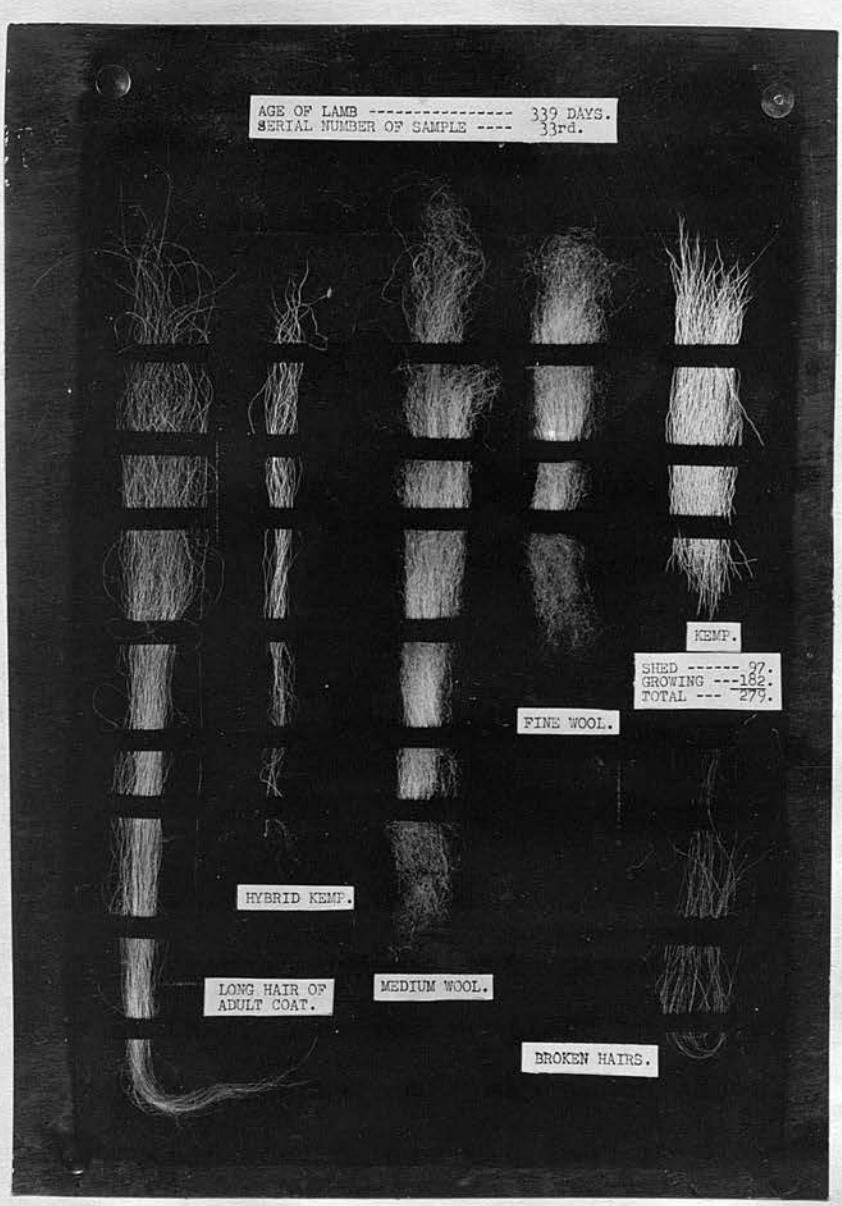


Fig.15. A marked reduction in diameter of the long-hairs at their proximal portions is to be noticed. Hybrid kemps become finer synchronously, and also both type of wool fibres decrease in diameter. Kemp has begun to shed to a greater extent. Broken hairs represent the distal deterioration of the long-hair fibres owing to mechanical influence, wear and tear, etc.

IV. FIBRE DEVELOPMENT.

According to Dry (9) the developmental history of the fibres of the mouse can be divided into three phases as follows:-

(1) The Anagen Phase; the longest part of the growing period, lasting from the initiation of growth in utero up to the Catagen phase in the post natal period;

(2) The Catagen Phase; during which the root decreases in size;

and (3) The Telogen Phase; when the fibre has ceased to grow, the medulla-free base then terminates in a little club which is characteristic of every deciduous fibre.

These developmental phases are observed in the fibre types of the birth-coat of the Blackfaced lamb, the Anagen commencing to function in utero.

The first stage of development, that of the Anagen, is when the fibre is developing from its follicle in the foetal stages and is gradually increasing in diameter. This stage occurs after birth in the case of some of the wool fibres. The second or Catagen stage of development entirely takes place after birth and is characterised by a fining down of fibre structure. This stage is an indication of physiological changes in the skin and is a forerunner of the last/

last stage, the Telogen, in which the fibres are shed and terminate in little clubs at their proximal ends.

The history of the different phases of each fibre type in the sheep is discussed later. There are various important differences.

Heterotype "A".

The term Heterotype "A" is assigned to that type of fibre which has variations in structure in different areas. In any typical Heterotype "A" fibre there can be seen those features which are regarded as characteristic of hair, of wool, and of intermediate fibres.

Crew and Blyth (4) have grouped the birth-coat fibres of the Blackface into three types and termed the first two Heterotypes and the last Wool.

At birth Heterotype "A" ranges second on the length scale but increases in length very rapidly to occupy the top of the scale, from approximately two and a half months onwards. It can be differentiated with the greatest of ease from the other groups. The best and most satisfactory character to distinguish it by is the fine, crimpy and woolly distal end which shows up distinctly. This tip is quite a specific character. (see Figs. 8 and 9). On separation of these/

these fibres from a sample taken at birth their tips appear very fine, crimpy and tapering. These tips gradually increase in diameter until in the middle of the shaft the fibres show an opaque, white, rod-like medulla similar to that of hair. This portion of the fibre is straight for a considerable period and only assumes an irregular waviness when the fibre fines down in the latter part of the Winter months (see Fig. 15),

proximally

The cause of the fining down of the fibres in their proximal portions during Winter months has not yet been definitely determined but it is probably due to more than one factor.

It may be assumed that this particular characteristic is inherited from its prototypes which shed their coats annually and is probably a modification brought about through domestication for many generations. The coat of the mammal is influenced by various environmental conditions, such as those associated with climate, elevation, the state of nutrition and health; and the care and management of the animal. Duerden (11) and Keller (16).

Northcroft (19) discovered that the hairy fibres in the Romney Marsh breed at birth have a fine apical end about half an inch long. About the time of birth they thicken and in the coarse of a few weeks or/

or months the fine apical end is usually broken off.

By the time the Blackfaced lamb has reached the age of six months approximately, the Heterotype "A" fibres gradually deteriorate distally in having their fine woolly crimpy ends broken off bit by bit, like the Romney, with the subsequent appearance of a uniform structure for the greatest part of its length. At this stage, the fibre being uniform in diameter with an opaque whiteness, structurally resembles hair in the more generally accepted sense of the word. Accordingly, an alteration is made in the nomenclature of this type of fibre when the term "Long-hair" replaces its initial predecessor "Heterotype "A".

In a few cases there is an apparent overlapping between the Heterotype "A" and Heterotype "B" groups where the distal ends display characters of an intermediate nature. In such cases the length and diameter standards of distinction were employed to effect separation into the two classes. The Heterotype "B" fibres at one particular time are longer and at another are shorter than the Heterotype "A" fibres. In addition, they exhibit characteristic features in possessing an enlarged diameter distally and proximally, with a fluctuation along the shaft between these extremities. These features enabled standards of distinction to be determined with accuracy.

Another/

Another point worth stressing is that when confusion arises it is advisable to compare the features of the different groups on their own basis and then test the doubtful fibre with the two types nearest related in structure, in order to verify by experiment to which group it belongs.

At birth Heterotype "A" fibres are shorter than the Heterotype "B" group and are then in no way responsible for the characteristic appearance of the birth-coat. The curl seen on the surface of the fleece of the newly-born lamb owes its characters entirely to the arrangement of the Heterotype "B" class of fibres. When these latter fibres start shedding the spiral appearance of the birth-coat is then determined by the longest remaining group, the Heterotype "A". These latter fibres deteriorate distally as the length and age increases in that their fine tips get broken by the natural wear and tear to which the surface of the fleece is exposed with the result that the secondary spiral of the juvenile-coat is lost.

The fibres belonging to the Heterotype "A" group are produced by those follicles in the skin which are least liable to changes. It is well established that these follicles are never inactive and attain their highest activity in summer, during which/

time nutritional and environmental conditions are most favourable. During Winter, when the conditions for feeding and environment are adverse, follicular activity correspondingly diminishes and consequently a gradual fining down of the proximal portions of the fibres results which is in accordance with the transmission of the metabolic gradient from the one stage to the other.

According to Salaman (25) there is in the rabbit insufficient evidence to decide whether the highly variable shape of the individual fibre throughout its length is controlled entirely by the follicle or whether it is partly dependant on changes outside it. But this latter suggestion is inconsistent with the view that wool is an inert and virtually dead structure extruded from the follicle and up to date there does not seem to be any adequate evidence on which to challenge the widely held opinion that the characterisation of the wool fibre is determined by the follicle itself. Several of the Heterotype "A" fibres show, at a fairly early date while the body weight is still increasing rapidly, a marked and distinct proximal fining down although the adjacent follicles have not produced any such abnormality. No satisfactory physiological explanation can account for these differences; particularly when the live weight

may/

may have increased to the extent of four pounds in a fortnight. Moreover, it is incredible that a setback of a few days might produce such a profound defect.

The so-called Anagen phase, Dry (9), starts entirely in utero on different parts in the foetal skin. In the post-natal period the follicles deviate from the Anagen towards the Catagen phase, and the reverse is also true, whenever induced by other factors to do so.

The Catagen phase or fining down is best observed in thick medullated fibres and especially in the Heterotype "A" fibres, where, through the loss of the medulla and the absence of air inclusions, the opaque white appearance of the shaft of the fibre is lost.

The occurrence of this Catagen phase appears to depend upon climatic and nutritional conditions. In Blackfaced sheep not exposed to unduly severe weather on low ground pastures it occurs and is quite recognisable, but in those exposed to severe weather and at the same time restricted in feeding, i.e., typical mountain sheep, it is even more pronounced. On the other hand, in young sheep, (particularly Showyard sheep and high quality breeding rams) which are wintered in sheds and given an abundance of good food, it is often difficult and sometimes impossible to/

to recognise it at all. It is here suggested that it is possible in most breeds of sheep to demonstrate a similar catagenic condition by a careful examination of the few thick medullated fibres which, in practically all breeds, can be found in the region of the britch.

On examining very young animals and embryos it is found that the longer fibres, like Heterotype "A" and Heterotype "B", are developed earlier than the shorter wool fibres, the follicles of the former being deeper in the skin than are the wool follicles. Barker (2) suggests that there is some relationship between thickness of fibre and depth of growth from the skin. The Heterotype "A" type of follicle originates at an early stage in the embryo and it seems most probable that no more of its kind are developed after birth. These follicles produce fibres of nearly equal growth rate, and any which only became active some time after birth would result in an irregularity in the lengths of the fibres of this class, which, however, is not the case.

Only in very few instances is a small proportion of these fibres shed during the development of the birth-coat; the follicles gradually pass into the Telogen phase only in extreme old age.

Heterotype "A" follicles in general never cease/

cease to function even under adverse conditions, and the only decreased activity they show is shortly prior to the shedding of other fibres. They resume their normal physiological functions to the full in Summer. The same follicle is therefore able to produce two entirely different fibre structures. It has the capacity to adjust itself to its fluctuating supply of nourishment, which is determined by varying environmental influences (e.g., climate, altitude, herbage, etc.) upon the physiological constitution of the body.

These fibres serve a very profitable purpose both to the sheep and to the breeder. They retain the entire fleece on the body prior to shearing when the majority of the fibres of other types are detached from the skin, and in this way they afford the chief means of security to the breeder for his following clip. To the sheep itself they constitute a means whereby the growth of wool may respond to, and harmonise with the supply of nourishment available and with the fluctuating environmental conditions in perfect adjustment. They help to maintain the balance between heat production and loss on the exterior surface of the body, during the extremes of Summer and Winter temperatures. Therefore the increased activity in Summer after clipping which produces/

produces a thicker fibre than in Winter, when weather conditions are more severe and food less available, naturally follows. With the fining down of the fibres in Winter more follicles of the fine wool type are brought into action in ratio to the decreased activity of the Heterotype "A" class. This seems to maintain the necessary body temperature under adverse conditions of climate and available nourishment.

Heterotype "B".

To this type the distinguishing term Heterotype "B" is assigned. These fibres range first on the length scale at birth. As development of these fibres proceeds, they do not show a rate of increase in length equal to that of the Heterotype "A" class - which rapidly become the longest fibres in the juvenile coat. Just prior to two and one half months the follicles of the Heterotype "B" fibres exhibit a decreased follicular activity which is suggestive of the approaching phenomenon of shedding.

A characteristic Heterotype "B" fibre is distinguished by its unique and peculiar sickle-shaped tip, composed of a coarse and opaque white structure, which gradually merges into a fine and less opaque one, while the original structure is reproduced/

reproduced in the rest of the fibre and extends fairly close to the root where a gradual fining down is effected constituting a Catagen phase, and finally showing a complete shedding, - the Telogen phase (Figs. 8, 9 and 11).

In a few instances these fibres are not shed in toto as is usual but continue to grow and for the purpose of this description are classified under the category of "Long-hair", after the age of several months. This phenomenon is very striking and important on the grounds that the kemp probability factor (which is discussed later) is less than when these fibres are all shed and replaced.

The relative proportion of Heterotype "B" at birth indicates the amount of kemp in the ultimate adult coat to a certain extent. The shedding is very significant from about two months onwards.

The fibre structure varies in accordance with the type of the birth-coat. In a strong, straight lamb's coat more coarse strong Heterotype "B" fibres are found. There they range from one extreme, the coarsest typical Heterotype "B" fibre, to the other, so-called "Intermediate" fibre which falls intermediate in structure between Heterotypes "A" and "B". This intermediate type only occurs to any extent in the straight coat and is seldom found in the soft curly coats where the distinguishing features between Heterotypes "A" and "B" are very marked.

Heterotype "B" fibres are entirely responsible for the formation of the primary curl at birth on account of their lengths and their curved tips. As age increases the length of these "B" fibres diminishes relatively, with the result that the secondary curl is produced by the longest fibres, viz., Heterotype "A".

The Anagen phase of these fibres starts in the foetal stage and continues for some considerable time after birth, growth being for the most part very rapid. The function of the follicle, which ceases or undergoes a decreased activity in the Catagen and Telogen phases is renewed after the "B" fibre has shed and a new kemp fibre is subsequently produced. Dry (9) states that Segall quotes Garcia as saying that in Man there is no sign in a follicle to indicate that one hair has been substituted for another. As the result of my observations it can be confidently stated that this does not apply to the sheep. The different phases are repeated again in the same follicle but to produce a different type of fibre.

These follicles are periodic in activity and are closely harmonised with the physiological mechanism of the body in that they respond to such various factors as nurture, environment, constitution and age of the sheep. They are so adapted to utilise the store/

store of nourishment most economically in providing a dual purpose coat which fits in with the Summer and Winter conditions remarkably well, especially during the first year of life. On the whole they are inactive in Winter and afford more skin space and nourishment to other follicles which are able to satisfy the biological and physiological requirements of the body better than themselves.

In Summer they fulfil a most active part while a proportion of the wool follicles are not operating. This potentiality of the follicle has undoubtedly been inherited by the modern Blackfaced breed from its ancestral prototypes. They correspond very closely in function of time to the coarse hair follicles of the wild sheep but during the course of evolution have modified their functions to produce birth-coat fibres previous to the development of kemp.

The presence of large numbers of Heterotype "B" fibres is highly undesirable and it behoves the breeder to select animals which have this periodic function transformed into a continuous one, that is the ultimate production of long hair.

The fact that in those lambs which produce most kemp when adult the number of typical shedding Heterotype "B" fibres is greatest, and that in those in which there is a larger proportion of intermediate fibres/

fibres less kemp is ultimately developed, is an important indication of the different degree of evolution reached by different individuals of the breed.

Wool

An attempt is made to analyse the fibres of the wool fraction of each sample into two groups as far as possible; they are termed Medium Wool and Fine Wool.

(a) Medium Wool. The medium wool fibres commence to grow as fine, non-medullated, crimpy fibres and are gradually transformed into coarser, finely-medullated structures. During Winter their shafts undergo a decrease in diameter, when their medulla disappear and they exhibit a Catagen phase to be shed in the "susceptible" period in Spring. Roberts (23) pointed out that there is a seasonal "susceptible period" in the life of the animal during which time a cotting of the fleece generally occurs. This is preceded by a Telogen phase associated with the "rise " of the wool, which is looked upon by the practical sheep-owner as indicating the time for shedding.

Each medium wool fibre comprises two distinct structures, pertaining to both hair and wool (Figs. 14 and 15).

The/

The Medium type in the Blackface is very similar to the Intermediate (b) type of fibre in the Ovis vignei and has much in common with it.

It is not always possible satisfactorily to distinguish the two classes of wool from one another, since a considerable amount of overlapping is encountered in the early stages of the development of the coat. The medium wool corresponds to the "wool-hair" occasionally found in improved Merino sheep and readily found in certain other breeds like the Romney Marsh and Cheviot. It is quite different from the general term long-hair as applied to Blackfaced sheep; to use the term wool-hair for long-hair would be incorrect. The existence of graded differences between fine wool, medium wool, wool-hair (called also "gare-fibres"), and long-hair lends support to the evidence that the medium wool is a modification of the long-hair and that the improved Merino has been carried a stage further in the evolution of its fleece than have other breeds.

The Catagen phase of both long-hair and medium wool happens approximately at the same time in Spring when their proximal ends are similar in many respects. Here, however, the similarity between the two types ceases; each deviates in that the medium wool is shed and the long-hair recommences its previously thickened type of growth.

These/

These medium fibres, being shorter than the longer growing hairy fibres, have no significant influence on the external appearance of the coat. In certain birth-coats, however, they are of some importance since they are mainly responsible for the phenomenon of the "Undercoat", which will be discussed later.

On account of the extreme irregularity in length of this type the suggestion is made that some of the fibres start their Anagen phase in utero and others only commence sometime after birth. Tänzer (15) maintains that new wool follicles occasionally develop in the Karakul and Electoral sheep even when they are adult. There is no doubt that the Anagen phase of the medium wool fibre starts at a later stage of uterine life than does the longer heterotype fibre. For a considerable time after birth new follicles develop to produce medium wool and fine wool, and generally it is the earlier developing follicles that give rise to medium wool whereas the later ones yield fine wool. This is purely a tentative theory since the fibre that develops at an early stage is subjected to Summer conditions which tend to coarsen it. Those, which develop at such a stage that they are not influenced by the Summer conditions, will produce fine wool.

In/

In Winter the fibres fine down proximally in the Catagen phase and reach the Telogen phase approximately in Spring. The follicles remain inactive for some weeks at least in Summer.

(b) Fine Wool. As the coat reaches maturity fine wool fibres are more likely to develop. Length, absence of medulla, and uniformity of diameter are the chief characters of fine wool. These fibres are of great importance when the wool is used for commercial purposes, since they are chiefly responsible for producing high spinning qualities of yarn, having a high count.

The physiological constitution of the follicles is such that they may, and usually do, produce fine wool, but are also subjected to considerable external and internal influences at any time of growth which may result in a distinct thickening, and it is quite probable that the medium wool is only a modification of the fine wool.

In nearly every instance the Anagen phase starts some time after birth when the external and internal influences are less felt. The fibre is transmuted gradually into the Catagen and Telogen phases in accordance with the physiology of its growth and in accordance with the behaviour with other types of fibre.

The time of the season in which a lamb is born will most probably affect the numerical proportion of fine and medium wool. The later birth takes place the less opportunity is there in the adult fleece for the medium to predominate over the fine wool and vice versa.

The fine wool follicles remain comparatively inactive in the Summer months, in a similar way to those of the medium fibres.

The fibres contribute nothing to the appearance of the birth-coat but serve the purpose of giving bulk to the proximal portion of the staple along with the medium wool, which consequently endows the fleece with better powers of body heat, conservation and protection.

General Comparisons of the Development of the Various Fibre Groups.

The time stages of development in neighbouring follicles on the shoulder area are correlated with one another. It is possible to determine fairly accurately the order of commencement of the Anagen phase, the Catagen phase, and the Telogen phase of any particular fibre generation.

In comparing different parts of the skin (e.g., shoulder/

shoulder and britch) with one another significant differences in the developmental stages are discovered. The transition from one phase to the next may be gradual or rapid, and adjacent follicles may vary considerably in this respect. The series of phases is completely repeated annually in the wool and kemp follicles, but in the case of hair follicles only the first two stages are seen. The follicles producing the short true hair on the face and legs are as a rule not subjected to such marked physiological changes. The diversity in length of the fibres before birth appears to indicate the difference of the initial developmental stages.

The physiological development of the fibres in the Scottish Blackfaced sheep has not yet been investigated with any great exactitude, and much further research work is needed on the subject.

V. THE BIRTH-COAT.

The coat of the lamb commences to develop *in utero* within the first three months of foetal life and the extremities are the first parts of the foetus to become covered with fibres.

Various parts of the body develop follicles at different periods of uterine life and the curls produced by the longer fibres are quite visible during the latter part of the fifth month of the gestation period.

The curl is mainly produced at birth by the long, coarse, medullated Heterotype "B" fibres and may turn in either a clock-wise or anti-clock-wise manner like the coat of the Angora kid. Duerden and Spencer (13) (see Fig. 16). The curls of the new-born lamb vary much in size and closeness, according to the fineness or coarseness of the individual fibre.

Different Types of Birth-Coats. Of the eleven birth-coats investigated no two were similar (even including twins) as regards texture, formation of curl, the regional distribution of colour, or density of the fibres. The character and formation of the curl varied a great deal in one individual and usually the anterior dorsal regions had the curl most pronounced/

Figs. 16 and 16a ------- Over.

Fig. 16.


INCHES IN EIGHTHS AND SIXTEENTHS
CENTIMETRES AND MILLIMETRES.
ANDREW H. BAIRD EDIN
INCHES IN TENTHS

Fig. 16a.

pronounced, while to the sides and on the forearms and lower parts of thighs almost any irregularity of curliness could be found. It was possible to select from the experimental lambs, of a few weeks old, different birth-coats as regards the formation of the curl, density of fibres and their macroscopical structure. Four distinct types could be defined, as follows:-

Type I: A Dense Curly Coat, e.g., Lamb No. 9 ♀ (See Figs. 17 & 18).

Type II: A Long Open Curly Coat, e.g., Lamb No. 2 ♂ (See Figs. 19 & 21).

Type III: Back Slightly Curly and Sides Wavy, e.g., Lamb No. 8 ♂ (See Figs. 22 & 23).

Type IV: A Straight Coat with a Slight Tendency to Waviness, e.g., Lamb No. 10. ♂ (See Figs. 24 & 25).

Type I: A Dense Curly Coat, e.g., Lamb No. 9 ♀ (See Figs. 17 & 18).

In this coat a fair amount of Het.(1) "B" fibres project beyond the surface of the fleece independently and produce a cloudy appearance on the surface of the coat. This type of coat has the greatest density of fibres per unit area.,(2) (A.T. Nos. 7-9), and is associated with fullness of handle. The curls are much narrower than those of the ordinary curly/

(1) Het. = Heterotype.

(2) A.T. = Appendix Table.

Figs. 17 and 18 ---------- Over.

Fig. 17. Type I, A Dense Curly Coat, Lamb No.9 ♀

The character of the curl is illustrated on the left side of the animal 3 weeks after birth. A diffused cloudy appearance is noticeable and is produced by the Heterotype "B" fibres which stand out independent between the curly tufts of fibres on the surface of t birth-coat.

Fig. 10. Type I, A Dense Curly Coat, Lamb No.9 ♀.

The photograph shows the change that has taken place at a later stage in the curl on the same coat between 3 weeks of age, Fig. 17, and about 4 1/2 months'growth. The long, narrow, tight spirals shown are again photographed from the left side of the animal. They are very pronounced. The average %age of kemp in the adult coat is 9.1%.

curly coat and afterwards have a tight narrow spiral tuft which is produced by the fine crimpy ends of the Het. "A" fibres.

The wool fibres are present in considerable numbers, and are of fine commercial quality, uniform in diameter throughout their length and they seldom contain any of the coarser wool fibres.

For commercial purposes this type offers a great opportunity to manufacturers on account of its fine quality of wool and the relatively smaller size of the coarse long-hair fibres in the adult fleece.

The average percentage of kemp determined by count in the adult coat ranks rather high and is the only serious defect of this type. In lamb No. 6, a similar type of coat is noticed and presents a fairly high figure of kemp (A.T. Nos. 4-5).

The curl is more pronounced in the shoulder areas, on the back, neck and sides.

Type II: A Long Open Curly Coat, e.g., Lamb No.2 ♂ (See Figs. 19 & 21)

This type is very easily identified by its ropy and small open staples which fall apart very easily and expose the bare skin of the young animal to severe external conditions.

The density in relation to other types of coats is/

Figs. 19 and 20 --------- Over.

Fig. 19. Type II, A Long, Open Curly Coat, Lamb No. 2, ♂.

The character of the curl is illustrated on the left side of the animal 3 weeks after birth. The structure of the curl is fairly wide and open with visible interspaces between the staples. This type of coat has a marked tendency to produce an " Undercoat " with a distinct curl in the interior of the fleece, especially on the back and withers.

Fig. 20. Type II, A Long, Open, Curly Coat, Lamb No. 2 ♂.

The photograph shows the appearance of the curl on the same coat as in Fig. 19 when the lamb was 4 1/2 months old. The staples on the left side of the body have lost their curly distal ends to some extent, and their ropiness is illustrated by the long strands of fibres. The average %age of kemp in the adult coat is 5.4%.

Figs. 19 and 20 --------- Over.

is less and can be detected by the handle of the fleece which lacks that all important feature of bulkiness.

The formation of the curl is quite distinct and wide, but its distribution varies, as in all other coats, in being irregular from one part of the body to another. The curl is partly a regional feature that is associated with a silky and lustrous coat, since the more pronounced the curl in an area the more soft, silky and lustrous is the wool there.

There is a great tendency for this coat to produce an "Undercoat" with a distinct curl which will be discussed later. Matting or cotting of fibres is facilitated by means of the openness of the staples which encourages undercoat curling and allows foreign matter to get entangled in the adult coat. A fair proportion of wool fibres is present, but these lack the quality of the wool of Type I. The different fibre groups are more distinctly differentiated from one another than in the coarse wavy type of coat.

The average percentage of kemp in the adult coat is 5.4% which is a medium figure when comparing it with other coats that turn out to be kempy (A.T. Nos. 5-6).

This coat should not be encouraged by breeders on account of its defects; viz., absence of bulkiness, ropiness of staple, and tendency to form an undercoat.

Type III: Back slightly Curly and Sides Wavy, e.g., Lamb No. 8 ♂ (See Figs. 22 and 23)

This coat is intermediate in appearance between a straight and a curly coat; the curls are not distinctly demarcated but there is a tendency towards waviness on the sides of the lamb. The general aspect of the coat is produced by the coarser physical structure of the long Het. "B" fibres at birth. Later on the coat changes into a curly one owing to the increase in fibre length of the Het. "A" fibres which reach beyond the Het. "B" fibres, and in this way the curl of the Het. "A" fibres becomes visible, being produced by the fine curly distal ends of these (See Figs. 25 & 26). The density does not differ much from that in the coat of Type IV, and there is plenty of bulk when handled.

The respective fibre groups in this coat are much coarser in structure than those pertaining to a curly coat. An overlapping of fibre groups is observed and the quality of the coat is slightly harsh and strong to the touch.

The majority of Het. "B" fibres become shed and are replaced by kemp fibres with the result that the coat turns out to be kempy, giving an adult figure of 12% kemp.

Figs. 21 and 22 ------- Over.

Fig. 21. Type III, Back Slightly Curly and Sides Wavy, Lamb No. 8, ♂.

The left side of the coat is illustrated; it possesses a marked waviness of staples at 3 weeks after birth. A slight degree of curliness is observed round the neck and shoulder areas, not well shown in the print on account of technical difficulty in photographing.

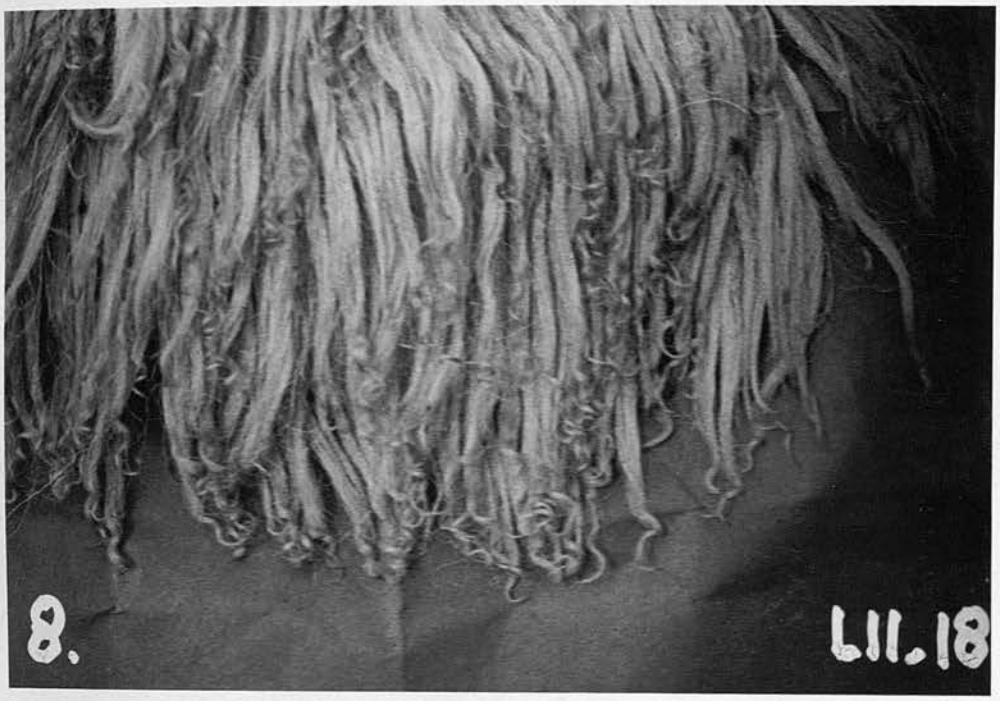


Fig. 22. Type III, Back Slightly Curly and Sides Wavy, Lamb No. 8, ♂.

This photograph illustrates the type of the curl on the left side of the same coat at 4 1/2 months. The coat assumes a definites curl as a result of the shedding of the coarse-tipped Heterotype "B" fibres, which are replaced by kemp fibres later. An average figure of 12.0% kemp on the shoulder area was obtained in the adult coat. The staples are obviously longer than those illustrated in this lamb's brother, No. 10, (Fig. 24).

Figs. 21 and 22 ---------- Over.

Type IV: A Straight Coat with a Tendency to Waviness. e.g., Lamb No. 10 ♂ (See Figs. 24 & 25)

Occasionally, a straight coat with a tendency towards waviness is produced. This has a reasonable density of growing fibres (A.T. Nos. 7-9) and shows large solid staples. The component fibres comprising the staple are coarse and the two wool classes of fibres overlap to a great extent during the first few months after birth. The straightness of the coat is mainly due to a great percentage of Het. "B" and Het. "A" fibres. The numbers of these latter predominate over the number of wool fibres in this type of coat (A.T. Nos. 1-4).

In a coarse coat like this an overlapping of the longer Heterotype groups of fibres is encountered. The coat after a while assumes a less distinct curl when comparing it with Type III, and is characterised by a harsh and bulky feel.

This coat sheds the Het. "B" fibres at an earlier date than any other coat does and the discarded fibres are consequently shorter in length than those of a curly coat which are shed at a later date. A certain proportion of the Het. "B" fibres does not shed but changes, to become long-hair in the adult fleece with the result that far less kemp is present in the adult fleece/

Figs. 23 and 24 -------- Over.

Fig. 23. Type IV, A Straight Coat with a Slight Tendency to Waviness, Lamb No. 10, ♂.

This photograph, of the left side, illustrates the type of coat which is mainly straight but shows a slight waviness towards the anterior part of the body. The lamb is three weeks old.

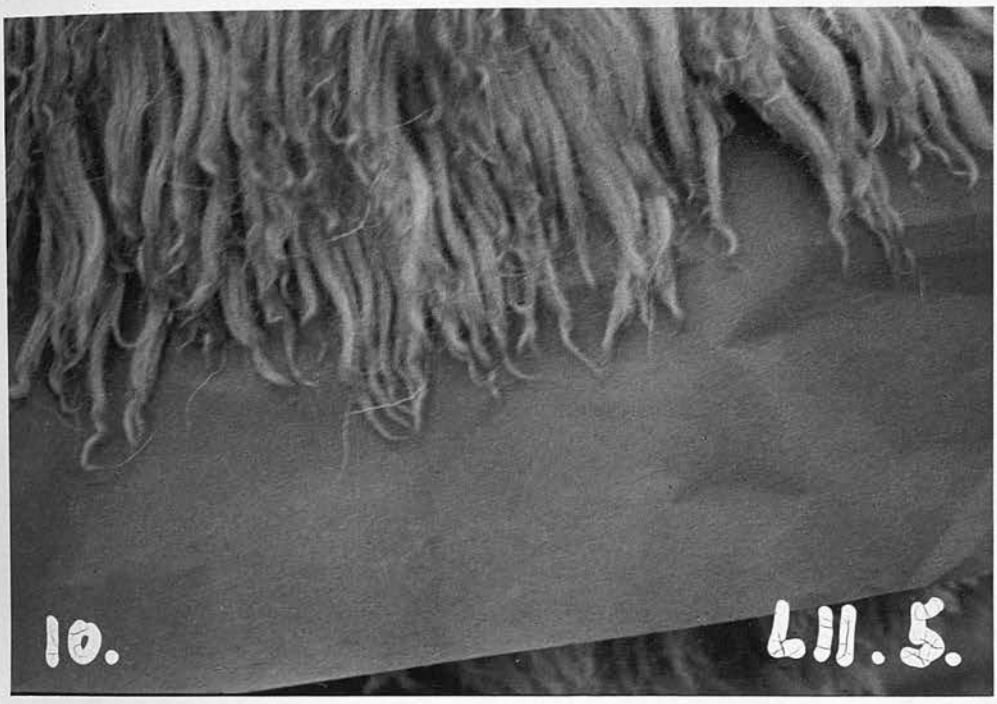


Fig. 24. Type LV, A Straight Coat with a Slight Tendency to Waviness, Lamb No. 10, ♂.

The change of the curl on the left side is illustrated. The photograph is of the left hand side of the same coat taken at 4 1/2 months of age. The coat has assumed a very slight curl on account of a portion of the coarse-tipped Heterotype "B" fibres which did not shed. An average figure of 1.8% kemp on the shoulder area was found in the adult coat. The staples are shorter than those illustrated in the brother, lamb No. 8.

Figs. 23 and 24 -------- Over.

fleece than in any other type of coat.

An average figure of 1.8% kemp in the mature fleece has been determined and it is suggested that is very satisfactory from the manufacturer's point of view.

Discussion of Birth-coat.

Various other types of coats are observed intermediate in appearance between those already described. There is, in all probability, a definite range between two extremes. Those types selected are not necessarily representative of the whole range. There is no hard and fast rule by which one type of coat can be distinguished from another, chiefly, because of the regional variability of the curl on the body. One type of coat may appear similar in curliness to another on one part of the body while in other areas no similarity may be determinable. The different types of coats described can, however, be identified easily in the majority of cases.

The birth-coat may develop into either a long, a short or an intermediate coat in the adult stage as regards length of staple while the percentage of kemp fibres may range from high to low, so that the shorter the staple the less kemp fibres are produced and vice versa./

versa. Three pairs of twin lambs show that this is the case; their adult fleeces of twelve months' growth varying proportionately in kemp content in direct ratio to the lengths of staples. The data in the following table are selected to illustrate this fact.

Identification number of Lamb & Sex.		Type of Juvenile-Coat.	In Adult Coat; Length of Staple	%age of Kemp.
150	♂	Curly	Long	16.0
151	♀	Curly	Short	10.5
152	♀	Curly	Short	12.2
153	♀	Curly	Long	17.5
8	♂	Curly	Long	12.0
10	♂	Slightly-Curly	Short	1.8

Other coats were not available in the adult stage for examination. The coats in the table were compared on a basis of family performance since the pairs are twins; the differences cannot be directly applied to coats from animals of different breeding. The first two pairs of twins have the same father and the mothers are from the same strain of ewes.

A short-stapled coat is associated with a thick staple with plenty of bulk in it, while a long-stapled coat grows a thinner staple with less bulk and density. At the same time it is not possible to state definitely which type produces the heavier weight of clipped wool.

In a straight to wavy coat with no primary curl the speed of shedding of Het. "B" fibres is

associated with the speed of appearance and character of the secondary curl in the juvenile coat. If such a straight-to-wavy coat assumes a definite secondary curl (See Figs. 21 & 22, Lamb No. 8 ♂), this is due to the fact that the majority of Het. "B" fibres have shed and will be replaced by new kemp fibres resulting in a kempy adult fleece. On the other hand if the coat assumes the curly formation only to a slight extent after a few months' growth (See Figs. 23 & 24, Lamb No. 10 ♂), it is clear that the majority of Het."B" fibres have not shed and therefore there is no chance for new kemp fibres to develop; accordingly the ultimate coat will be comparatively free from kemp fibres.

The most critical stage in the life of a mountain sheep is that immediately following birth. The lambs that have a dense, straight-to-wavy hairy covering at birth are noticeably quick in getting on to their legs and taking their first suck of milk. The breeder therefore selects for a thick coat at birth and a dense weather-resisting adult fleece. This is also the case in the Welsh Mountain breed of sheep. Roberts (22). The manufacturer desires absence of kemp, a certain fineness of fibre in the Blackface, and in addition the elimination of coloured fibres./

fibres. The ideal policy for selection should be to breed a type of coat which will satisfy the needs and wants of both breeder and manufacturer within such limits as are possible. The type of coat that is represented in Type IV - a straight-to-wavy one- appears to be shown by this work to be the nearest to the ideal Type.

A slight modification of Type IV coat might also prove satisfactory although the percentage of kemp in some of these cases (e.g., Nos. 4 & 5 lambs) is slightly more than in the case of the ideal type. A dense curly lamb's coat, as in Type I, has the great disadvantage that it will give a high percentage of kemp in the adult fleece.

The best criteria on which to select Blackfaced sheep from the point of view of wool would seem to be as follows:-

(1) A thick densely-planted coat at birth;

(2) Kemp reduced to a minimum in the juvenile stage;

(3) A formation and texture of the primary curl, which corresponds to the straight-to-wavy Type IV which is described.

It is scarcely likely that the hardiness of the sheep will be impaired if the thick coat of the lamb is retained and the kemp reduced to a minimum, yet some breeders still believe that kemp is associated with/

with hardiness in some obscure way or another.

No particular importance seems to be attached to fineness of fibres by the manufacturer of Blackfaced wool. The different types of fibres, constituting the coarse type of Blackfaced fleece, are much coarser than those in the soft type which is composed of finer wool and long-hair fibres, yet each type can find a ready market.

Improvement of the birth-coat may be effected in two ways. Firstly, by selecting for a coarse, straight, dense type of coat which has the capacity to retain rather than shed the Het. "B" fibres, the forerunners of kemp, and will eventually turn out to be a coarse fleece with relatively little kemp but plenty of long-hair. This hard type of fleece is praised for its rain-shedding qualities by the breeder and required by the Italian market for mattress-making. It is of course to be assumed that environment plays a very important rôle in the expression of the character of the fleece, but it is not desirable to complicate matters at this stage by emphasis upon environmental influence, since the sheep used in this experiment were all kept under similar conditions at this Institute and were grazed together as one flock.

Secondly,/

Secondly, by selecting a dense curly type of coat with wool fibres of a fine commercial quality. The kemp should constitute only a small proportion of the fleece; the only way to determine this is by careful examination. The explanation of the variations of kempiness lies in the expression of the gene or genes in the germ cell responsible for kempiness. Severe selection should be practised each year on the lambs which are to be kept to become breeding animals later, since variations in them are liable to be reproduced later in their offspring. Probably the most important facts to keep in mind are: (1) the type of birth-coat, and (2) the rate of the shedding of the Het. "B" fibres in the lamb's coat. Roberts (24) has stated that in the Welsh Mountain sheep the birth-coats which shed did not produce a thick growth of kemp later. In the Blackfaced sheep the reverse is the case, since if the Het. "B" fibres of the birth-coat persist, as in Fig. 23 Lamb No. 10 ♂, a fleece relatively free from kemp is developed. To eliminate the kemp does not necessitate sacrificing the good quality of the birth-coat. It is believed that the type of birth-coat and the percentage of kemp in the adult fleece are inherited though several factors are concerned, and therefore one way of reducing kemp is/

is to select adult animals for breeding, with little or no kemp in their fleeces, and to practice severe selection of lambs while they are still in the juvenile stage of growth - i.e., probably at birth and again at the time of castration or weaning. This selection would be based upon an examination of the primary curl, of the rate of shedding of Het. "B" fibres, upon the length of staple and upon the appearance of the secondary curl, as already described. This would enable one to secure a strain of sheep, in which lambs of the type required by the farmer, and wool of the type desired by the manufacturer would be produced.

Further, it may eventually be possible to correlate the regional distribution of primary curl on the body with the regional distribution of kemp in the fleece. If this correlation is possible it could be determined in the juvenile coat when the curls are most pronounced and the kemp-indicating fibres are being shed.

The Transformation of the Curl. As has been mentioned the birth-coat covering of the Blackfaced lamb carries primary curls of fibres on the surface of the fleece. (Figs. 16 & 16a). After birth, these curls continue their growth, and from approximately two months onwards/

onwards the curl becomes transformed to a secondary curl, or short spiral tuft, at the distal end of the staple (Figs. 25 & 26).

The direction of the secondary spiral usually shows a reverse between the first and second turns, i.e., the first is usually anti-clockwise and the second clockwise; in some cases these directions are reversed. These spirals are produced by adjacent fibres fitting over one another, the ends of individual fibres having the same shape as the tufts Duerden (10). When the individual fibres are closely spiraled, the distal tuft is long and narrow as in Type I (Fig. 18), but where the spiral is wide the tufts are larger, more open and less pronounced (Fig. 20).

The character of the tuft is expressed by the relative proportions and length of Het. "B" and Het. "A" fibres present at different periods in the same staple. The secondary spiral tuft in the juvenile coat is produced by the long Het. "A" fibres in most cases, except in a coarse straight coat where a certain proportion of Het. "B" fibres are not shed but persist in the coat. There are several stages through which the transformation of the curl passes. Figs. 25 and 26 show the transformation of primary to secondary/

Figs. 25 and 26 ------ Over.

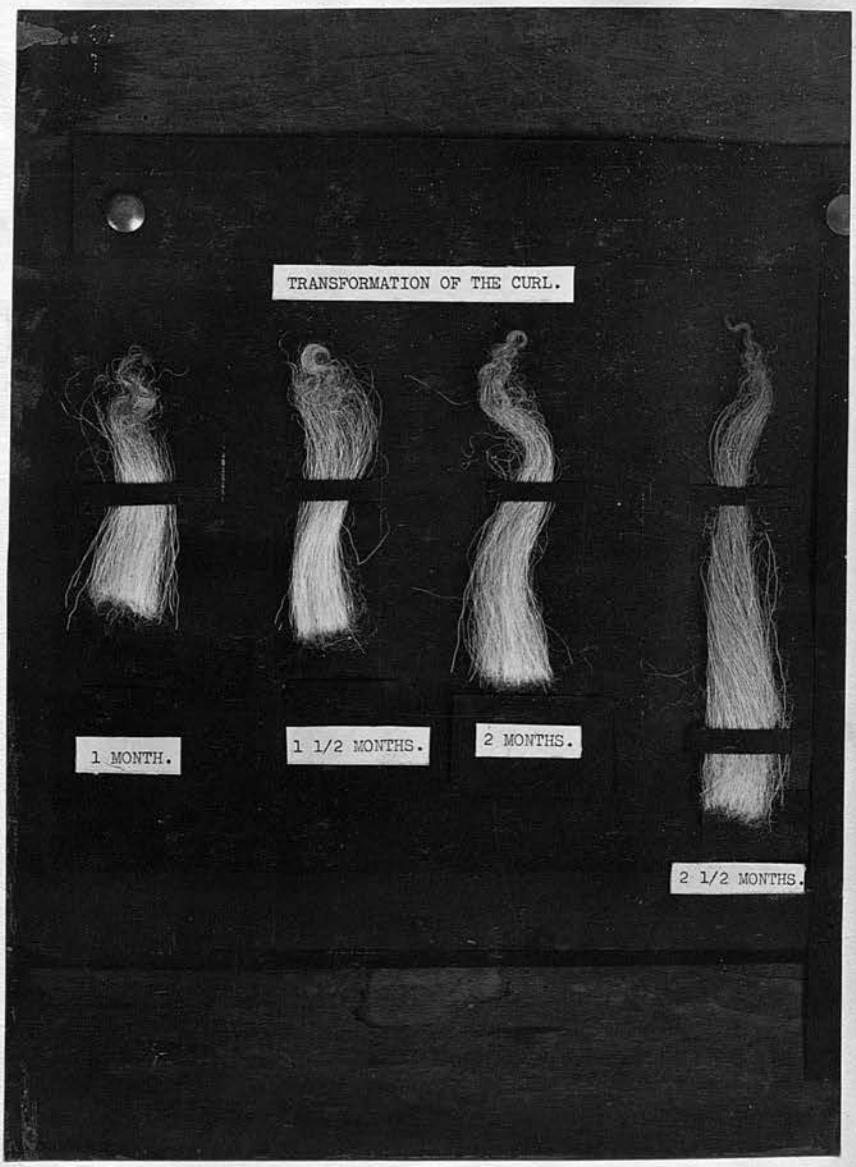


Fig. 25.

Figs. 25 and 26. The photographs illustrate the transformation of the curl of the birth-coat on the left side of one lamb, viz. No. 9 ♀. The samples were removed at the ages stated under each staple. The curl is pronounced in the three early stages and assumes a spiral arrangement with the increase of age from 2 1/2 months onwards. Later, at 5 months this

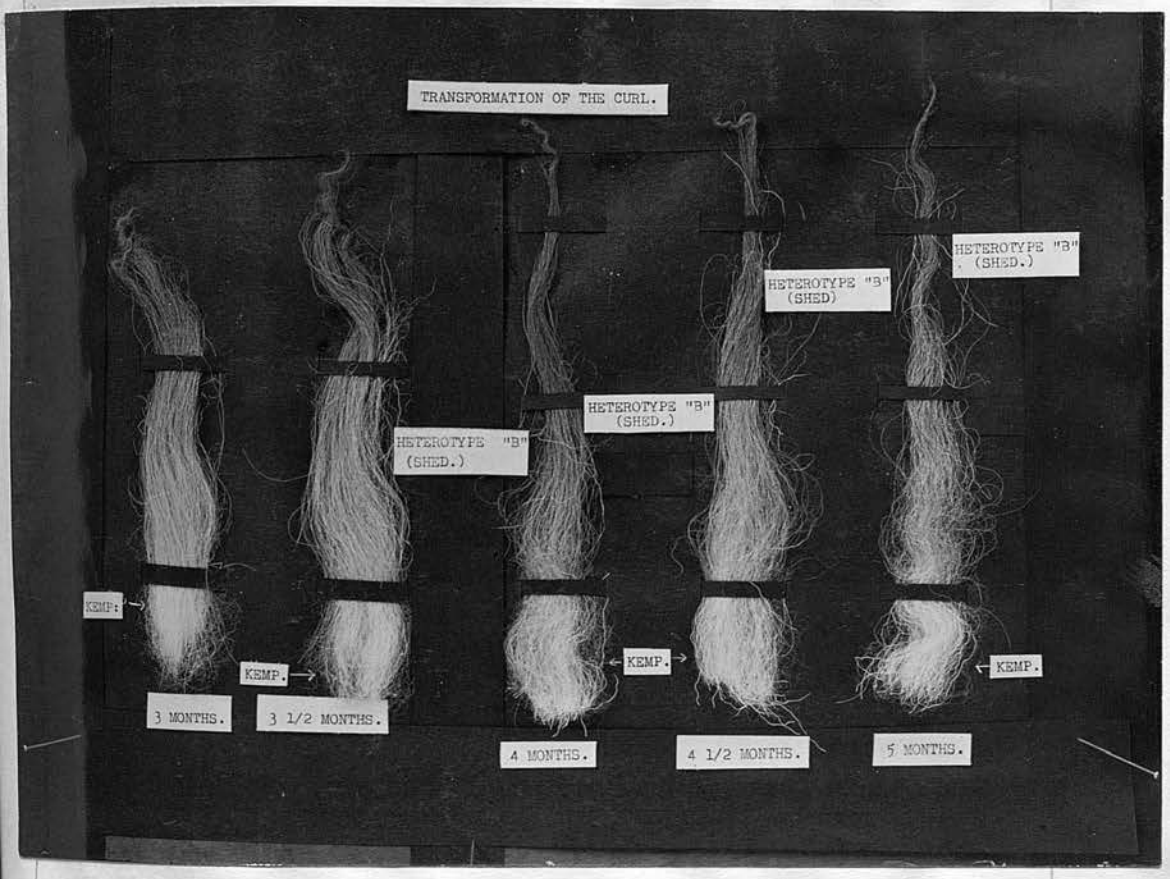


Fig. 26.

Figs. 25 and 26 (contd.). spiral becomes indistinct and is lost eventually. The development of kemp, preceded by the shedding of the Heterotype "B" fibres, is clearly illustrated in the later staples. The shed fibres are gradually pushed up towards the distal end of the staple by the growing fibres. The kemps increase in length at a rate corresponding to the time of the shedding of Heterotype "B" fibres, which are their precursors.(See Page 119).

Figs. 25 and 26 -------- Over.

secondary curl in staples taken from the left side of the same animal at intervals from birth up to 5 months' growth when the secondary curl is completely lost. The secondary curl is eventually lost through the deterioration of the fine crimpy distal ends of the Het. "A" fibres which are destroyed by environmental influences, e.g., weather, ordinary wear and tear of the fleece, handling, etc. Probably each individual sheep differs from others in the mode of transformation of the curl, and there are also some regional differences in various areas of the body.

It can be assumed, however, that the neck and shoulder areas retain the curl later than any other region of the body, while the back and side vary in this respect, the haunch losing the curl the quickest.

Appearance of Undercoat Curl. The Undercoat Curl is an interesting phenomenon which occurred in some of the birth-coats at the approximate age of 2½ months. A number of lambs showing this curl and arising from different strains of sheep were examined on various farms. In these cases it was found that the birth-coat exhibited a tertiary curl in the interior of the fleece. This tertiary curl becomes significant only when the longer medium wool fibres have attained a reasonable/

reasonable length to form a curl entirely by themselves. Apparently there is no fixed time for the first appearance of the curl but it is mainly an individual variation determined by age, density of the fleece and length and size of staple. It is most prominent in the juvenile stage of birth-coat development and disappears gradually as the coat reaches the adult stage. This tertiary curl has several different appearances; in some coats it may be very outstanding while in others it is only slightly visible, producing small curly tufts of wool, called "neps". This tertiary curl is mainly located on the area of the withers where it covers approximately the size of a man's hand. It is largely associated with decreased density of the coat so that when the coat is open and long, a curl is formed almost one third of the distance from the proximal end of the staple (Fig. 27).

The staples on the area of the withers are usually ropy and long with empty spaces among them to allow the tertiary curl a free scope for expansion.

This undercoat phenomenon seems to be inherited since one male is liable to produce several coats with this undesirable feature. It occurs particularly in strains of sheep which carry a long open curly coat with soft silky feel. Such coats have a lustrous appearance/

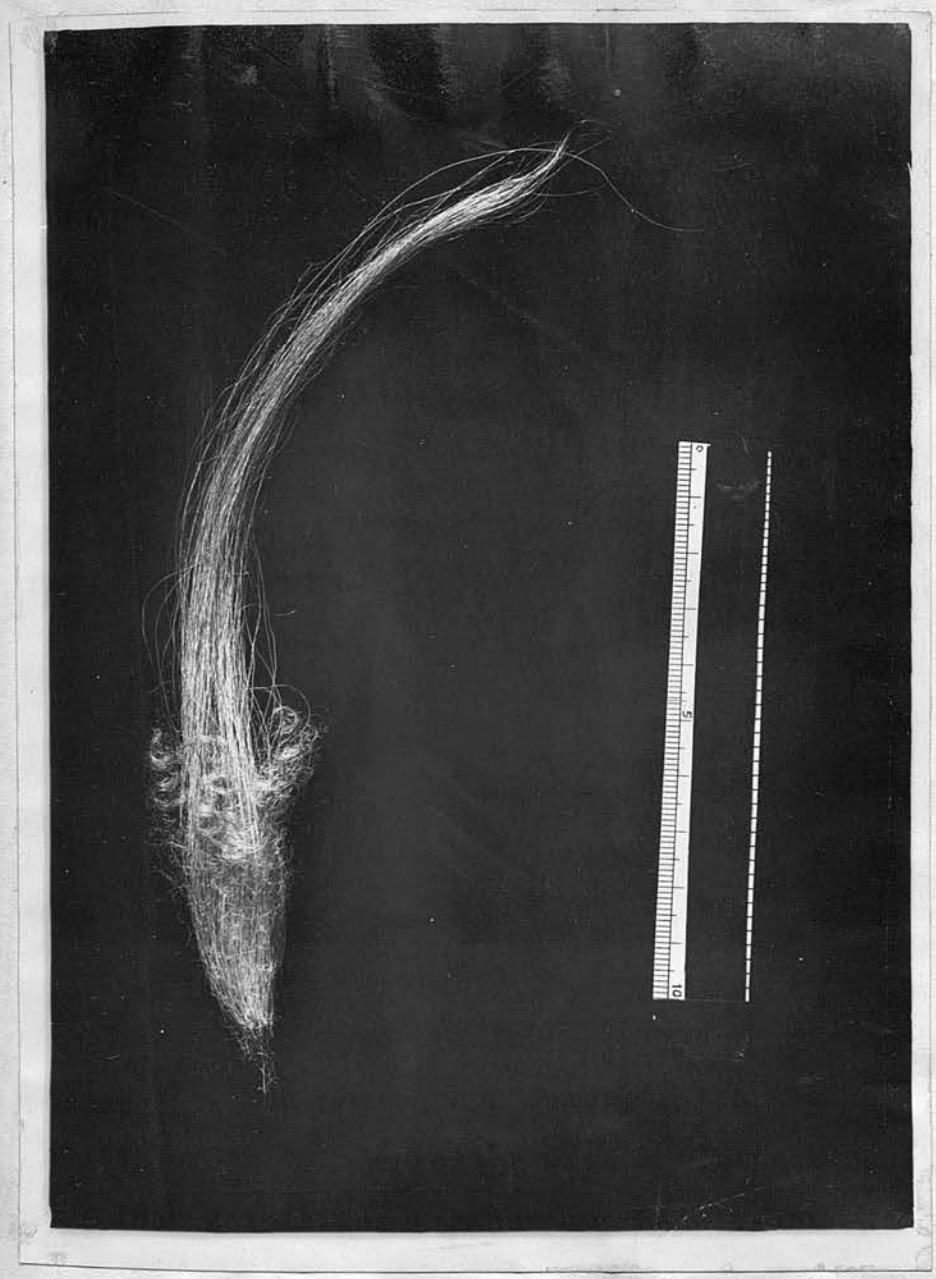


Fig. 27 . The photograph demonstrates the appearance of an " Undercoat " with a distinct curl. A 7 1/4 inch staple was taken from the withers. It shows the curl 2 inches from the base at an age of 6 months. The long medium wool fibres are mainly responsible for this tertiary type of curl; the photograph illustrates it clearly.

appearance while the wool fibres possess a commercial spinning quality of high standard, but are entirely undesirable for sheep kept either at high altitudes where maximum protection from the weather is required from the fleece, or in districts with a heavy annual rainfall and snowfall.

There is a marked tendency for an open coat like this to produce a matting or "cotting" of the fibres in the interior of the fleece during late Winter or early Spring. The formation of this undesirable "cot" is greatly facilitated by the presence of a tertiary curl and will be discussed later.

VI. DENSITY.

Density of follicles on histological sections of the pelt was first described by Nathusius and more recently by Tänzer (29) in histological studies of the development of the follicle and pattern of fibre groups in the Karakul sheep.

An attempt has been made by Tänzer (26) to determine, by surface calculation, whether in the Karakul the number of groups (which may be expressed by the density of the supporting hairs) increases in proportion to the increase of the skin surface. He maintained that hair density is proportionate to body surface in the Karakul breed of sheep.

On the Blackfaced sheep fine small contiguous areas of the skin centred around the point of the shoulder (Fig. 3) were marked out and the wool removed from each at weekly and later at fortnightly intervals by the triangular method of determining density (see page 19). The same method was carried out on the haunch of one sheep to compare the density between shoulder and haunch areas and to determine the relative proportions of the different types of fibres on the two areas.

Endeavours have been made to correlate density

of fibres per unit area of the lamb's skin with ultimate adult density. In the progress of density observations it was found necessary to devise and make use of a method for comparing the degrees of obscured or corrected density in lambs of different ages. This consisted of relating fleece density to the rate of growth in size of the lamb as evidenced by the increase of weight. It has been possible to devise a method whereby knowing the age and weight of the lamb and the observed density, at a given date, it is possible to determine the comparable corrected density figure, which could be used for evaluating the density of the adult fleece within a normal limit of error.

Determination of Corrected Density. The corrected density signifies the number of growing fibres on the increased area of the original triangle at the times when periodic observations were made. Each triangle covered an approximate area of 1 sq.cm. on the body at the commencement of the experiment, and corrections were made to bring all density figures to a comparable standard basis of 1 sq.cm. area. According to the increase in size of each triangle over its original size, the relative number of growing fibres was determined on each sampling day. The corrected density/

density figure was obtained from the observed density figure, which latter consisted of the actual count of growing fibres on each sampling area.

According to Armsby (1), p. 259, the body surfaces of animals of the same shape are proportional to their weight in grams to the power of $\frac{2}{3}$. This relation may be expressed by the following formula:-

$$S = kW^{\frac{2}{3}}$$

where W = Weight in grams*

S = Surface area of the body in square centimetres.

k = A Constant (i.e., 9.41)

The value of the constant k is 9.41 for animals in medium condition, and this figure is used for calculating the increased surface area in square centimetres on the lambs in this experiment.

The result of applying the formula $S = kW^{\frac{2}{3}}$ to the figures obtained for Lamb No. 6 ♀ (Table on page 96) is as follows:-

$$S = 9.41 \times 5533^{\frac{2}{3}}$$

$$= 2943.$$

so that the surface area of this lamb's skin at the given date (2-4 weeks) was 2929 sq.cms.

The next reading of weight gives a value for S of 3418 sq.cms., so that each original square centimetre/

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* 454 grams = 1 lb. Avoirdupois.

Lamb No. 6 ♀. (A Dense Curly Type of Coat).

Age in Weeks.	Live-weight in grams.	$S = kW^{\frac{2}{3}}$ (in sq. cms.)	Area of Observed Density (sq.cm.)	Observed Density (No. of fibres per sq. cm.)	Area Increase for Corrected Density Figure Area (i.e. sq.cms.)	Corrected Density
2-4	5533	2943	1	2964	1	2964
4-6	6923	3418	1	2580	1.167	3011
6-8	10555	4529	1	2625	1.546	4058
8-10	14528	5603	1	2006	1.913	3837
10-12	17138	6255	1	2513	2.136	5368
12-14	19976	6928	1	2181	2.365	5158
14-16	20487	7044	1	1470	2.405	3535
16-18	23381	7695	1	1678	2.627	4408
18-20	22927	7595	1	1928	2.593	4999
20-22	23267	7667	1	1897	2.618	4966
22-24	24062	7841	1	2095	2.677	5608

Detail table of one lamb showing how the corrected density figures were arrived at from live-weight and observed density figures.

centimetre of lamb's skin has in the time mentioned (two weeks) increased to -

$\frac{3418}{2943}$ of its original area.

i.e. = 1.167 sq.cms.

Observations of density of number of fibres were, however, made at each sampling day from 1 sq.cm. of skin only. To determine the corrected density figure it was therefore necessary to multiply the observed density figure by the figure obtained as above for increased size of the original area of one square centimetre.

Example: In 1 sq.cm. there are 2580 fibres.

" 1.167 sq.cms. there are 2580 x 1.167 fibres.

= 3011 fibres.

The corrected density, 3011, represents the number of fibres on the increased area of the original 1 sq.cm. triangle, at the same date when the observed density was determined. A table was constructed for each lamb as shown on page 96.

The figures for live-weight (in grams), observed density (per sq.cm.) and corrected density are given in the appendix tables Nos. 7-10, along with the number, sex and age of every lamb. In the same tables the average live-weight and average corrected density figures/

figures at fortnightly intervals are given, for the total number of lambs in the experiment.

Correlation of Live-Weight and Corrected Density Figures from 1 Week to 38 Weeks old. It was necessary to determine whether periodic live-weight increases were in any way correlated statistically with the corrected density values obtained by the methods outlined in the preceding pages. For assistance with this part of the work the writer is indebted to Dr. A.C. Aitken, Lecturer in Statistics, Edinburgh University, who has kindly suggested the most appropriate methods to use, and has greatly helped in the preparation of the correlation tables.

The figures for live-weight and corrected density are divided by a unit figure of 4779 and 2100 respectively. The units obtained by this division are then smoothed by a special method and finally the relative increments of the two tables are obtained from the differences of the smoothed units, (i.e., by multiplying the respective differences with their respective units), e.g., 4779 x 0.29 = 1386 and 2100 x 0.13 = 273 (see Table on page 99). The smoothed unit figures are plotted on a logarithmic graph paper (Fig. 28), while the actual unit figures are represented in each case by black dots on the graph/

Table of Average Live-Weights (in grams) and Average Corrected Density Figures.

Age in Weeks.	Live-Weight (in grams).	Unit = 4779 Units.	Unit = 4779 Smoothed Units.	Differences of Smoothed Units.	Increments of Live-weight (in grams).	Corrected Density.	Unit = 2100 Units.	Unit = 2100 Smoothed Units.	Differences of Smoothed Units.	Increments of Corrected Density.
1-2	5018	1.05	1.05	-		2144	1.02	1.02	-	-
2-4	6427	1.34	1.34	.29	1386	2208	1.05	1.15	.13	273
4-6	9025	1.9	1.9	.56	2676	2870	1.37	1.37	.22	462
6-8	12540	2.6	2.83	.93	4444	3592	1.71	1.72	.35	735
8-10	16698	3.49	3.48	.65	3106	4404	2.10	2.17	.45	945
10-12	19768	4.12	4.09	.61	2915	5401	2.57	2.45	.28	588
12-14	23188	4.85	4.68	.59	2819	5827	2.77	2.66	.21	441
14-16	23432	4.9	5.01	.33	1577	5309	2.53	2.78	.12	252
16-18	25361	5.31	5.26	.25	1195	6056	2.88	2.76	-.02	- 42
18-20	26076	5.46	5.51	.25	1195	5972	2.84	2.71	-.05	-105
20-22	25367	5.31	5.35	-.16	- 765	5510	2.62	2.74	.03	63
22-24	25556	5.35	5.34	-.01	- 47	5635	2.68	2.77	.03	63
24-26	26067	5.45	5.49	.15	717	6352	3.02	2.98	.21	441
26-28	27694	5.79	5.71	.22	1051	6921	3.29	3.21	.23	483
28-30	28337	5.93	5.93	.22	1051	7368	3.51	3.45	.24	504
30-32	29623	6.2	6.27	.34	1625	7526	3.58	3.72	.27	567
32-34	30701	6.42	6.42	.15	717	8804	4.19	4.19	.47	987
34-36	33104	6.93	6.93	.51	2437	9991	4.76	4.76	.57	1197
36-38	31249	6.54	6.54	-.39	-1864	11568	5.51	5.51	.75	1575

graph to show the degree of variation from the actual units.

The formula for smoothing, if $U'o$ is the smoothed value of Uo, was determined to be:

$$U'o = Uo - 3/7\ \delta^4 Uo - 2/21\ \delta^6 Uo.$$

$\delta^4 Uo$ and $\delta^6 Uo$ are the 4th and 6th "central differences" i.e., if a table of differences is constructed, the central differences of a datum U are those which lie on the same horizontal line as U. The method is a complicated but useful one.

The live-weight and corrected density figures are represented in a graph (Fig. 28) to show the average relative increases of the two factors in relation to one another during the growth of the animals in a specified time. The general live-weight trend is shown by a continuous black line plotted somewhat above a dashed-line which signifies the average trend of the corrected density figures. The two curves correspond very closely to one another and a significant positive correlation figure of 0.88 with a probably error of $\pm$ 0.036, has been determined for these two curves.

The graph shows that live-weight increases very rapidly up to 5 months, during which period lambs should be fed heavily to get a rapid growth rate.

After/

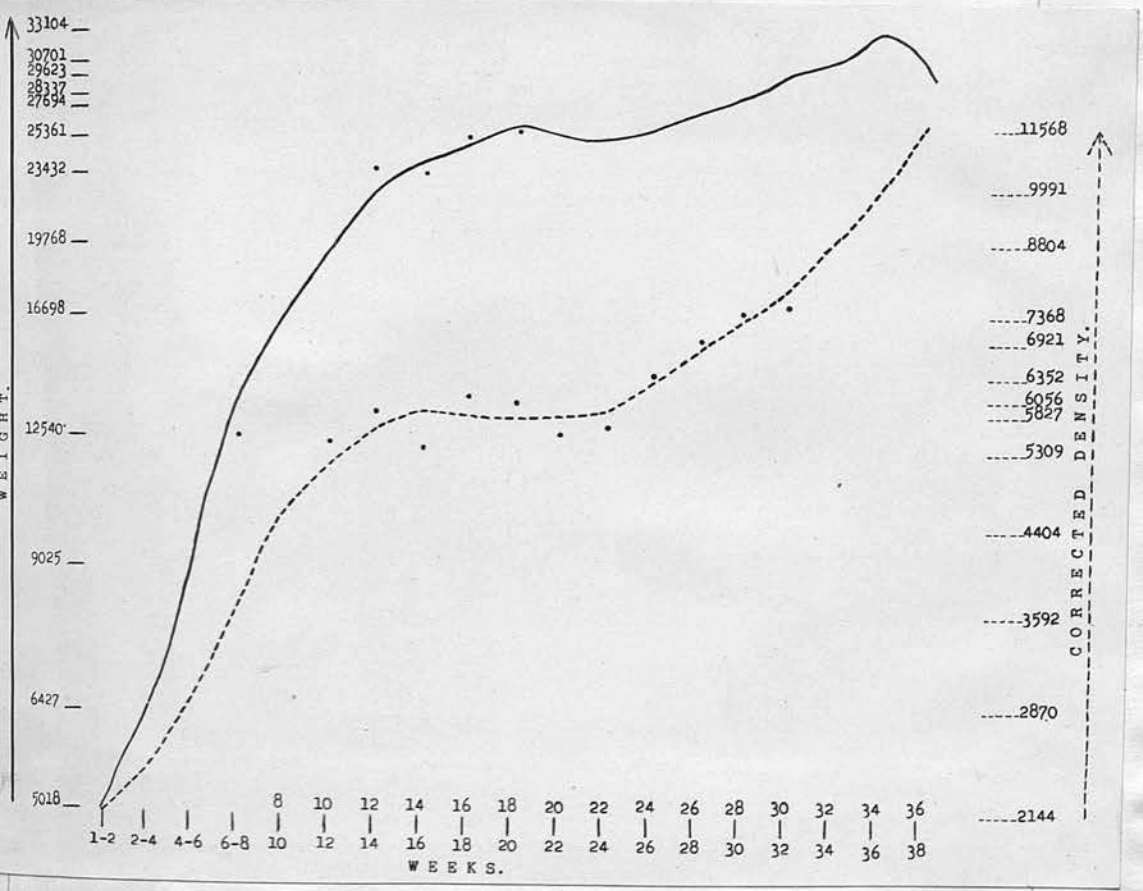

Fig. 28 . The graph demonstrates, by a black continuous line, the average increase of live-weight of the animals from 1 week to 38 weeks old. The average increase of corrected density (No. of fibres per unit of area) is indicated by a dashed-line. The figures on the left side of the graph are the live-weights (in grams) of the animals, while those on the right side are corrected density figures. There is a significant positive correlation figure of 0.88 with a probable error of ± 0.036, between the two factors.

After 5 months the capacity for putting on weight becomes less (see Table on page99) and the animals are more subjected to environmental influences, such as nutrition, disease, etc.

A conformity to the rule that greater density of fibres corresponds to a greater surface area, or vice versa, cannot be established, although the animal with the smaller surface will generally be seen to show the greater density. It should be mentioned, of course, that the surface area in the lamb is relatively much greater than in the adult. Tanzer (26). Fibres with the same absolute thickness will take up a much greater space in relation to the body surface in the lamb than in the adult sheep.

In Fig. 28 the corrected density values increase in proportion to the live-weight but not to such a marked extent in the beginning as at the end of the period.

A considerable early increase in body weight results in a somewhat less relative increase in surface area and therefore a less increase of corrected density value. It is possible to postulate, therefore, that the large heavy animal in the later growing stages exhibits a smaller corrected density figure than does the smaller, lighter animal of the same age.

The/

The writer is aware that this examination does not offer a complete solution of the problem of growth rate and its relationship to fleece density, but the findings are considered to be significant and indicative of the need for further study.

Observations on Density. The average observed density figures vary from 1849 to 2687 fibres per sq. cm. but there is an average range between 2000 and 2100 in most cases (see A.T. Nos. 7-10). The marked differences in density may have been influenced partly or entirely by the following factors:-

(1) The development of new fibres;

(2) The stretching of the skin on the growing animal;

(3) Irregular local grouping or location of follicles;

(4) The shedding of birth-coat fibres;

(5) Irritation of the skin by sampling with consequent small localised contraction of the cutaneous muscle;

(6) Condition of the animal;

and (7) Individual error.

As already stated, after birth there is an increase in the number of fibres per unit area which can only be accounted for by postulating that certain new/

new fibres develop after birth, viz., wool and kemp fibres. Because of this the relative proportions of the different types are altered and the density changed to a slight extent. The stretching of the skin, during periodic observations from birth onwards, is very irregular as a result of which the density per unit area is affected. The stretching of the skin, i.e., its increase in surface area, follows in ratio to the increase in body weight; it is greatest during the first two weeks of life, and in subsequent equal periods shows a gradually descending amount of increase which is correlated with the descending body weight increase figures. At no time, however, is the increase in surface area of the skin quite regular, in that growth in longitudinal directions of the body is faster than growth in transverse directions.

The arrangement of follicles in the different triangles on the shoulder area varies. The follicles are supposed to be situated in groups and the group numbers vary from one area to the other. An alteration of this sort results in a difference in density in adjoining areas. It is impossible to make any allowance for the variation in localisation of follicle groups on different areas of the body: it is not even certain whether this localisation is specific or irregular. These matters require further detailed study.

The gradual shedding of Het. "B" fibres influences the density from approximately 2½ months onwards. They were not calculated for density determination after they were shed in toto. The method of sampling may entail a slight contraction of the skin by passing quills, etc., along the surface of it but the response is generally minute. The individual error in taking the samples may introduce another minor complication.

The bodily condition of the animal at the time of sampling may be considered as another factor which to some extent influences the number of fibres per unit area. If the health of the animal is such that it loses 4 or 5 lbs. in an interval of 1 week the density may increase in proportion to the shrinkage of the skin.

The area on the haunch of one animal is less densely covered with fibres than that of the shoulder. The density of the coat is associated with bulky feel and in the Blackface as in most other breeds a dense coat seems to be correlated with length of staple, i.e., a coat with a long staple is less dense than a coat with a shorter staple. The dense bulky coat possesses wool fibres which are finer and more uniform in diameter, and has fewer coarse and undesirable long-hair fibres than those found in the long open coat.

Environment/

Environment plays a very important rôle in the expression of the character of the fleece in consequence of which the character of the fibres may be modified to a coarser type. In these experiments, however, environment was as nearly uniform and constant as is possible.

VII. EVOLUTION OF NEW FIBRE TYPES IN THE FLEECE AFTER BIRTH.

Wool. During the first 2½ months after birth new wool fibres are continuously developing with the result that the wool fraction increases quite rapidly. From that time the increase is less rapid but a few new wool fibres still develop for a considerable period up to the adult stage. The differences in length of the wool fibres are probably due to the irregularity of follicular activity. The time at which the follicle commences to function determines the length and diameter of the fibre, so that it may be classed with either medium wool or fine wool as the case may be.

Kemp. Kemp starts to develop on different animals at varying times. The earliest appearance of kemp was noticed in one lamb at the age of 7-8 weeks, and the latest appearance was in another lamb at the age of 23 weeks approximately. There is accordingly a wide range of time for the commencement of kemp growth in different animals. On the shoulder area of one animal, viz., No. 153 ♀, an interval of 120 days was discovered between the time when the first kemp fibres developed and the date of the appearance of the latest kemp. The fibres which grow at such a late date are much/

much shorter in length when shed in late Summer than those that started to grow earlier. These differences in time of growth are more prevalent on the posterior parts of the body than on the shoulder and neck areas. Once the kemp has started, the growth is very rapid and far surpasses the growth rate of the wool fibres. Some animals grow kemp of a type differing from normal, in that they may be smaller in diameter, less medullated and less wavy when compared with the more typical coarse, medullated and wavy type of kemp on other animals. The type of kemp produced is most probably profoundly influenced by environmental conditions (see pages 118 & 121).

Hybrid Kemp. The hybrid kemp is a type of fibre intermediate in structure between kemp and hair. It possesses the character of a kemp fibre for about half way along its distal end, in consequence of which it is impossible to differentiate it from the typical kemp fibre at that stage of development when both types are equal in length and diameter. At the commencement of growth these hybrid kemps have a long, fine, needle-pointed tip but this characteristic is not sufficient to enable them to be grouped as a class. It is only possible from about 150 days onwards to distinguish satisfactorily the hybrid kemp from true kemp./

kemp. (Fig. 29). The hybrid kemp fibre has a smaller diameter and shows a less opaque white colour than the true kemp, but it has a similar long, sharp, pointed-tip (Figs. 14 and 15). These fibres grow extremely fast and rapidly exceed the kemp in length. When the coat has reached the adult stage they are equal in length to the long-hair fibres. The hybrid kemps are uniform in length but vary greatly in diameter and waviness. They have a peculiarity of twisting and turning in all possible directions among the adjacent fibres and this intertwining is partly responsible for the cot in the fleece which will be described later. In the adult coat they are easily distinguished from hair on account of their opaque white colour and distal ends.

All the fibres which showed a structure like this were classed with the kemp group because they are undesirable fibres from the manufacturer's point of view. They fine down synchronously with the long-hair in Winter and do not shed but continue their growth in Summer producing a coarse, opaque, white structure. After shearing it is difficult to distinguish the hybrid kemp from the long-hair, to which group they then belong.

The examination of the fleece of indoor-fed sheep sometimes/

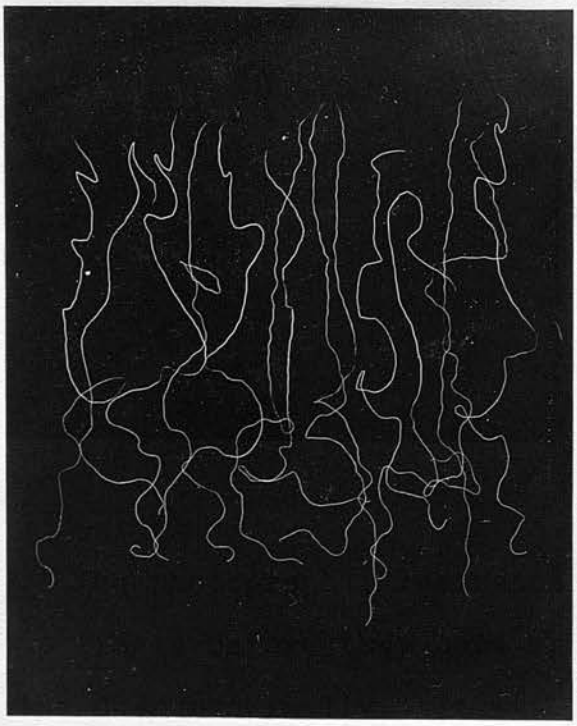

Fig. 29. The photograph illustrates a number of hybrid kemp fibres before they have reached the stage of fining down proximally. It was taken from the left side of lamb No. 150 ♂. The fibres display kempy characteristics at their distal ends, a distinct break half way along their lengths with an irregular wave proximally. They turn and twist in all possible directions especially in the proximal parts of the fibre. The relationship of the hybrid kemp fibre to the other types of fibres in the Blackfaced fleece is similar to the relationship of the Intermediate (a) type of fibre in the Ovis vignei.

sometimes shows that there is a small proportion of strong, opaque white fibres which are intermediate in structure between the long-hair and kemp. Such fibres are irregularly crimped at intervals, with plain, straight, intervening spaces along the lengths of their shafts (see Fig. 30). The modification of such a type of fibre may be the result of a response which the hybrid kemp follicle has made, probably due to the extra supply of nourishment received. It is therefore assumed that the hybrid kemp follicle is subjected to environmental conditions and retains the potentiality of producing a fibre with a coarse, white structure similar to that in the adult coat at 1 year old. It may be postulated that the hybrid kemp observed in the coat at 1 year of age is a modification of the long-hair. After the first year of growth the variation is less significant with the result that the fibre is not easily recognised. The fleeces of such lambs as show numbers of hybrid kemps should have less kemp the following season, because these hybrid kemp fibres would then be indistinguishable from the long-hair group.

The hybrid kemp corresponds to the Intermediate (a) type of fibre present in the Ovis vignei, (Fig. 1), so far as its relationship to other types of fibres is/

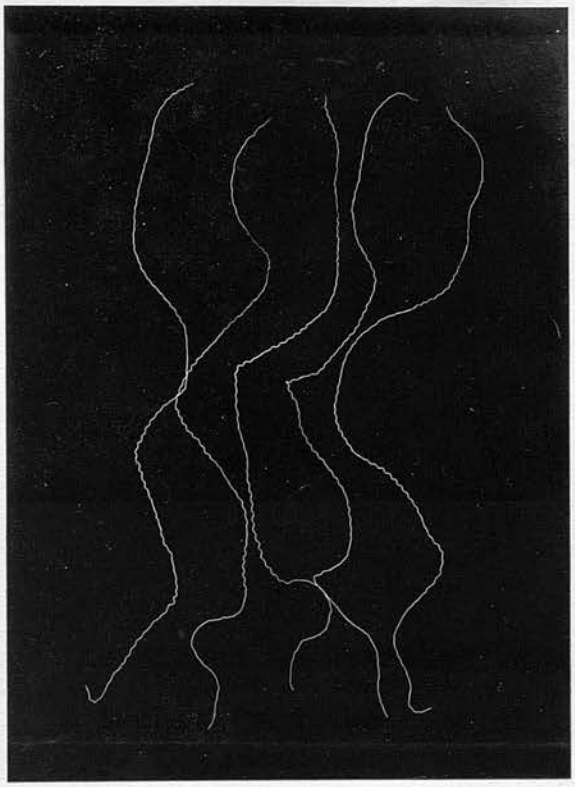

Fig. 30. The fibres illustrated were taken from the left side, 2 inches from the head of the last rib, from a heavily fed ram more than a year old. The modification of the fibres is such that they are irregularly crimped at intervals with plain, straight, intervening spaces along the lengths of their shafts. They are in all probability produced from the original Het. "B" follicles but instead of following the normal course of producing hybrid kemp, they tend to grow a fibre similar to long-hair in structure after the first clip.

is concerned. The foregoing phenomena lend some support to the theory that the modern Blackfaced fleece has evolved from that type of coat possessed by Ovis vignei.

The reduction in the amount of the kemp in the fleece is affected mechanically in two ways: firstly, by the Het. "B" fibres persisting in the fleece and therefore not being replaced by kemp fibres; secondly, by the hybrid kemp fibres changing over to the long-hair after the first season's growth. There is probably a correlation between the growing Het. "B" fibres and the hybrid kemps as regards growth and structure.

It is a well-known fact that aged Blackfaces of either sex possess fewer typical long-hair fibres in later life than they showed when young. These observations of the evolutionary differences between those fibres which develop from Het. "A" birth-coat fibres and those which develop from persisting Het. "B" fibres, suggest that these latter are shed in aged sheep earlier than the typical long-hair fibres.

VIII. DISCARDING OF FIBRES IN THE JUVENILE COAT.

Heterotype "B". The birth-coat of the Scottish blackfaced lamb has the characteristic of shedding a certain proportion of its fibres at an age of 7-8 weeks onwards. The fibres which are shed during that time belong to the Het. "B" class, and can be recognised by their proximal ends exhibiting small clubs. They are distributed free in the staple without any contact with the skin and some are pushed towards the distal end of the staple by the growing fibres (Fig. 26) and eventually escape from the coat altogether. As the coat reaches a growth of 7 or 8 months the shed Het. "B" fibres appear very similar to kemp in some respects, e.g., in colour, brittleness, length and diameter. At this stage, shed Het. "B" and true kemp fibres are easily confused with one another (Fig. 31), so that the kemp content of the fleece is liable to be misinterpreted by including the visible shed Het. "B" fibres which lie on the exterior of the fleece; in practice this should be avoided. The confusion will not arise when the kemp has increased somewhat in length; it is then quite distinct from the shed Het. "B" type of fibre. Some lambs shed their Het. "B" type of fibres earlier than others and consequently there is a difference in length/

length between these fibres in individual animals. The haunch retains the shed Het. "B" fibres in the adult coat much longer than the shoulder does and has a greater number of these fibres in comparison with the shoulder. As a result of this one should expect more kemp on the haunch than on the shoulder area which is actually the case. It will be shown later that the Het. "B" fibres are the forerunners of kemp.

Kemp. During the development of the adult coat the kemp fibres start to shed at irregular intervals. The true kemp fibres vary a great deal in length when shed on account of their difference in time of development and period of growth. In cases where a few kemp fibres have started to grow at an exceptionally late date their shedding occurs very soon, with the result that short kemp fibres are produced with two pointed ends; these correspond macroscopically in structure to those short shed kemps which are frequently found on the fore and hind flanks and around the posterior parts of the jaws.

A short-stapled fleece has the characteristic of shedding the kemp fibres at an earlier time than a long-stapled fleece and in both types the shoulder is denuded of kemp sooner than the haunch when the annual shedding starts. Darling (8) has found that in the Scottish/

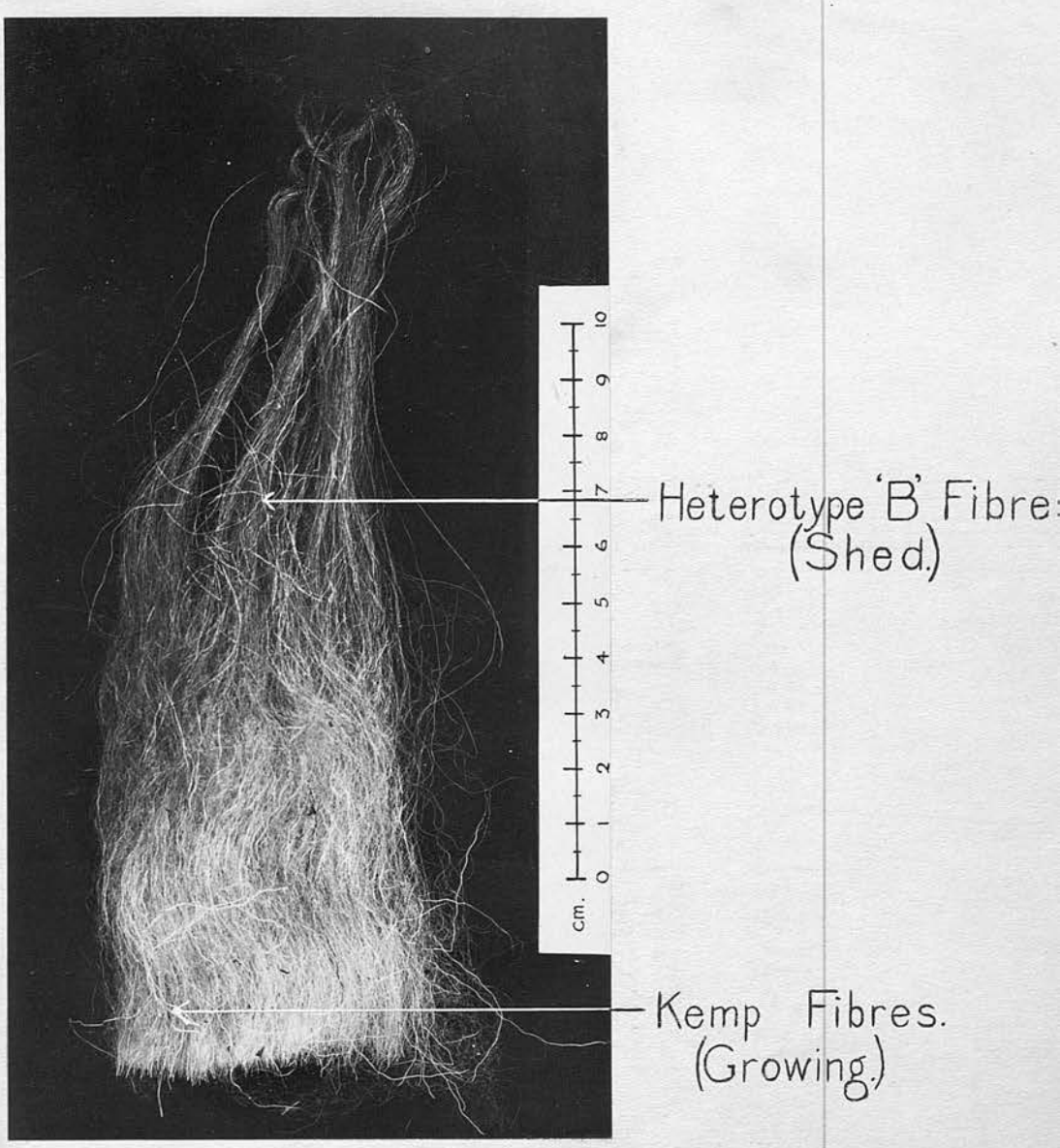

Fig. 31. A staple taken from the withers of a Blackfaced lamb at the age of 6 months. The white shed Het. "B" fibres at the distal end of the staple may be readily confused with the white growing kemp fibres towards the proximal part of the staple. This confusion may lead to a wrong estimation of the %age of kemp during the development of the coat in the first year.

Scottish Blackfaced sheep kemp gradually disappears from the shoulder area in extreme old age and it was also illustrated by Mr. W.C. Miller at this Institute that kemp may be entirely absent on the fore part of the body in aged breeding ewes, while the areas on the haunch, saddle and sides were still densely covered with kemp fibres.

It should be interesting to investigate which type of coat sheds the kemp quickest and in greatest numbers and what are their physical characteristics.

The fining down of the hybrid kemp and the shedding of the true kemp occur simultaneously (Fig. 14) in the late Winter months when new fine wool fibres are found densely packed in the fleece, the exigencies of Nature demanding a dense warm coat to protect the skin against inclement weather conditions. Environment, therefore, exerts its influence on these two related types of follicles, in that both produce a very similar undesirable type of fibre during Summer but deviate from one another during the Winter when the one fines down and the other is shed. It is accordingly postulated that environment may to some extent modify the expression of the inherited capacity to produce kemp.

If this is correct, those animals which live under/

under favourable conditions of weather and nutrition should produce a coarser type of coat with a greater proportion of coarse long-hair fibres (since some potential kemps are modified into hybrid kemps and are classed as coarse long-hair) and a reduction in the amount of recognisable true kemps, than is the case in sheep living under adverse conditions. In actuality this is particularly well demonstrated by examining samples of wool from Lanarkshire, Peeblesshire and other southern parts of Scotland where weather conditions are less severe, and comparing them with samples from the sheep on the exposed higher mountains of northern Perthshire for example. There is no doubt that the coarser class of fleece is always found on the sheep of the former mentioned districts.

The shed kemp fibres were included for density determination since they are retained in the staples constituting just as great a disadvantage to the manufacturer as if they had still been growing on the skin.

Correlation between Shedding of Het. "B" and Appearance of Kemp. There is ample proof that one follicle can produce a fibre with a heterogeneous structure in successive periods of time.

The/

The Het. "B" fibres are shed at different periods on the individual animals but the average time for shedding was determined to be from 2½ months onwards. They are shed gradually in the early stages of the development of the birth-coat and subsequently new kemp fibres develop in ratio to the shedding of the deciduous Het. "B" fibres. The following facts came to light and they suggest that Het. "B" fibres are the precursors of kemp:-

(1) The sooner the Het. "B" fibres are shed the earlier the development of kemp;

(2) The distal ends of the new kemp fibres correspond in number with the visible shed ends of the Het. "B" fibres in most individuals;

(3) The time at which the Het. "B" fibres are shed influences the length of the kemp fibres when they begin to grow, i.e., the sooner the Het. "B" fibres are shed the longer the kemp, and the later they shed the shorter the kemp, when making comparisons at that time when the fibres replace each other;

and (4) There is a negative correlation between the proportions by count of kemp and Het. "B" fibres and a correlation figure of -0.94 with a probable error of ±0.03 was obtained. The correlation indicates that the Het. "B" fibres decrease in number in direct ratio to the increase of kemp fibres.

It/

It was found by Mr. W.C. Miller at this Institute that in rare cases the tips of kemp fibres adhered to the brush-like shed, proximal ends of the shed Het. "B" fibres. It can be assumed with exactitude that the kemp fibre develops from a specific type of follicle which primarily produces a different type of fibre, i.e., the Het. "B" fibre of the birth-coat. One is justified in assuming that some new kemp follicles develop after birth on the ground that the Blackfaced breed will probably have some characteristics in common with its wild ancestor, Ovis vignei, which so far as is known produces only kemp fibres from kemp follicles. In addition to this, it is mentioned that kemp fibres are produced at variable times and the late developing follicles are possibly of an independent origin.

Darling (8) has shown that the variability of the kemp fraction is much higher than that of the long-hair and wool fraction in the aged classes of Blackfaced sheep. The evolution of the Blackfaced fleece has progressed to a stage where the kemp is preceded in most cases by a type of fibre which has structural characters in common with kemp, e.g., the mid-portional diameter of a Het. "B" fibre is the same as that of kemp. This constitutional and genetical/

genetical behaviour of the follicle can be modified by the environment to such an extent that kemp might be eliminated if some of the kemp follicles did not cast out their fibres but continued to grow. Kemp is probably the expression of one or more genetic factors which can be modified by selective breeding and environment to such an extent that this undesirable type of fibre may be eliminated from the fleece.

IX. CHANGING PROPORTIONS OF DIFFERENT TYPES OF FIBRES DURING THE COURSE OF THE EXPERIMENT.

During the development of the birth-coat the ratios of the different fibre types to one another vary from week to week. These ratios represent the percentage in counts of each type of fibre. The relative variations in successive intervals are most pronounced during the first 3 or 4 months (Fig. 32). The relative proportions of the fibre types are given at weekly and, later, at fortnightly intervals in the appendix tables, Nos. 1 to 6. Careful analysis of these tables discloses the following variation in the different fibre types:-

(1) Heterotype "B". From birth onwards the percentage of this type decreases gradually as new wool and kemp fibres commence to grow. This decrease in amount is partly due to the development of the new fibre types and not entirely to shedding. The Het. "B" fibres disappear altogether from the fleece at 5 or 6 months of age and do not reappear at a later stage. They are correlated in a positive manner with the Het. "A" class of fibres. The correlation figure is + 0.78 with a probable error of $\pm$0.083. The correlation is thus very significant. Both types of fibres decrease with increasing age of the animal (Fig. 32).

Correlations Between Different Fibre Types.

Increase = + Decrease = -	Type Of Fibre.	Correlation Figure(r).	Correlation Error(Er).
+ -	Kemp Het."B"	- 0.94	± 0.03
+ -	Kemp Long-Hair	- 0.96	± 0.014
+ +	Kemp Wool	+ 0.65	± 0.078
+ -	Wool Long-Hair	- 0.869	± 0.029
- -	Het."B" Het."A"	+ 0.78	± 0.083

These correlations were obtained by a standard formula using statistical methods.

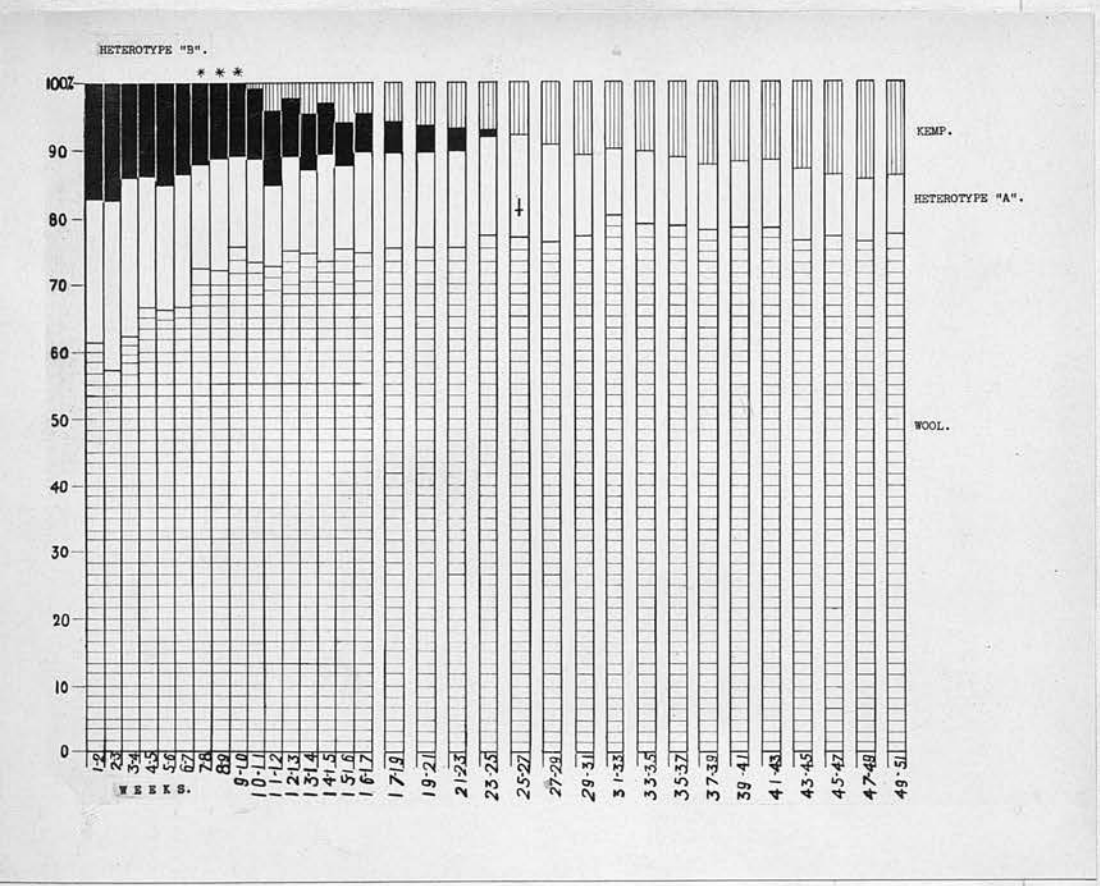

Fig. 32. The histogram represents the average percentages in count of the different types of fibres at weekly and later at fortnightly intervals. Each class of fibre is illustrated by a different method of shading.

* * * these indicate the dates when Het. "B" fibres commence to shed; it will be seen that commencement of shedding is followed immediately by the appearance of kemp fibres.

† indicates the time (25 - 27 weeks) when the Het. "B" and Het. "A" types of fibres were classed together and termed "long-hair."

There are marked correlations between the various types of fibres as shown on the opposite page.

(2) Heterotype "A". There is a marked decrease in the percentage of this type of fibre during the early stages of growth but the percentage remains fairly constant when the coat has reached the adult condition. At this stage the Het. "A" passes over into the long-hair class of fibres (Fig. 32). There is in later stages of development a significant negative correlation between long-hair and kemp; the correlation is -0.96 with a probable error of ±0.014.

(3) Wool. The wool class represents both medium wool and fine wool fibres which both increase in number up to about 2½ months after birth. In the adult stage the proportion of wool remains constant (Fig. 32). There is a significant negative correlation figure between wool and long-hair of -0.869 with a probable error of ± 0.029.

(4) Kemp. The percentage of kemp fibres increases gradually from 2½ months of age onwards, but apart from seasonal shedding they probably remain fairly constant in number in the adult coat although the process of shedding of some kemp fibres naturally influences this constancy.

The count figures for birth-coat and juvenile coat are more true biological indicators than the weight figures which are much more easily affected by environment.

Deductions. The correlation figures which were obtained from percentage counts between the different fibre types are very significant and may be used for postulating a workable theory which will harmonise with present-day breeding methods.

The proportion of long-hair and wool fibres is important, since by affording greater or lesser protection the fleece may affect the health of the sheep, and its value to the manufacturer may change. The optimum proportions of these two fibre types are probably determined by environmental conditions; i.e., a severe climate tends to reduce the number of long-hair fibres in the fleece while the wool fibres are increased in number. A milder climate, however, tends to produce an opposite change of proportions of the two fibre types resulting in an increase in long-hair.

As the animal approaches old age the long-hair fibres gradually diminish in number, the withers and shoulder areas being usually the first parts of the body to shed these fibres permanently. It is not possible to determine from the phenotypical constitution of the birth-coat what the genotypical constitution will be, since two coats with similar proportions of fibre types at birth may differ to a great extent

in/

n the proportion of long-hair fibres growing when
dult.

The casting of the long-hair fibres can be pre-
ented within limits by selection and the sheep which
re liable to shed early before old age, and their
rogeny, should be culled from the breeding stock. On
o account should rams possessing this defective,
nherited factor of early loss of long-hair be chosen
or breeding purposes.

The balance between long-hair and wool can be
ontrolled by selective breeding if special attention
s paid to the percentage of the two types present in
he juvenile coat. This necessitates further study of
he proportions of these two fibre types.

The negative correlation between long-hair and
ool indicates that while the wool proportion in-
reases the long-hair decreases with the advance of
ge. This relationship can be balanced by selecting
hose lambs with a medium birth-coat which will yield
a fleece in old age with sufficient long-hair fibres
to protect the animal, but a sufficiently low
proportion of these not to detract from the commercial
value of the fleece.

It can be conceived that under trying conditions
any attempt to increase the size of the sheep will be
detrimental;/

detrimental; nor can the staple length be increased greatly without seriously handicapping the sheep for travelling in the snow. An effort should be made to select lambs from parents which possess desirable mutton features along with a uniform fleece of good quality, especially on the belly; since the character of the wool on this part of the body is an indication of the animal's capacity to retain the growing fibres on the back in old age.

X. THE COT IN THE ADULT COAT.

During the development of the adult coat (i.e., rom about 9 months onwards) cotting usually occurs. his varies in relation to the type of coat, its ensity and the proportion of deciduous fibres in the leece. The following factors are conducive to the ormation of the preliminary cot:-

(1) A long open coat with the presence of an undercoat in the interior of the fleece;
(2) Humidity of the atmosphere;
(3) Intermingling of foreign matter with the fibres in the inner parts of the fleece;
(4) Presence of shed Het. "B" fibres;
and (5) A large proportion of hybrid kemp fibres.

(1) A coat which lacks density of Het. "A" fibres usually provides enough space for an undercoat, which is associated with the tertiary type of curl, to appear. These curls become readily intertwined, at a certain stage, with the curls of adjacent staples, foreign matter and shed fibres.

(2) The humidity of the atmosphere considerably influences the tertiary curl of the undercoat. The degree of curl is augmented by moist conditions when a very dense, undesirable mat of fibres results. This phenomenon/

phenomenon only appears under wet atmospheric conditions and disappears partly when the atmospheric conditions become dryer. Where the undercoat is absent the phenomenon is less severe.

(3) The occurrence of foreign matter greatly aids the formation of an early cot. Sheep which feed from hay-racks are frequently covered with portions of the stems, chaff, etc., from plants on those parts of the body exposed to the foreign matter. Accordingly, the cot appears earlier and most markedly on the withers, back and neck areas. The deposition of foreign matter in the fleece is very objectionable and should be avoided if possible by covering the upper parts of the hay-rack. Care and management therefore influence the cot.

(4) The cot tends to appear first at that part of the staple where some of the shed Het. "B" fibres are still interspersed among the growing fibres. The presence of the remaining shed Het. "B" fibres assists the intertwining of fibres at that stage when the wool has increased sufficiently in length to prevent them from falling out of the fleece. The shed Het. "B" fibres are not usually numerous at such a late date and the severity of the preliminary cot is thus reduced.

(5) The hybrid kemp fibres are mostly responsible for/

for the severity of the preliminary cot which extends over a period of approximately 3 or 4 months. Some of the hybrid kemps are not able to penetrate the cotted line with the result that their distal ends turn in the reverse direction back towards the skin (Fig. 29).

The early cot which arises during the development of the adult coat hinders the progress of the faster growing fibres, with the result that they deviate from the general course of growth. The long-hair fibres assume a distinct, deep wave along their proximal parts (Fig. 33). Most of the hybrid kemp fibres deviate into all possible directions (Fig. 34) while some join the long-hair fibres to produce the waves which range from the skin surface up to the line where the preliminary cot causes a hindrance. The slow-growing fibres, e.g., medium wool and fine wool, continue to grow in their normal direction, except for a few which are forced out of the line of growth by the mechanical force of the quicker growing fibres which produce the waves. When a staple, as shown in Fig. 33, is taken between the fore-finger and thumb of either hand at the two ends, the waves cannot be stretched straight on account of the limited amount of elasticity afforded by the straight growing wool fibres. It is however possible to stretch the waves straight by cutting the wool fibres with scissors.

Both/

Fig. 33. The photograph shows a staple taken from the left britch of lamb No. 152 ♀, at the stage of 9 months. A proportion of the long-hair fibres have been removed in order to demonstrate the proximal waves more clearly. The first stages of the preliminary cot are indicated. The waves towards the proximal end of the staple are mainly produced by long-hair fibres along with some hybrid kemp fibres. Most of the wool fibres, which are not clearly visible, continue to grow in their normal straight course and these slow-growing fibres prevent the attenuation of the waves after removal of the sample.

Fig. 34. The illustration displays the inter-twining of the hybrid kemp fibres at their proximal ends during the stages of the preliminary cot. The different figures in the plate demonstrate the criss-cross directions of the hybrid kemp fibres, when forced up from below by the growing follicles and obstructed above by the preliminary cotted line.

Both long-hair and hybrid kemp fibres may form loops at the preliminary cotted line and these loops further facilitate the intertwining of fibres. Short shed kemp fibres are distributed among the confused mass of fibres along with broken parts of other types of fibres.

The preliminary cot starts about 3 or 4 months earlier than the true cot and the former offers some resistance when an attempt is made to separate the individual staples for sampling purposes. This might affect the density to a slight extent if care is not taken to disregard the broken ended fibres for density determinations.

In Spring a true cot replaces the preliminary one when the great majority of the wool fibres are shed from their follicles. The process of shedding is irregular and slow and may be caused by physiological and environmental influences. Before the actual shedding occurs, all the growing types of fibres have already been reduced in diameter along a portion of their proximal ends. The ends of those wool fibres which shed are extremely convoluted, and intertwine with the similarly convoluted, terminal portions of other growing fibres to produce the true cot. Immediately after the cot there appears in the fleece a brownish-yellow line, caused by a surplus exudation of/

of yolk from the vacant follicles. Each cot is characterised by this colour band phenomenon.

The matted area extends from where the preliminary cot has started to function and gradually increases in degree to the stage where the matted area has reached the climax of the true cot. Every individual has its own "susceptible period" during which time the mature fleece starts to cot and the phenomenon is largely influenced by the constitutional and hereditary characters of the animal.

The type of coat that sheds the Het. "B" and kemp fibres at an earlier date than another type starts to cot earlier. A short dense coat cots earlier than a long open coat since the former type sheds its fibres in advance of the latter type. The average "susceptible period" is partly influenced by environmental conditions which act by modifying the diameters of the various fibre types in the first place, and the date of shedding of the wool fibres, secondly.

Discarding of Wool Fibres in the Adult Coat. The wool follicle sheds its fibre annually in Spring and is the last of the series that stops functioning. This cessation occupies some few weeks. The wool is shed at a period which is less variable than the period of initiation of its growth, since some follicles start to develop during uterine life and others/

others not until some time after birth. After the first shedding most wool follicles start to function from Mid-summer onwards, but they increase in numbers in proportion to the severity of the weather in the Winter months which necessitates a greater retention of body heat.

A tentative theory is propounded that under severe environmental conditions more wool follicles may be developed. This is possibly effected at the expense of some of the kemp fibres which are shed in Winter; they may be replaced by finer and warmer wool fibres for a better retention of body heat.

The fact that percentage counts of kemp and wool are correlated in a positive manner with a significant figure of +0.65 and a probable error of ± 0.078, appears to be strong supplementary evidence that some of the follicles can produce both kemp and wool fibres in successive periods to enable the animal to accommodate itself to extreme conditions. The contention is held that dormant wool follicles are also present which may become functional later to suit the requirements of the body. If, however, the conditions are favourable a proportion of the wool follicles may be induced to produce a coarser type of wool fibre. The reason probably is that the body needs less conservation of heat under such circumstances and the supply of nutrition is greater.

The kemp, on the other hand, will be induced to shed in smaller numbers and some kemp follicles may continue their growth to produce coarse, long-hair fibres.

Environment is the agency by which the genetical constitution of the animal is modified, to give rise to different types of fleeces in relation to the geological distribution of the Blackfaced sheep.

XI. SUMMARY

1. An investigation has been carried out on the development of the fleece of the Blackface from birth to maturity. Eleven lambs were used, serial samples were taken at weekly then fortnightly intervals from the right shoulder by the triangular method of sampling. These were analysed for density, form and structure, and a statistical survey was made of the fibres which are deciduous and those which succeed them. The phenomenon of cotting of the mature fleece was also studied.

2. It has been shown that in the birth-coat the Het. "A" fibres develop into the adult long-hairs without shedding, that typically Het. "B" fibres are deciduous and are succeeded by kemp, and that the percentage numbers of fine wool and medium wool fibres increase from birth to $2\frac{1}{2}$ months. Typical kemp fibres have a fairly constant life history in that they grow for an average of 6 to 8 months and are then shed and succeeded later by others which grow from the same follicles. Other kemp fibres may develop into a new type called "hybrid kemp", while these later may also arise from non-shed Het. "B" fibres.

3. It has been demonstrated that there is:-

(1) A negative correlation of -0.94 ± 0.03 between/

between Kemp and Heterotype "B" fibres;

(2) A negative correlation of -0.96 ± 0.014 between Kemp and Long-hair fibres;

(3) A positive correlation of +0.65 ± 0.078 between Kemp and Wool fibres;

(4) A negative correlation of -0.869 ± 0.029 between Long-hair and Wool fibres;

and (5) A positive correlation of +0.78 ± 0.083 between Heterotype "A" and Heterotype "B" fibres.

4. It has been shown that it is possible to classify the birth-coats into four distinct categories as follows:-

Type A, a dense curly type of coat;

Type B, a long open curly type of coat;

Type C, with back slightly curly and sides wavy;

and Type D, a straight-to-wavy type of coat.

These types give rise to adult fleeces which have differing percentages of kemp, differing adult densities, different characteristics and it is shown that the best lambs to select for stud purposes are those of the D type and the least desirable are those of the B type.

5. The character and transition of the curl of the birth-coat has been investigated and it has been shown that/

that lambs with a D type of coat shed their deciduous fibres earliest while those of type B shed latest. It is shown that distribution of curl in the birth-coat is associated with distribution of kemp in the adult coat. Three types of curl, primary, secondary and tertiary are discussed, and the method of their formation and their fibre constitution are demonstrated.

6. The variations in observed density of total number of fibres per unit area of the skin are given and calculations of corrected densities are made using the growth-to-skin-area proportion formula of Armsby. A table/between density and rate of body weight increase is given. of correlation/

7. The phenomenon of cotting in the adult fleece has been shown to consist of 2 phases, a preliminary when entanglement of hybrid kemp fibres occurs, and a true cot where shedding of wool fibres and their subsequent felting in the fleece takes place. The mechanical forces responsible for the cot in the fleece are discussed in detail.

8. It is postulated that it is possible to make preliminary selections of breeding animals for wool quality by reference to the type and character of the lamb's/

lamb's coat, and its behaviour during the first $2\frac{1}{2}$ months of life.

9. The results of the investigation show that it should be possible to eliminate the kemp without necessarily sacrificing the optimum relative proportions of long-hair and wool fibres in the adult fleece. Kemp is probably the expression of one or more genetic factors and its proportion and weight in the fleece can be modified by selective breeding and environment to such an extent that it can be -

(1) reduced in amount to negligible proportions;

(2) encouraged to develop into a hybrid kemp or subsequent long-hair type of fibre, which would not be undesirable;

or (3) eliminated entirely by careful and continued selection.

10. It is provisionally suggested that by suitable manipulation of the environment the character of the adult fleece may be altered within certain limits, but that fibre constitution of the fleece and birth-coat characteristics are genetical.

11. The modification of the modern Blackfaced fleece from an ancestral type similar to, if not identical with, the fleece of Ovis vignei, is suggested, and the evidence given by fibre modifications from birth to maturity is reviewed.

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XIII. BIBLIOGRAPHY.

1. Armsby, H.P. (1922),
" The Nutrition of Farm Animals ",
Macmillan & Co., New York.

2. Barker, A.F. (1922),
" Wool Analysis of a Flock of Highland Blackfaced Sheep ",
Journ. Text. Inst., Vol. 13, Pp. 3-8.

3. Barker, S.G. (1929),
" Wool, A Study of the Fibre ",
Empire Marketing Board Publ., No. 21.

4. Crew, F.A.E. and Blyth, J.S.S. (1923),
" On Fibres of Intermediate Character found in the Fleece of Ovis vignei ",
Ann. Appl. Biol., Vol. 10, Nos. 3 & 4, Pp. 295 - 300.

5. Crew, F.A.E. and Blyth, J.S.S. (1922),
" A Micrological Study of the Fleece of the Blackfaced Lamb ",
Journ. Text. Inst., Vol. 13, No. 7, Pp. 149 - 156.

6. Blyth, J.S.S. (1923),
" Micrological Analysis of Two Fleeces from Blackfaced Sheep ",
Ann. Appl. Biol., Vol. 10, Nos. 3 & 4, Pp. 301 - 311.

7. Blyth, J.S.S. (1926),
" Kemp Fibres in Fleeces of British Breeds of Sheep ",
Brit. Res. Ass. Wool. Worst. Indust. Publ., No. 59, Pp. 28 - 32.

8. Darling, F.F. (1930),
Thesis; " Studies in the Biology of the Scottish Mountain Blackfaced Breed of Sheep ",
University Library, Edinburgh.

9. Dry, F.W. (1926),
" The Coat of the Mouse, (Mus musculus)",
Journ. Genet., Vol. 16, Pp. 287 - 340.

10. Duerden, J.E. (1927),
" Studies of Sheep and Wool ",
Dept. of Agric. Union of S.Afric., Sci. Bull. No. 59, 38 pp.

11. Duerden, J.E. (1929),
" The Zoology of the Fleece ",
S.Afric. Journ. Sci.,Vol. 26, Pp. 459 - 469.

12. Duerden, J.E. and Ritchie, M. (1924),
" Development of the Merino Wool Fibre ",
S.Afric. Journ. Sci. Vol.,21, Pp. 480 - 497.

13. Duerden, J.E. and Spencer, M.R. (1927),
" The Coat of the Angora ",
S.Afric. Journ. Sci., Vol. 24, Pp. 418 - 420.

14. Duerden, J.E. and Whitnall, A.B.M. (1930),
" Seasonal Variations in the Coat of some Domestic Mammals ",
S.Afric. Journ. Sci., Vol. 27. Pp. 521 - 545.

15. Frölich, G., Spöttel, W. and Tänzer, E. (1929),
" Wollkunde " (Study of Wool),
Springer, Berlin.

16. Keller, K. (1931),
" Observations of the Accepted Theory of Heredity in Relation to Animal Husbandry ",
Abs. in Vet. Rec., Vol. 11, No. 2, Pp. 36 - 38.

17. M ' Millan, R. (1915),
" Blackfaced Sheep ",
Trans. High. Agric. Soc. Scotl., Vol. 27, Pp. 142 - 158.

18. Nichols, J.E. (1927),
" On the Occurrence of Dark Fibres in the Suffolk Fleece, with Particular Reference to the Birth-Coat of the Lamb ",
Journ. Text. Inst., Vol. 18, Pp. 329 - 333.

19. Northcroft, E.F. (1929),
" New Zealand Wool Fibres ",
N. Z. Dept. of Scientific
& Industrial Res., Bull. No.
7, 31 pp.

20. Oliver, T.(1931),
" Wool Technology and Regional Geography",
A. Walker & Son, Ltd.,
Galashiels.

21. Pease, A.E. (1929),
" Observations on Blackfaced Sheep.
Their Origin and History ",
Journ. Yorks. Agric. Soc.,
No. 87, Pp. 5-- 22.

22. Roberts, J.A.F. (1926),
" Research Work in Animal Breeding at
the College Farm of the University
College of North Wales, Bangor --- II",
Welsh. Journ. Agric., Vol.
2, Pp. 58 - 65.

23. Roberts, J.A.F. (1926),
" The Cotted Fleece ",
Journ. Text. Inst., Vol. 17,
No. 3, Pp. 171 - 179.

24. Roberts, J.A.F. (1926),
" Kemp in the Fleece of the Welsh
Mountain Sheep ",
Journ. Text. Inst., Vol. 17,
Pp. 1274 - 1290.

25. Salaman, R.N. (1922),
" The Inheritance of Fur Types and
Hair Characters in Rabbits ",
Journ. Genet., Vol. 12,
Pp. 179 - 207.

26. Tänzer, E. (1928),
" Haut und Haar beim Karakul in
Rassenanalytischen Vergleich ". (A
Comparative Analysis of Skin and
Hair in the Karakul).
Kuhn-Archiv, Band 18,
Pp. 151 - 301.

27. Wilson, J.F. (1929),
" The Meddulated Wool Fibre ",
Hilgardia, Vol. 4, No. 5,
Pp. 135 - 152.

XIV. APPENDIX TABLE; No.1.

Analyses of Right Shoulder.

WEEKLY SAMPLES.

Identification number of Lamb &	Sex.	Age in Weeks.	Percentage count of fibre group. Kemp.	H.T."B".	H.T."A".	Wool.
* 150	♂	1-2	-	16.3	29.5	54.2
151	♀	1-2	-	25.8	27.2	47.0
153	♀	1-2	-	16.6	15.9	67.5
152	♀	1-2	-	13.3	18.9	67.8
153	♀	1-2	-	14.8	13.4	71.8
Average of 5 Analyses =			-	17.4	20.9	61.7
150	♂	2-3	-	18.6	26.7	54.7
151	♀	2-3	-	20.3	26.7	53.0
153	♀	2-3	-	13.2	16.4	70.4
5	♀	2-3	-	18.8	20.7	60.5
4	♂	2-3	-	18.9	33.3	47.8
Average of 5 Analyses =			-	17.9	24.8	57.3
151	♀	3-4	-	15.9	24.3	59.8
153	♀	3-4	-	14.1	12.4	73.5
6	♀	3-4	-	18.3	21.1	60.6
2	♂	3-4	-	18.2	19.8	62.0
3	♂	3-4	-	15.2	20.5	64.3
9	♀	3-4	-	15.5	22.1	62.4
4	♂	3-4	-	14.6	32.1	53.3
5	♀	3-4	-	13.0	21.5	65.5
8	♂	3-4	-	14.3	23.8	61.9
10	♂	3-4	-	16.3	33.0	50.7
11	♀	3-4	-	14.3	21.6	64.1
18	♀	3-4	-	12.6	21.2	66.2
12	♂	3-4	-	10.8	17.8	71.4
17	♀	3-4	-	7.4	24.7	67.9
13	♀	3-4	-	14.8	27.4	57.8
16	♂	3-4	-	14.9	29.8	55.3
14	♂	3-4	-	13.3	20.0	66.7
15	♂	3-4	-	15.6	27.9	56.5
19	♀	3-4	-	19.1	33.3	47.6
20	♀	3-4	-	10.4	21.5	68.1
7	♂	3-4	-	12.9	21.2	65.9
Average of 21 Analyses =			-	14.4	23.6	62.0
151	♀	4-5	-	18.3	15.6	66.1
153	♀	4-5	-	13.3	12.2	74.5
6	♀	4-5	-	8.7	21.6	69.7
2	♂	4-5	-	15.1	20.4	64.5
3	♂	4-5	-	13.3	19.6	67.1
9	♀	4-5	-	14.2	19.0	66.8
10	♂	4-5	-	15.6	26.6	57.8
8	♂	4-5	-	13.2	21.2	65.6
Average of 8 Analyses =			-	14.0	19.5	66.5

* Twin lambs are put in a bracket, e.g. 150 / 151.

APPENDIX TABLE; No.2.

Analyses of Right Shoulder.

Weekly Samples.

Identification number of Lamb &	Sex.	Age in Weeks.	Percentage count of fibre group. Kemp.	H.T."B".	H.T."A".	Wool.
151	♀	5-6	-	19.7	19.2	61.1
153	♀	5-6	-	14.5	12.2	73.3
5	♀	5-6	-	19.8	16.8	63.4
4	♂	5-6	0.2	11.1	24.1	64.6
7	♂	5-6	-	11.2	21.7	67.1
Average of 5 Analyses =			-	15.3	18.8	65.9
151	♀	6-7	-	18.7	23.0	58.3
2	♂	6-7	0.1	12.7	18.0	69.2
6	♀	6-7	0.1	14.3	17.1	68.5
3	♂	6-7	-	10.9	17.2	71.9
9	♀	6-7	0.2	12.6	16.1	71.1
10	♂	6-7	-	14.5	28.2	57.3
8	♂	6-7	-	11.1	19.0	69.9
Average of 7 Analyses =			0.06	13.5	19.8	66.6
151	♀	7-8	-	16.8	19.9	63.3
153	♀	7-8	-	10.9	12.9	76.2
5	♀	7-8	-	13.1	10.4	76.5
4	♂	7-8	-	8.8	18.5	72.7
7	♂	7-8	-	12.2	13.7	74.1
Average of 5 Analyses =			-	12.3	15.1	72.6
151	♀	8-9	-	17.5	20.9	61.6
153	♀	8-9	0.3	10.8	8.9	80.0
6	♀	8-9	0.3	12.0	18.6	69.1
2	♂	8-9	-	11.3	15.4	73.3
3	♂	8-9	-	10.6	16.3	73.1
9	♀	8-9	-	10.0	13.7	76.3
8	♂	8-9	0.2	9.2	13.5	77.1
10	♂	8-9	0.1	11.2	22.5	66.1
Average of 8 Analyses =			0.1	11.6	16.1	72.2
151	♀	9-10	-	12.8	16.4	70.8
153	♀	9-10	1.7	10.8	9.0	78.5
7	♂	9-10	-	8.0	14.1	77.9
5	♀	9-10	-	11.0	10.4	78.6
4	♂	9-10	0.1	7.4	19.2	73.3
Average of 5 Analyses =			0.4	10.0	13.8	75.8
151	♀	10-11	-	15.5	18.1	66.4
153	♀	10-11	5.4	10.5	10.7	73.4
6	♀	10-11	0.8	11.4	16.7	71.1
2	♂	10-11	-	10.5	15.7	73.8
3	♂	10-11	0.2	9.6	12.9	77.3
9	♀	10-11	-	9.0	12.0	79.0
8	♂	10-11	0.5	7.4	13.6	78.5
10	♂	10-11	-	10.8	20.9	68.1
Average of 8 Analyses =			0.9	10.6	15.1	73.4

APPENDIX TABLE;No.3.

Analyses of Right Shoulder.

Weekly Samples.

Identification number of Lamb &	Sex.	Age in Weeks.	Percentage count of fibre group. Kemp.	H.T."B".	H.T."A".	Wool.
151	♀	11-12	-	12.8	12.8	74.4
153	♀	11-12	8.1	10.0	11.4	70.5
Average of 2 Analyses =			4.0	11.4	12.1	72.5
151	♀	12-13	2.6	10.9	13.8	72.7
153	♀	12-13	9.8	8.1	9.0	73.1
5	♀	12-13	-	6.1	14.2	79.7
4	♂	12-13	-	6.4	18.3	75.3
6	♀	12-13	2.1	11.7	16.7	69.5
2	♂	12-13	0.2	8.5	15.8	75.5
10	♂	12-13	0.7	10.5	19.4	69.4
8	♂	12-13	0.7	5.1	10.1	84.1
Average of 8 Analyses =			2.7	8.4	14.0	74.9
151	♀	13-14	7.0	7.9	13.1	72.0
153	♀	13-14	10.5	8.3	9.9	71.3
3	♂	13-14	1.4	7.8	15.1	75.7
9	♀	13-14	0.5	9.1	11.4	79.0
Average of 4 Analyses =			4.8	8.3	12.4	74.5
151	♀	14-15	7.7	6.3	13.5	72.5
6	♀	14-15	6.0	12.2	18.5	63.3
2	♂	14-15	2.0	7.7	14.4	75.9
5	♀	14-15	0.7	6.7	14.4	78.2
4	♂	14-15	0.7	7.3	17.4	74.6
10	♂	14-15	1.3	7.7	18.8	72.2
8	♂	14-15	3.7	5.8	10.7	79.8
Average of 7 Analyses =			3.2	7.6	15.4	73.8
151	♀	15-16	7.9	7.8	13.8	70.5
153	♀	15-16	11.1	2.1	9.6	77.2
3	♂	15-16	3.0	8.4	14.5	74.1
9	♀	15-16	1.8	7.9	11.2	79.1
Average of 4 Analyses =			5.9	6.6	12.3	75.2
151	♀	16-17	9.4	4.2	13.3	73.1
6	♀	16-17	3.5	8.5	18.4	69.6
2	♂	16-17	3.1	7.8	15.1	74.0
5	♀	16-17	1.3	5.1	14.8	78.8
4	♂	16-17	0.3	3.8	17.0	78.9
10	♂	16-17	2.0	7.6	20.6	69.8
8	♂	16-17	11.2	3.7	8.9	78.2
Average of 7 Analyses =			4.4	5.8	15.2	74.6

APPENDIX TABLE; No.4.

Analyses of Right Shoulder.

Fortnightly Samples.

Identification number of Lamb &	Sex.	Age in Weeks.	Percentage count of fibre group. Kemp.	H.T."B".	H.T."A".	Wool.
151	♀	17-19	9.4	1.3	14.8	74.5
153	♀	17-19	7.6	0.5	7.2	84.7
6	♀	17-19	8.0	8.0	17.0	67.0
2	♂	17-19	4.2	5.4	18.5	71.9
3	♂	17-19	3.7	7.4	15.4	73.5
9	♀	17-19	7.4	5.3	12.4	74.9
10	♂	17-19	1.8	6.9	18.7	72.6
8	♂	17-19	9.6	2.5	9.1	78.8
5	♀	17-19	4.4	3.5	13.8	78.3
4	♂	17-19	3.4	4.5	15.5	76.6
Average of 10 Analyses =			5.9	4.5	14.3	75.3
151	♀	19-21	8.8	0.4	15.8	75.0
153	♀	19-21	12.1	0.8	8.8	78.2
6	♀	19-21	8.9	4.3	19.5	67.3
2	♂	19-21	5.4	4.2	13.5	76.9
3	♂	19-21	4.5	5.3	15.5	74.7
9	♀	19-21	8.6	3.6	11.5	76.3
10	♂	19-21	1.8	7.8	20.0	70.4
8	♂	19-21	9.3	3.7	10.3	76.7
5	♀	19-21	3.5	3.3	12.1	81.1
4	♂	19-21	4.8	2.9	15.3	77.0
Average of 10 Analyses =			6.8	3.6	14.2	75.4
151	♀	21-23	11.8	0.3	16.4	71.5
153	♀	21-23	12.3	4.6	8.4	74.7
6	♀	21-23	9.5	1.2	17.4	71.9
2	♂	21-23	4.6	4.0	15.8	75.6
3	♂	21-23	4.3	4.3	16.0	75.4
9	♀	21-23	8.3	5.8	11.2	74.7
10	♂	21-23	1.8	6.6	19.4	72.2
8	♂	21-23	12.0	0.2	7.9	79.9
5	♀	21-23	5.1	1.1	11.8	82.0
4	♂	21-23	5.3	0.2	14.9	79.6
Average of 10 Analyses =			7.5	2.8	13.9	75.8
151	♀	23-25	9.5	1.3	11.2	78.0
153	♀	23-25	13.2	0.1	7.6	79.1
6	♀	23-25	9.2	1.2	18.1	71.5
2	♂	23-25	5.9	2.8	17.0	74.3
3	♂	23-25	4.2	3.0	14.2	78.6
9	♀	23-25	9.5	0.1	12.8	77.6
5	♀	23-25	4.7	0.2	12.1	83.0
4	♂	23-25	5.2	-	14.5	80.3
Average of 8 Analyses =			7.7	1.1	13.4	77.8

APPENDIX TABLE; No.5.

Analyses of Right Shoulder.

Fortnightly Samples.

Identification number of Lamb &	Sex.	Age in Weeks.	Percentage count of fibre group. Kemp.	H.T."B". H.T."A". *LONG-HAIR.	Wool.
151	♀	25-27	10.5	13.7	75.8
153	♀	25-27	15.5	8.3	76.2
6	♀	25-27	11.4	18.4	70.2
2	♂	25-27	4.9	19.4	75.7
3	♂	25-27	4.4	19.5	76.1
9	♀	25-27	9.1	11.2	79.7
5	♀	25-27	4.0	13.5	82.5
4	♂	25-27	5.2	15.1	79.7
Average of 8 Analyses =			8.1	14.9	77.0
151	♀	27-29	10.9	13.4	75.7
153	♀	27-29	15.5	10.1	74.4
6	♀	27-29	11.2	18.7	70.1
5	♀	27-29	5.3	13.0	81.7
3	♂	27-29	5.2	16.1	78.7
Average of 5 Analyses =			9.6	14.3	76.1
151	♀	29-31	11.8	15.1	73.1
153	♀	29-31	17.5	6.9	75.6
5	♀	29-31	4.4	12.4	83.2
Average of 3 Analyses =			11.2	11.5	77.3
151	♀	31-33	10.6	12.0	77.4
153	♀	31-33	16.4	6.1	77.5
152	♀	31-33	11.6	8.2	80.2
5	♀	31-33	4.3	13.2	82.5
Average of 4 Analyses =			10.0	9.9	80.1
151	♀	33-35	10.1	12.0	77.9
150	♂	33-35	11.9	11.1	77.0
153	♀	33-35	16.5	7.0	76.5
152	♀	33-35	8.3	10.8	80.9
5	♀	33-35	4.9	13.3	81.8
Average of 5 Analyses =			10.4	10.8	78.8
151	♀	35-37	9.6	12.3	78.1
150	♂	35-37	13.0	8.8	78.2
153	♀	35-37	17.3	7.7	75.0
152	♀	35-37	14.3	7.6	78.1
5	♀	35-37	3.4	13.7	82.9
Average of 5 Analyses =			11.5	10.0	78.5

*Long-Hair = Heterotype "B" + Heterotype "A".

APPENDIX TABLE; No.6.

Analyses of Right Shoulder.

Fortnightly Samples.

Identification number of Lamb &	Sex.	Age in Weeks.	Percentage count of fibre group. Kemp.	H.T."B". LONG-HAIR.	H.T."A". LONG-HAIR.	Wool.
151	♀	37-39	11.8	14.8		73.4
150	♂	37-39	15.3	9.3		75.4
153	♀	37-39	17.1	7.6		75.3
152	♀	37-39	12.4	7.4		80.2
5	♀	37-39	4.8	10.2		85.0
Average of 5 Analyses =			12.3	9.8		77.9
151	♀	39-41	9.2	13.5		77.3
150	♂	39-41	14.2	10.7		75.1
153	♀	39-41	19.5	7.0		73.5
152	♀	39-41	12.0	5.4		82.6
5	♀	39-41	4.2	12.6		83.2
Average of 5 Analyses =			11.8	9.8		78.3
151	♀	41-43	10.2	13.8		76.0
150	♂	41-43	11.8	10.7		77.5
153	♀	41-43	17.3	8.5		74.2
152	♀	41-43	13.4	6.6		80.0
5	♂	41-43	5.0	11.1		83.9
Average of 5 Analyses =			11.6	10.1		78.3
151	♀	43-45	11.9	12.6		75.5
150	♂	43-45	16.8	8.7		74.5
153	♀	43-45	17.7	9.2		73.1
152	♀	43-45	12.7	6.5		80.8
5	♀	43-45	5.2	14.6		80.2
Average of 5 Analyses =			12.9	10.3		76.8
151	♀	45-47	9.1	12.3		78.6
150	♂	45-47	15.2	7.9		76.9
153	♀	45-47	18.2	8.2		73.6
152	♀	45-47	12.1	7.9		80.0
Average of 4 Analyses =			13.6	9.1		77.3
151	♀	47-49	11.2	13.2		75.6
150	♂	47-49	20.2	6.8		73.0
153	♀	47-49	16.7	8.9		74.4
152	♀	47-49	9.4	7.0		83.6
Average of 4 Analyses =			14.4	9.0		76.6
151	♀	49-51	9.8	11.7		78.5
150	♂	49-51	11.9	10.7		77.4
153	♀	49-51	17.7	7.0		75.3
152	♀	49-51	15.7	5.3		79.0
Average of 4 Analyses =			13.8	8.7		77.5

APPENDIX TABLE; No. 7.

Live-weight and Density figures.

Identification number of Lamb & Sex.		Age in Weeks.	Live-weight in Grams.	Observed Density. (per sq. cm.)	Corrected Density.
150	♂	1-2	5108	1312	1312
151	♀	1-2	3461	2008	2008
✳152	♀	1-2	3292	2538	2538
152	♀	1-2	6243	2225	3337
153	♀	1-2	4086	2015	2015
153	♀	1-2	5675	1814	2258
153	♀	1-2	7264	1053	1543
Average of 7 lambs =			5018	1852	2144
150	♂	2-4	6583	1568	1882
151	♀	2-4	4426	1571	1854
151	♀	2-4	5221	1346	1777
153	♀	2-4	9193	2074	3561
153	♀	2-4	11066	1684	3078
2	♂	2-4	6528	2505	2505
6	♀	2-4	5533	2964	2964
3	♂	2-4	6696	2098	2098
9	♀	2-4	6611	2463	2463
4	♂	2-4	4994	2173	2173
5	♀	2-4	4994	2171	2171
8	♂	2-4	5845	2409	2409
10	♂	2-4	5504	1717	1717
4	♂	2-4	6356	1591	1898
5	♀	2-4	6356	1880	2207
7	♂	2-4	6923	2324	2324
11	♀	2-4	†	2954	2954
18	♀	2-4		3127	3127
12	♂	2-4		2685	2685
17	♀	2-4		2202	2202
13	♀	2-4		1901	1901
16	♂	2-4		1845	1845
14	♂	2-4		2523	2523
15	♂	2-4		1807	1807
19	♀	2-4		2018	2018
20	♀	2-4		2067	2067
Average of 16 and 26 lambs =			6427	2141	2208
151	♀	4-6	6923	1512	2404
151	♀	4-6	8399	1393	2521
153	♀	4-6	13336	1600	3520
153	♀	4-6	15067	1717	4100
7	♂	4-6	8853	2004	2361
2	♂	4-6	7718	2078	2323
6	♀	4-6	6923	2580	3011
3	♂	4-6	8796	2298	2758
9	♀	4-6	8739	2126	2562
4	♂	4-6	9647	2413	3742
5	♀	4-6	9534	1639	2522
8	♂	4-6	7434	2509	2945
10	♂	4-6	5959	2414	2544
Average of 13 lambs =			9025	2022	2870

✳ In some cases the lambs were sampled more than once in the given period.

† The Live-weights of lambs from No.11 to No.20 are not available; and the number of lambs regarded for the average Live-weight and Density determinations differs from 16 to 26 in number respectively.

APPENDIX TABLE: No.8

LIVE-WEIGHT and DENSITY figures.

Identification number of Lamb & Sex.		Age in Weeks.	Live-weight in Grams.	Observed Density (per sq.cm.)	Corrected Density.
151	♀	6-8	10101	1630	3325
151	♀	6-8	12258	1266	2937
153	♀	6-8	16855	1803	4635
2	♂	6-8	11804	2342	3475
6	♀	6-8	10555	2625	4058
3	♂	6-8	13676	1881	3034
9	♀	6-8	12825	2086	3246
4	♂	6-8	13733	2507	4921
5	♀	6-8	13506	2042	3965
8	♂	6-8	11917	1898	3050
10	♂	6-8	9988	1849	2749
7	♂	6-8	13279	2400	3706
Average of 12 lambs =			12540	2027	3592
151	♀	8-10	13166	1325	3233
151	♀	8-10	15209	1502	4025
153	♀	8-10	19408	1735	4901
153	♀	8-10	21111	2282	6816
2	♂	8-10	15776	2322	4182
6	♀	8-10	14528	2006	3837
3	♂	8-10	18500	2147	4230
9	♀	8-10	17592	2478	4760
4	♂	8-10	16230	2040	4476
5	♀	8-10	16457	1988	4403
8	♂	8-10	16457	2035	4056
10	♂	8-10	14528	2026	3858
7	♂	8-10	18155	2200	4180
Average of 13 lambs =			16698	2006	4404
151	♀	10-12	17762	1716	5096
151	♀	10-12	18841	1951	6029
153	♀	10-12	22757	1521	4782
153	♀	10-12	23835	1740	5639
2	♂	10-12	19181	2165	4442
6	♀	10-12	17138	2513	5368
3	♂	10-12	21905	2463	5428
9	♀	10-12	20316	2934	6199
4	♂	10-12	19408	2316	5725
5	♀	10-12	19522	2335	5791
8	♂	10-12	18501	2467	5316
10	♂	10-12	18046	2263	4992
Average of 12 lambs =			19768	2199	5401
151	♀	12-14	20657	1983	6524
151	♀	12-14	23721	2057	7426
153	♀	12-14	25764	1737	5905
153	♀	12-14	26672	1920	6700
2	♂	12-14	21678	2027	4512
6	♀	12-14	19976	2181	5158
3	♂	12-14	25310	2238	5432
9	♀	12-14	23948	2774	6541
8	♂	12-14	22473	1933	4742
10	♂	12-14	21678	2141	5331
Average of 10 lambs =			23188	2099	5827

APPENDIX TABLE; No. 9.

Live-weight and Density figures.

Identification number of Lamb & Sex.		Age in Weeks.	Live-weight in Grams.	Observed Density. (per sq.cm.)	Corrected Density.
151	♀	14-16	24232	1692	6193
151	♀	14-16	25764	2034	7749
153	♀	14-16	29056	2021	7457
2	♂	14-16	22246	2247	5089
6	♀	14-16	20487	1470	3535
3	♂	14-16	25878	1896	4672
9	♀	14-16	24516	2176	5216
4	♂	14-16	20430	1857	4750
5	♀	14-16	20430	1824	4655
8	♂	14-16	22700	1843	4552
10	♂	14-16	22019	1800	4534
Average of 11 lambs =			23432	1896	5309
153	♀	16-18	27807	1978	7101
151	♀	16-18	26105	2130	8194
2	♂	16-18	25651	2235	5567
6	♀	16-18	23381	1678	4408
3	♂	16-18	28829	2111	5588
9	♀	16-18	27353	2800	7218
4	♂	16-18	23097	1720	4773
5	♀	16-18	19976	2490	6275
8	♂	16-18	26105	2268	6151
10	♂	16-18	25310	1912	5287
Average of 10 lambs =			25361	2132	6056
151	♀	18-20	25310	2033	7664
153	♀	18-20	28375	1964	7148
2	♂	18-20	24743	1808	4397
6	♀	18-20	22927	1928	4999
3	♂	18-20	30191	1936	5285
9	♀	18-20	29169	2414	6496
4	♂	18-20	22586	2304	6301
5	♀	18-20	22530	2433	6642
8	♂	18-20	27240	2216	6180
10	♂	18-20	27694	1574	4613
Average of 10 lambs =			26076	2061	5972
151	♀	20-22	26218	1590	6137
153	♀	20-22	27694	1941	6987
2	♂	20-22	25083	2061	5143
6	♀	20-22	23267	1897	4966
3	♂	20-22	29907	2048	5554
4	♂	20-22	22927	1614	4461
5	♀	20-22	22473	1954	5325
Average of 7 lambs =			25367	1872	5510

APPENDIX TABLE; No. 10.

Live-weight and Density figures.

Identifieation number of Lamb & Sex.		Age in Weeks.	Live-weight in Grams.	Observed Density. (per sq.cm.)	Corrected Density.
151	♀	22-24	28034	1676	6771
153	♀	22-24	26616	1680	5863
2	♂	22-24	25878	1807	4526
6	♀	22-24	24062	2095	5608
4	♂	22-24	25878	1920	5750
5	♀	22-24	22870	1919	5293
Average of 6 lambs =			25556	1849	5635
151	♀	24-26	27694	1552	6209
153	♀	24-26	28715	1719	6309
5	♀	24-26	21792	2448	6539
Average of 3 lambs =			26067	1906.	6352
151	♀	26-28	28148	1740	7030
153	♀	26-28	32234	1698	6724
5	♀	26-28	22700	2554	7008
Average of 3 lambs =			27694	1997	6921
151	♀	28-30	29169	1525	6313
153	♀	28-30	32574	1815	7242
5	♀	28-30	23267	3063	8549
Average of 3 lambs =			28337	2134	7368
151	♀	30-32	29169	1665	6893
152	♀	30-32	33426	2686	8327
153	♀	30-32	33142	1739	7026
5	♀	30-32	22757	2859	7859
Average of 4 lambs =			29623	2237	7526
151	♀	32-34	30701	2201	9420
152	♀	32-34	34844	2098	10374
153	♀	32-34	33653	2163	8825
5	♀	32-34	23608	2342	6597
Average of 4 lambs =			30701	2201	8804
151	♀	34-36	31553	2275	9919
152	♀	34-36	34731	2692	13191
153	♀	34-36	33028	1703	6863
Average of 3 lambs =			33104	2223	9991
151	♀	36-38	28318	2364	9598
152	♀	36-38	34531	3372	16151
153	♀	36-38	30899	2326	8955
Average of 3 lambs =			31249	2687	11568
151	♀	38-40	27013	2074	8151
152	♀	38-40	33993	2128	10091
153	♀	38-40	31666	2166	8491
Average of 3 lambs =			30891	2123	8911