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Thesis submitted by

"B O U R N "

concerning subsection(e) 608, of
The Animal Husbandry Section of
the Master of Agricultural Science
Degree 1940.

STUDIES OF THE COAT OF THE NEW ZEALAND

ROMNEY LAMB.

practical and theoretical aspects of hair
morphology, with special reference to the
evolution of the fleece.

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INTRODUCTION.

The original purpose of the present thesis was to answer this question: "To what extent is a britch of high halo-hair abundance an indicator of the non-kemp hairiness of the fleece?" It was assumed by Dr. Dry in the light of earlier observations, that, on a britch with very many halo-hairs, the large Curly Tip fibres would be very hairy, and this has proved to be so. Especially did we want to learn about the degree of hairiness on the part of the fleece near to the britch. The gradient over the body from the britch was also much in mind, all the more because the boundary between the area on the britch with very many halo hairs and the neighbouring region with far fewer *halo* hairs is often abrupt.

The aim of the work was that just defined, but the analysis of the samples examined provided information on a number of other matters, several of which may be thought more interesting than the problem proposed at the outset. These various results are reported in this thesis.

In carrying out this work it was inevitable that I should review the facts and ideas contributed by earlier workers at the Massey Agricultural College. Their work has all passed through my mind. This little band of workers, it has been pointed out to me, has never been large and it has always been isolated. I have entered this school of thought from Professor Prawochenski's Department of the University of Cracow (Cracow, Poland) and have sometimes found myself offering interpretations alternative to those put forward at the Massey Agricultural College. These ideas have been welcomed, although those holding the older views tell me that they do not expect to prove wrong every time.

This will explain why I have dealt with my subject broadly and at some length. Not only has the method of presentation helped my working acquaintance with the class of fact and mode of thought of my new associates, but at the same time I have been encouraged to review critically the conceptions about the fleece which I have encountered in New Zealand.

x

W.F.

Guided thoughtfully by Dr. F.W. Dry, and his closest associate, Mr. J.A. Sutherland, who were kind enough to teach me the principles of Fibre Type Arrays, I was surprised to find the sheep's birthcoat such a wonderful object for a fundamental study of manifold aspects of wool. One may think that the birthcoat is a "microcosmos" of its own, and, if one has a suitable method of approach the birthcoat - I am sure - will turn out to be an indispensable object for biological studies.

Dr. Dry's pioneering work has already furnished not only the concept of approach, this being the Fibre Type arrays, but also the material for comparative study. This work and line of thought have opened up quite a new branch of biological science, which can be called "Comparative anatomy of wool". This new discipline - I am convinced - will open a large field for investigations, which will help to get far deeper understanding of wool, from the purely practical point of view. Also, it will, to my mind, throw light upon such vivid problems as those of Goldschmid's^T physiological genetics, as well as the question of evolution. Let me be permitted to give but one example. The pre-natal-check, as we understand it now, is a force, which mainly causes fibres at the head

of an array to be fine; We can distinguish at least three important properties of the check, namely:

- (i) the outset, that is, the time when the pre-natal check starts to work;
- (ii) The intensity, that is the strength of the check, whether it is powerful enough to cause the fibre to be fine throughout or in the neck region only,
- and finally,
- (iii) The extension of the check, that is, how far it extends in the Curly-Tip Group.

The pre-natal check is the result of the work of genes. This work we can measure very accurately. For instance, In Valley arrays the outset can be measured by the number of Halo-hairs and super sickle A fibres, the intensity by number of fine sickle fibres and the extension by number of checked curly-tip fibres. We can, furthermore, express the measurement as a percentage of certain fibre types, this being decidedly more advantageous and probably ~~too~~ more accurate^{too} than arbitrary terms used in Goldschmidt's "vestigial" case in *Drosophila*. (It seems to me that the work of genes causing "vestigial" in *Drosophila*, is very similar to the work of genes causing the pre-natal check in the birthcoat).

I have dealt to some extent with the question of the evolution of the fleece in the New Zealand Romney breed. The material for this part of my thesis has been growing during the course of my investigation, which indeed had nothing to do with the problem of the evolution of the fleece and therefore I could hardly be accused of "having an eye seeing what the eye looks for". Indeed, it was too great a temptation not to use data obtained in the course of the present investigation in an attempt to outline the way in which the evolution of the fleece has probably taken place.

The study of evolutionary processes requires evidence from three sources: Paleontological, embryological, and genetical. These sources are discussed in my thesis, using perhaps different wording. In passing, we may add, that by embryology of wool, is meant the developmental changes as noted in the prenatal part of a staple. It is felt, however, that an explanation must be given as to the first source. Dry's Experimental sheep could hardly claim to be paleontological examples. Nevertheless, I feel at ease to say that as far as paleontology serves as a source of evidence of evolutionary changes, Dry's Experimental flock may be regarded as a source of phylogenetical evidence of the evolution of the fleece, provided, however, that no one will agree to regard

the Merino wool (being generally of Plain array) as the most evolved wool - that is, the most removed from the wild sheep's coat, and on the other hand, the mixed woolled sheep (Blackface, Polish Cakiel, N-type- being probably at least of Plateau array) as the last evolved wool, that is, not too far removed from the wild coat. This being so, we can claim to be in a very fortunate position to have the "paleontological" evidence not in the form of fossils, but in the form of live sheep. As to me, I have had the opportunity to get acquainted with Polish mixed woolled sheep as well as Merinos. The gap between them was too broad to bridge. The bridge, however, is to be found in Dry's Experimental flock. Indeed, it was worthwhile to sail seven seas, at least, to find the "lost" links in the chain of the fleece's evolution. Yet, although my new home is remote from Central Europe, it is interesting to have it pointed out to me that the work in which I have come to take part has roots in Vienna, in Told's fibre types, and in Amsterdam, in de Meijere's fundamentals of hair arrangement and development. I am told, besides, that the voyage from Europe should have been made by the Cape, where Duerden's "birth thinning" foreshadowed the pre-natal check.

My philosophy, it is hinted to me, occasionally shows signs of running ahead of my facts. This, if it be true, is deemed a merit in the department where I work, provided one be aware of the free rein given to imagination.

It is a source of pride rather than shame in this department that a paper once submitted to Professor T.B.S. Haldane in his capacity of Editor of "The Journal of Genetics" was refused on the score of being too speculative.

Speculation is valued here for two quite different reasons. In the first place on present knowledge the surest scoring shots in livestock breeding - one naturally thinks of progeny testing - are apt to be clumsy. Deeper understanding may make defter strokes possible, and this understanding will be gained only through lively imagination.

Speculation is also welcomed because adventurous thinking is essential if our material is to yield some contribution to fundamental genetics. When indeed one reflects how willing to speculate about evolution comparative morphologists have been on less explored material, this provides our justification. To be sure, the value of

such phylogenetic speculation has been called into question by Bateson himself. Yet whatever a paleontologist can show cause to believe has taken place, it is the business of the geneticist to discover the genetic principles therein involved, and it is a very similar sort of thing that is being attempted with the manifold variations revealed in the coat of the sheep.

The importance of the pastoral industry attracted attention to wool research. Hence the intensive study of the fibre types of the Romney coat and their development. Once this investigation was well launched, the conviction came to prevail that this class of facts, serving as a basis for the planning and interpretation of experimental breeding, would be of value to pure genetics. That this is not an unreasonable probability, as pointed out before, is apparent in this thesis.

At the end of this introduction, I feel it is my duty to apologise for having written this thesis in very poor English. In spite of having started to learn English before being taught "hair-splitting" it has turned out that I am a far poorer linguist than a "hair-splitter". I hope indulgence will be granted me all the more, if one is not apt to lay ".....blame on the pear-tree for not bearing plums". (Alain).

SECTION I.

I. MATERIAL AND METHODS.

This thesis is based on a study of the birth-coats of Romney lambs, born in Dry's Experimental stock, in 1939. This flock has already been described by Dry and his co-workers (25,46) but since Section V deals with the evolution of the fleece of the New Zealand Romney it is considered necessary to describe some of the characteristics of the flock. Although no attempt will be made to give a full survey, certain points which are of great importance in connection with the evolution of the fleece will be stressed.

1. Dry's Experimental Romney Sheep.

Dry, in his recent work at Massey Agricultural College has been concerned with the genetics of kemp as well as with the genetics of wool. He has been able to build up a stock of pedigreed New Zealand Romney, with coat very different from typical Romney wool.

The foundation animals of this experimental flock, collected in 1929, were either cull Romney studs or Romney flock sheep from stud flocks. The same applies to the few animals introduced later. In view of this, anyone who has been working with a

primitive wool breed of sheep, such as native sheep of Poland, would be greatly surprised, as I was, to discover within such a stock a full range of wool types, differing in the amount of hairiness, its extension along the length of the staple, the fineness of the crimp and in other fleece characteristics, which will be described in due course.

Let us take a simple example in order to illustrate the comparison between some of the animals of Dry's flock and the primitive sheep just mentioned. According to Kaczkowski (32), and Prawochenski (40) the Polish mountain sheep of Gakiel is regarded as a typical example of a primitive sheep in which the coat consists of two main types: (i) the outer coat, and (ii) the inner coat. The former consists of two different types of fibres (i) those very hairy or "chalky" throughout their length, rigid, straight, long fibres, and (ii) a modification of these giving less hairy and shorter "transition fibres". The inner coat consists of fine short wool and is often called the down. Almost exactly analogous types are to be found in the Dry flock and we can adopt his terminology to describe the primitive fleece. Thus these most hairy and chalky outer coat fibres are no doubt largely Hairy-tip-curly-tip fibres,

the "transition fibres" are curly-tip fibres, while the down comprises heterotrichs. Very little, if any, work has been done on the shedding of fibres in the Polish Cakiel fleece, and therefore the comparison cannot be extended to the pre-curly-tip-fibre group. The latter, however, and especially halo-hairs could be linked up with certain shed fibres of the Scotch Blackfaces (34) and of wild sheep (10).

Returning now to the Experimental Romney sheep, we found that they may be roughly divided (46) into two groups, N-type and Non-N-type (17).

2. N-Type

Within this group all the intermediates exist, but as a rule the N-type is (15, 46) Grade VI! with Plateau array over the large part of the body. In other words, the N-type lambs have the coarsest birth-coat. But there are considerable variations in the coarseness, some N-type being as coarse, or coarser than the Polish Cakiel. In this comparison is included the very primitive type of Polish Cakiel, called by Prawochenski's school "KOZIARA", which is particularly coarse and primitive. It would be difficult to find any coarser long-woolled fleece among domestic sheep. Lamb No. 74 VI! (N-type) of Dry's experi-

mental Romney sheep is the most striking example of this in that samples of wool would be classed immediately as "Koziara" by one accustomed to that breed. So far N-types like No. 74 are rather exceptional. They occupy very well the extreme wing of the N-type group, which, in turn, links up with other long-woolled breeds of sheep situated lower on the ladder of the evolution of the fleece.

3. Non-N-Type

Within Non-N-type animals, again all intermediates occur. Grading of Halo-Hairs (13) ranged from VI down to I. In the N-type there is only one array to be found, namely Plateau (or near-Plateau). In Non-N-type lambs all others, including Plateau (on some regions) exist. It would not be feasible to draw a line of demarcation between the Non-N-type group of Dry's experimental Romneys and other New Zealand Romneys to be found in normal flocks. There are great variations within this group and the extreme wing can be linked up with the best Romney stud sheep.

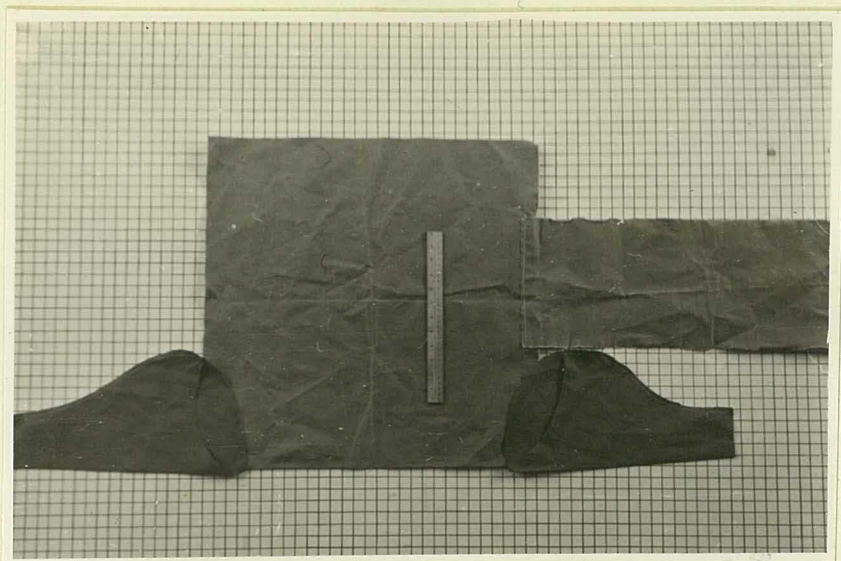


fig:1

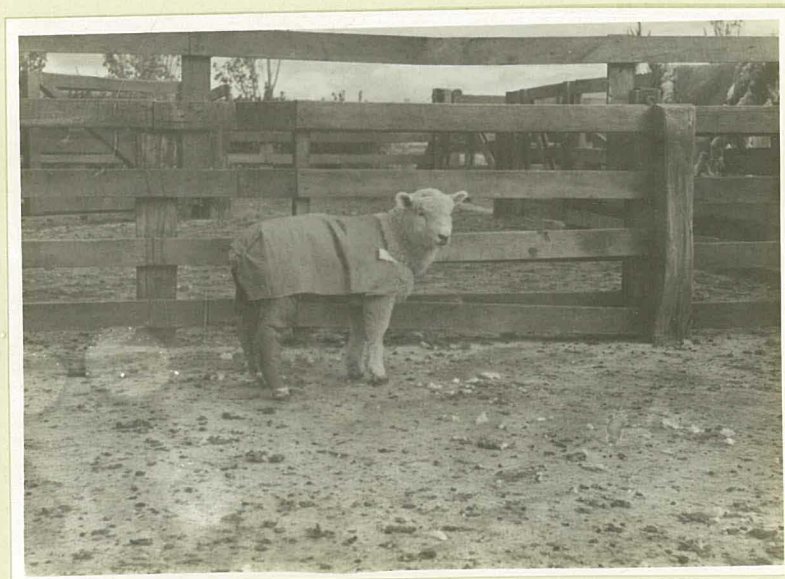


Fig. 2

Thus we can say that thanks to Dry's successful attempts to build up a stock of one breed, in which it was possible to find out all the divergence in plus and minus directions, from the common type, puts us in the position to study not only the different properties of the birth-coat, but also the progressive evolution of the birthcoat of the Romney.

4. Covering.

In order to protect the britch against the influence of weather it was necessary to alter the covers advised and described by Dry (15). These covers are shown in Figs. 1 and 2. Besides such covers, it was considered advisable to tie threads around the staples at the standard positions.

5. Sampling Positions.

There were six sampling positions, e.g.:

- (i) Britch, immediately posterior to the stifle joint and mid-way across the thigh.
- (ii) Half Britch, halfway between (i) and (iii).
- (iii) Rump On the mid-dorsal line, halfway between the standard back position and tail setting.
- (iv) Side On the right side at the distal end of

the last rib.

(v) Back, On the mid-dorsal line, level with the last rib.

(vi) Withers, On the mid-dorsal line level with the fifth rib.

6. Sampling Time

Samples were taken in the last week of January and the first week of February 1940. The lambs were from 148-181 days old, the mean being 168 days.

7. Laboratory Equipment

The equipment laboratory for sorting of fibres is very simple (46) and consists of a table covered with black velvet, two pairs of sharp pointed tweezers to grip single fibres, a microscope slide and a cover slip with a drop of benzol. This enables us to check with sufficient certainty whether some part of a fibre is medullated or not. Sometimes, as when studying the shedding situation, it is necessary to make a minute study and for this purpose a microscope is used. Further, it is desirable to have a benzol tray (23) and benzol in order to ascertain the general arrange-

ment of hairiness throughout the sample.

Although the equipment and the procedure is very simple, the conclusions to be drawn from them are often very complicated. Some six months were occupied in grasping all the details of the different features of the various arrays and during this time 136 arrays from 41 sheep were analysed.

A part of these samples, taken at three sampling times (October, February, Shearing time) belonged to Dr. Dry's stored material and were kindly placed by him at my disposal. The results of this work are not included in this thesis, but it will, on occasions, be necessary to recall some of the main features of these arrays.

I am grateful to Dr. F.W. Dry and to Mr. J.A. Sutherland for opportunities for discussing the most interesting of the arrays found and for their kindness in checking various features of the arrays.

8. Measurement.

The length of fibres was measured by means of a black ruler. The two ends of the fibre were gripped by two pairs of tweezers and stretched out until the crests of the crimps were straightened. This method was considered more desirable ^{for the present purpose} than the one used by the Polish Wool Institute.

9. Dyeing

Four lambs (N-type and Non-N-type) were dyed immediately after birth in order to ascertain -

- (i) the general arrangement of pre-natal fibres;
- (ii) the developmental cycle of post-natal fibres (histerotrichs); and
- (iii) shedding and succession.

On the advice of Mr. R. Waters, of this College, two dyestuffs were used -

- (i) Picric acid (yellow)
- (ii) Carbol Fuchsin (pink).

10. Dyeing the Sheath of Shed Fibres.

It was found that Orange G very rapidly dyes the sheaths of shed fibres, leaving the fibre uncoloured. The procedure is simple and consists merely of plunging the shed end in cold Orange G for 5-8 seconds.

11. Benzol Test.

All samples were tested by the Fleece Testing Department, using the photoelectric apparatus described by McMahon (35).

12. Tatooing.

At the suggestion of Dr. McMahon, four lambs (N-type and Non-N-type) were tatooed a few days after birth, in order to ascertain the behaviour of skin expansion in accordance with the growth of the body, especially on the hind quarters. It is hoped to publish jointly elsewhere the result of this preliminary investigation. For the present it is sufficient to mention that 9 well-defined points on the skin were tatooed and when the last observations were made on lambs at about six months, no appreciable shifting of the skin with reference to the skeleton, could be noted.

II. FIBRE TYPES AND FIBRE TYPE ARRAYS.

1. Introduction.

Dry discovered a number of fibre types in the birthcoat of the Romney. There are more or less closely related to one another, the types differing in certain characters. Thus there is sufficient difference to distinguish the fibre types and also there is sufficient similarity to show the relationship between those types. In other words, there is a transitional series of fibres easy to distinguish from each other. In some lambs the recognition of these fibre types is not difficult while in others considerable difficulties are encountered. These difficulties are due to the existence of intermediate fibres and therefore it is much better to regard a given fibre type as a series of fibres linked with preceding and subsequent types. It must, however, be emphasised, ⁱⁿ that/the majority of lambs under investigation the different types have, with practice, been clearly distinguishable.

Furthermore, Dr. Dry found differences in the number of fibre types present. In some examples certain types were not found while in others they were abundant. On the basis of "presence and absence" of a given type, he succeeded in arranging these fibre types into arrays and thus he laid the foundations of a new branch of wool zoology which might be termed "comparative anatomy of wool".

2. Fibre Types

The types of fibres found in the birthcoat of Romneys might be divided into three major groups :

- (i) Pre C.T. Group (Pre-Curly-Tip Group)
- (ii) C.T. Group (Curly-tip group)
- (iii) Post C.T. Group (Post Curly-tip group)

(i) Pre C.T. Group

consists of

- (a) Sub-halo-hairs
- (b) HHalo hairs
- (c) S.S.A. (Super Sickle A)
- (d) S.S.A' (Super Sickle A')
- (e) S.S.B. (Super Sickle B)
- (f) Sk. (Sickle fibres)

Fibres comprising this group have one common trait, e.g., the falcated tip. This sickle-like tip is better marked in super sickle and sickle series than in the remaining types of this group. These fibres

may be shed or persistent. As a rule Baby hairs and halo-hairs are all shed. All of them may be chalky. SSS.B. and Sk. may be either chalky or fine. Other details of this group will be discussed later.

(ii) Curly Tip-Group.

consists of : (a) H.T.C.T. (Hairy-tip-curly-tip fibres)
(b) C.T. (Curly-tip fibres)

Roughly speaking, there is only one point in which H.T.C.T. differs from C.T., namely the fineness of the tip. If the tip is not medullated it is fine and the fibre belongs to C.T. series provided that the tip is curled.

In my material H.T.C.T. is usually chalky throughout the post-natal region, right to the cut butt of the sample.

C.T. may be

- (a) Chalky throughout
- (b) Fine throughout
- (c) Chalky in the distal portion and fine in the proximal part.

(iii) Post Curly-Tip Group

consists entirely of Histerotrichs - that is, those fine fibres which start to pierce the skin of a lamb after birth but which are not successors of shed fibres.

3. The Fibre Type Arrays.

The arrays in order from the least to the most checked are

Plateau
Saddle
Ravine
Valley
Plain.

There are two further arrays, namely All-in and Escarpment. This latter was recognised and defined by Galpin (25). These two arrays are very rare and as they are confined to the poll and back regions they may be neglected.

Sutherland (46) defined these arrays as follows:

"Plateau: An array in which there is a complete, or almost complete lack of sickle fibres, that is, those fibres which owe their macroscopic appearance to a distinct check are absent."

"Saddle : An array in which chalky sickle fibres are found but in which there is a complete or almost complete lack of sickle fibres ⁿ time after birth."

- "Ravine: An association of fibres in which fine sickles but no checked curly-tip fibres are found."
- "Valley: An array in which the pre-natal check has been of sufficient intensity and duration to give fine sickle-fibres and checked curly-tip fibres. These latter are followed later in the array by curly-tip fibres that are definitely more robust."
- "Plain: An array in which there is little or no increase in coarseness from the fine sickle fibres to the curly tip fibres."

From the above definitions it is apparent that:

- (1) The Plateau, Saddle and Ravine arrays are defined by a lack of a particular type of fibre.

This is a somewhat negative definition, nevertheless it suits its purpose very well. This applies particularly to the Plateau array in which the lack of checked fibres is the most striking feature.

- (2) Each array, except Plateau, has its key type. In Saddle array the key type is chalky sickle-fibres while in the Ravine array the fine sickle-fibres, and in the Valley array the checked curly-tip fibres, are the key types respectively.

- (3) There are qualitative differences between arrays, e.g.

Saddle array has sickle-fibres, whereas Plateau array is lacking in this type, The Ravine array has sickle fibres, but no fine sickle fibres exist in Saddle or in Plateau arrays. The Valley array has both fine sickle fibres and checked curly-tip fibres, whereas none of the preceding arrays has them both. Only the Plain array does not differ qualitatively from the Valley array and therefore one may regard the Plain array as a super-fine Valley array.

- (4) There are quantitative differences within each array, e.g. One Valley array may differ from another as to the number of checked curly-tips; The Plain array differs from the Valley array as to the number of peak curly-tip fibres; the Ravine arrays may differ from each other as to the number of fine and chalky sickle-fibres, etc.

- (5) The classification of these arrays depends chiefly upon the pre-natal development of the fibres, although the post-natal career of indi- U16

^vidual fibres plays an important part in determining the array, e.g. if within a series of sickle fibres none of them is fine in the post-natal region the array cannot be classified as more depressed than saddle.

- (6) The Pre-curly-tip group and perhaps to a lesser extent the Curly-tip group is of decisive importance in the classification of the arrays; whereas the post-curly-tip group (Histerotrichs) is left out of account entirely.

III. FIBRE TYPES ON DIFFERENT BODY REGIONS.

A. PRE-CURLY-TIP GROUP

1. Sub-Halo-hairs.

Dry (16) described Sub-halo-hairs as "fibres which grow for a short time after birth, but are much shorter than hale-hairs, and shorter, too, than super-sickle-fibres and sickle fibres".

Sub-halo-hairs were found in three lambs in the Plateau array on the britch, though one odd sub-halo-hair was found on the rump in the Ravine array. Here, perhaps, are included baby halo-hairs, fibres like sub-halo-hairs, but finishing their growth before birth.

<u>TABLE I.</u>			
<u>No. of Lamb.</u>	<u>Array</u>	<u>Percentage of Total fibres</u>	<u>Percentage of pre-curlly-tip groups</u>
27	Plateau	0.6	6.6
46	Plateau	0.4	5.6
76	Plateau	0.6	4.3

The above Table shows that the percentage of Sub-Halo-hairs is negligible in any material which I have examined.

2. Halo-Hairs.

These fibres have been described by Dry (13) as "Hairy throughout and projecting above the rest of the coat at birth but completing their growth at about seven or eight weeks and almost invariably shedding during the next few weeks". Galpin (25), studying the prenatal development of the Romney birthcoat, has found that the first fibres piercing the skin are halo-hairs. Sutherland (46) in his very minute study of the plateau array on the back and other regions, brought to light many details of birthcoat fibres, hence it is not necessary to repeat once more what has already been described. Therefore we will confine the description of fibre types to the most important features.

(a) Halo-hair Shape

The shape varies from animal to animal and from one region to another, and even within a sample. In VI $\frac{1}{2}$ lambs, halo-hairs are not projecting above the surface of the birthcoat, but halos are bound together with super sickle fibres in broad curls. In this case they possess the same shape as the curls, namely broad and round tips. In lower

gradings than VI! the shape of the halo-hairs on the britch tends to be straight, whereas on other regions it tends to be rounded. It seems that the shape of these fibres depends upon the coarseness of the distal portion of the fibre. If the tip is heavily chalky the shape is more or less round, otherwise it is straight.

(b) Halo-hair Length.

The longest halo-hairs were found on the britch. Sometimes the differences in length are striking, but sometimes the length of halo-hairs on the britch is the same as on other regions. This is particularly true in the N-type group No.74,VI! (N-type) has very long halo-hair fibres in all six regions. When halo-hairs on the britch are compared with ones on the half-britch, the latter seem to be longer, but this difference is of no significance.

Usually, Halo-hairs are longer than all other fibres which constitute the bulk of the birthcoat. This is the rule in the more checked arrays. In arrays that are very little depressed or not at all, like Plateau or near-Plateau, the length differences are not clearly marked.

Let us illustrate this view with two examples:

No. of Lamb: 884 - (Sample 31.10.1931)

Britch - Saddle Array.

Length fibres in cm.

Halo-hairs	12-9
Super sickle A	10-6
Super Sickle A'	10-6
Super sickle B	9
Sickle	9-7
Curly tip	9-6

No. of Lamb: 1320 ♀ V

Britch - Plateau

Halo-hairs	11-9
Super sickle A	10-8
Hairy-tip-curly-tip	10-8
Curly-tip	6-2

Thus it is apparent that in less checked arrays some overlapping in the length of fibres occurs.

(c) Halo-hair Coarseness:

Within the N-type Group (VI!) there are no clear differences in the coarseness of halo-hairs on different regions of the body, but in the Non-N-Type group the coarseness of halo-hairs varies a good deal. Usually on the britch, halo-hairs were found coarser than on the other regions of the body. Whether these differences

are due to the body regions or to the different arrays it is difficult to state.

The coarseness of a halo-hair is not always even throughout length. In some halo-hairs, no matter ~~where~~ they come from, the proximal portion is much coarser, whereas the part of the distal portion which in super-sickles and sickle fibres is called the "neck" is less medullated.

In Plateau, there is no marked difference in coarseness between ^hhalo-hairs and other chalky fibres. Sometimes, indeed, Hairy-tip-curly-tip fibres look coarser than halo-hairs in the post-natal region.

(d) Halo-hair abundance on the same body region of different lambs.

For the present investigation the lambs were chosen with none or very few halo-hairs on the back standard position (Dry's Grading System, I, II and III), hence the only position with the Plateau array suitable for comparison is the britch. As is shown in the Tables in the Appendix, the abundance of halo-hairs on this region varies a good deal from animal to animal. The number of halo-hairs expressed as a percentage of total fibres ranges from 1.2 per cent to 5.4 per cent, the mean being 2.5 percent. /

Again the abun-

dance of these fibres expressed as percentage of the pre-early-tip group only, ranged from 14.9 per cent to 77.8 per cent, the mean being 30.3 per cent.

It will be interesting to note that Lamb No. 74, VI! on the back and 4! on the britch, and ^{ob}previously N-type, has less halo-hairs than a few others in this lot. We can readily understand this when we remember that in N-type halo-hairs which do not project above the surface of the birthcoat, and in tip form, are closely associated with related fibres with tips hidden in the curls of the birthcoat. For this reason it is more difficult to judge the abundance of halo-hairs.

(e) Halo-hair abundance on different body regions, of the same lamb.

Dry (16) published figures showing the correlation between grades of halo-hair abundance on different body regions:

"If one of the extremities has a very few or no halo hairs, you can count on the halo-hairs being negligible on the back."

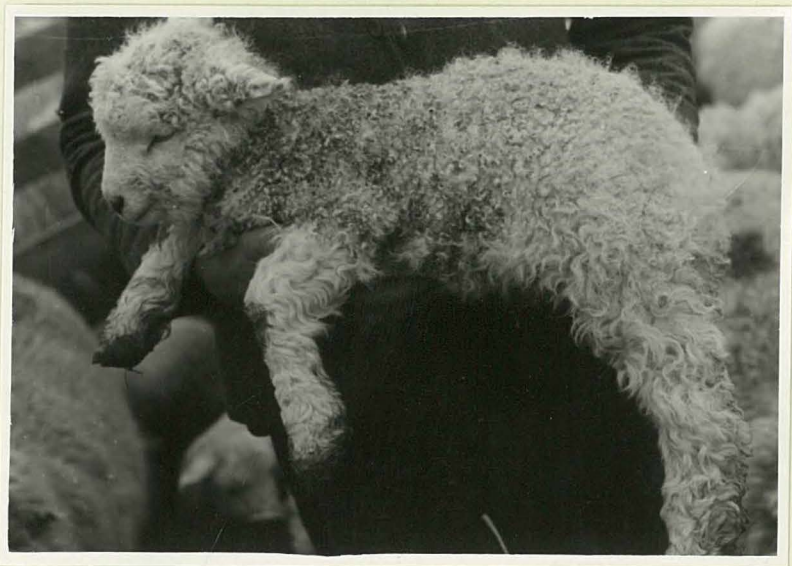


Fig. 3.

Lamb No. 196 VI! 4! with a sudden drop in
halo-hair abundance just behind the withers.

Further, he noted a sudden drop in the abundance of halo-hairs on the withers in "all lambs with the halo-hairs in appreciable abundance on the back, except some of the Very Many Grades". The present study fully confirms these statements. As to the sudden drop in the abundance of halo-hairs on the withers, it is very interesting to note that even in N-type animals such "drop" exists. The reduction of halo-hair abundance is not confined to the withers, but it reaches the shoulder and some parts of the side as well (Fig.3)

In all Non-N-type lambs in the present lot, halo-hair abundance on the britch was always higher or at least as high as on the back. For N-type lambs the data available is rather scarce, e.g:

The abundance of halo-hairs expressed as percentage of pre-curly-tip fibres.

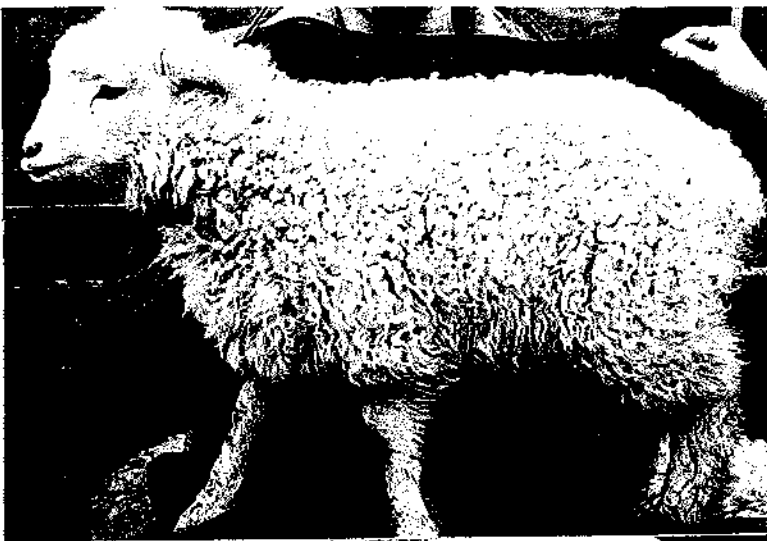
<u>No. 74 ♂ VI! (N-type)</u>	<u>No. 12 ♀ VI! (N-type)</u>
Britch	51.4
Half-britch	44.4
Rump	33.3
Side	51.5
Back	65.6
Withers	54
	56.1
	65.9
	43.7

From the above examples it is unsafe to draw general conclusions for N-type animals, but it may be pointed out that the britch does not always have the

highest percentage of halo-hairs in the pre-curly-tip group. On the contrary, the above data suggests that on the back the percentage of halo-hair may be higher and the percentage of super sickles lower than on other regions.

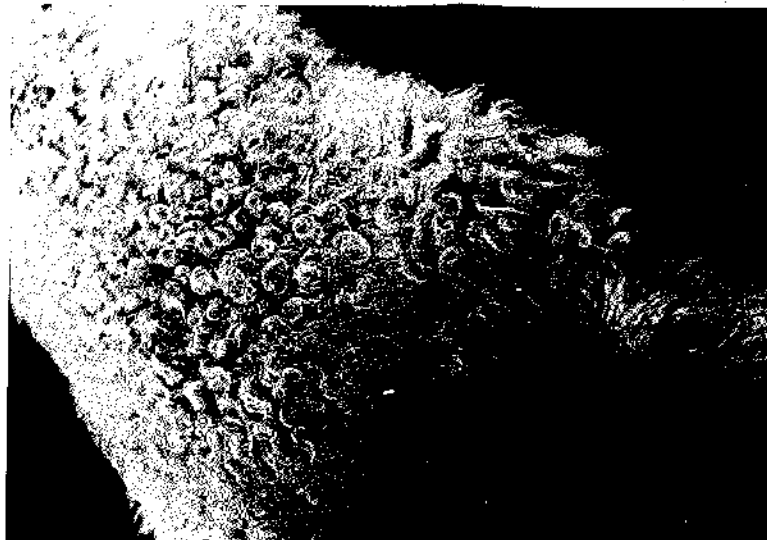
Before suggesting the significance of this preliminary finding, one should of course compare the several body regions of a larger number of lambs. It may, however, be pointed out, that in view of the increasing importance which is being given to the britch in judging the merits of the fleece, all relationships between the britch and other areas of the body deserve investigation. The practical experience of the Fleece Testing Department, Dry's work on halo-hairs, and the theoretical ideas emerging in the present research all combine to focus attention on the hind leg.

A series of plates is given that illustrates the most typical behaviour of halo-hairs on the hind quarter. This series starts with an N-type lamb (fig.4), that is the highest grade of halo-hair abundance. Lamb No. 198, VI, (fig.7), is a Borderline N-type, that is an animal in which the abundance of halo-hairs is very high, but halo-hairs are not associated closely enough with other constituents of the birthcoat - that is, they do not form the curl but are projecting above the other fibres. This picture shows that there is



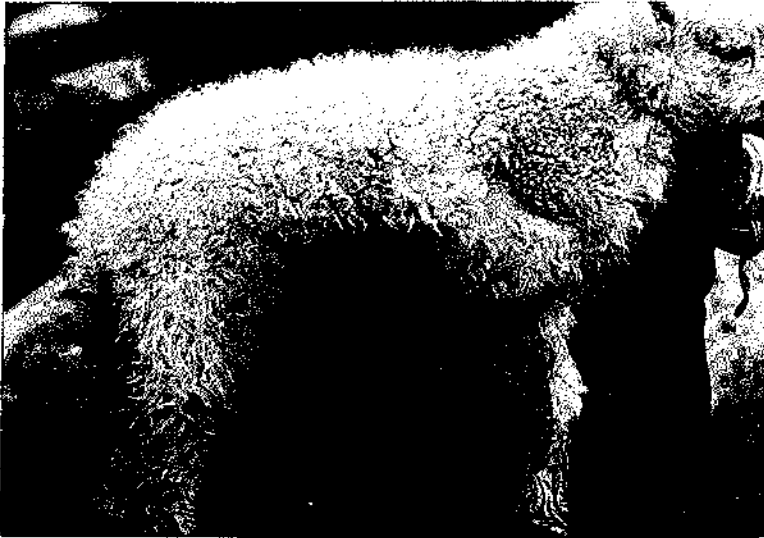
Lamb No. 105 VI: 4! (N-Type)

Fig. 4 & 5



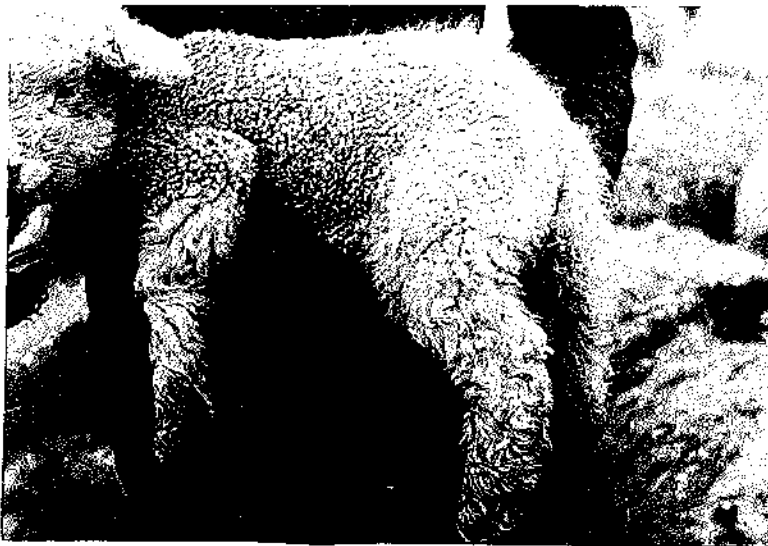
Lamb No. 79 VII: 4! (N-type)

Fig. 6



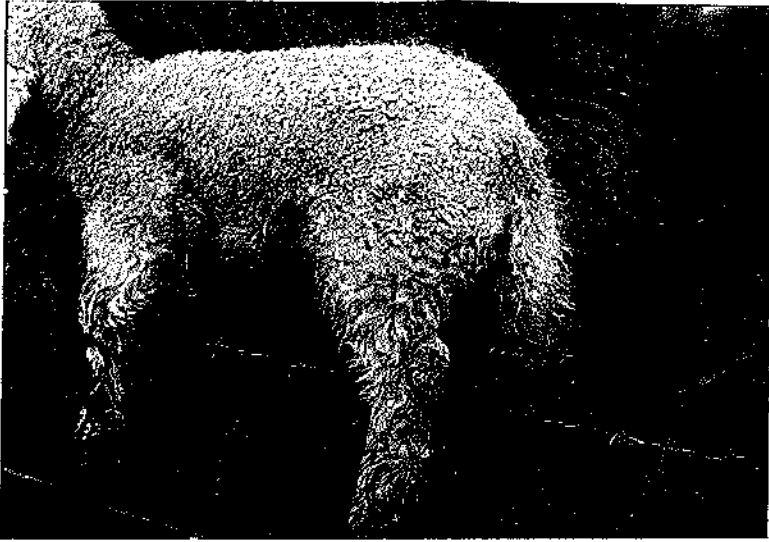
Lamb No. 198 VI - Borderline H-Type

Fig.7



Lamb No. 197 V. 4

Fig.8



Lamb No. 230 II 4

Fig.9



Lamb No. 206 II 4

Fig.10



Lamb No. 43 III 4
fig.11 & 12



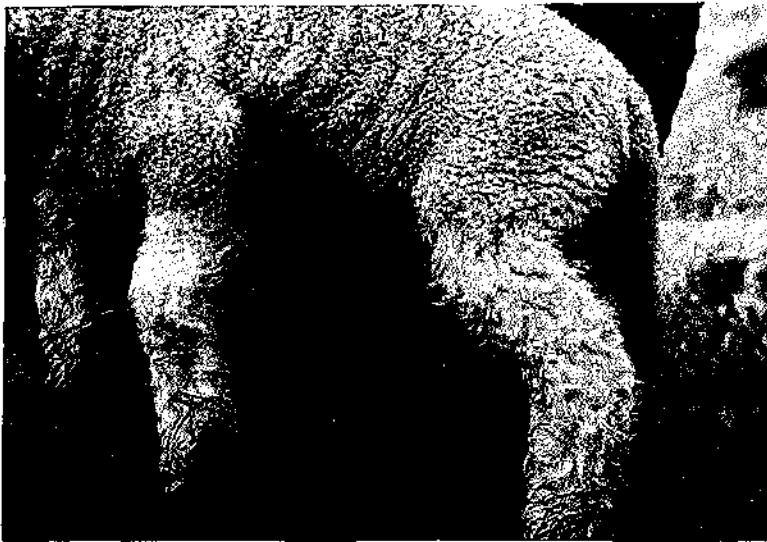
Lamb No. 46 IV 4

fig. 13



Lamb No. 81 V 4

fig. 14



Lamb No. 195 II 3

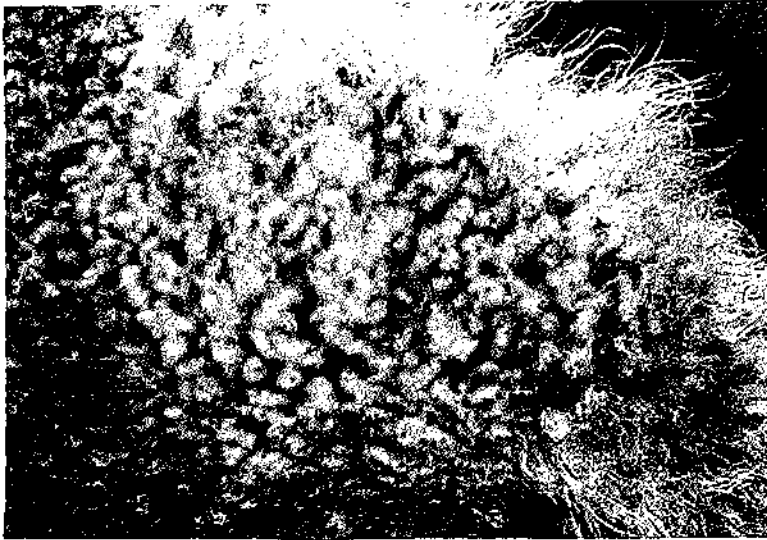
fig. 15



Lamb No. 94 II 3
Fig. 16



Lamb No. 6 II 2
Fig. 17



Lamb No. 6 II 2
Fig.18



Lamb No. 84 I 1.
Fig.19



Lamb No. 1 1 1
Fig. 20



Lamb No. 35 1 1
Fig. 21

✓
No

an appreciable decrease in the halo-hair abundance on the hindquarter, but the next picture shows us already a significant change.

The side and a rather large wedge on the hind quarter is almost entirely free of halo-hairs, but the rump has still a great number of halo-hairs. The further step is shown in Figs, 8 and 9, namely the reduction of halo-hair abundance on the rump as well as on the set of the tail. Lamb No. 206, II, 4, shows a still further step in this "clearing process". Here, however, must be pointed out that such a low abundance of halo-hairs on the tail is a rather unusual one at this stage of halo-hair abundance on the hind leg. Two further pictures (Lamb No. 43, III, 4) show that this wedge pushes its way downwards and still other pictures show the further decrease of halo-hair abundance. Thus lamb No. 195 II 3+ has a large part in the britch region free of halo-hairs, whereas lamb No. 6, II, 2 shows that the tip of this wedge already reaches the stifle joint, leaving at the same time margins of the britch with a good deal of halo-hairs, and finally the last three pictures show the britch entirely free of halo-hairs. From these pictures it is apparent that:

(i) The controlling force responsible for decreasing halo hair abundance acts firstly on the side, then wedging its way below the rump, reaches the set of the tail. Thus getting hold of a rather long base for further operations, it attacks the upper part of the hind quarter and simultaneously drives a wedge down toward the britch. As soon as the bulk of halo-hairs on the rump is annihilated it concentrates its attack on the britch and still in this wedging way it makes its way through until the field is entirely free of halo-hairs.

(ii) This process is rather clear cut, e.g. the standard britch position and the part below may be full of halo-hairs whereas only a few centimetres up the leg may be almost entirely free from halo-hairs.

3. Super-sickle A

These fibres are described by Dry (16) as "Chalky throughout the neck, coarse medulla thus being continuous from the start near the extreme tip into the post-natal region". Since halo-hairs are chalky throughout too, it is clear that in some arrays, especially

in those very little checked, that is arrays in which halo-hairs are closely associated with the rest of the birthcoat fibres, it is difficult to draw the line of demarcation between these two types of fibres. With regard to the length in such arrays as Plateau, or even Saddle, there is a gradual transition in the length of fibres from halo-hairs to super sickle A. This is, however, not the rule, for as Sutherland (46) pointed out, in such an array short "super sickle A fibres are found"; furthermore he suggested that these super sickle A fibres may be regarded as the successors of fibres which complete their growth and are shed long before the birth of a lamb. (Dry, 13). It may be recalled that in the more checked arrays, halo-hairs are definitely longer, at birth, than all other fibres and they project above the rest of the birthcoat.

(a) The Tip Shape

of super sickle A varies a good deal too. In Plateau arrays, especially on the birth of Non-N-type animals the tip of super sickle A is very often very chalky and more hook-like than sickle-like. Very often, too,

the super sickle A fibres in Plateau array on the
britch are more/closely associated with hairy-tip-
curly-tip than with other fibres. This, it will
be observed, is all part of the question of the
proportion of halo-hairs on the pre-curly-tip
group to which attention has been drawn on pages
54 and 66 . In more checked arrays, like
Ravine and Valley, the super sickle A fibres have
a very regular sickle shape; such a sickle tip
is easily distinguished from a halo-hair tip, for
the latter usually have the extreme tip fine and
then the tip becomes gradually thicker. In super
sickle fibres, when once medullation begins, a
little proximal to the extreme tip, the fibre quickly
thickens. This difference in the rate of thickening
is probably responsible for different shapes disting-
uishing halo hair tips from the tips of other fibres.
When the thickening tempo is slow the tip of a fibre
tends to be straight or at least rounded, hence the
tip shape of halo hairs. When, however, the medul-
lation starts a little proximal to the extreme tip
and rapidly thickens, the tips of such a fibre tend
to be sickle like. If the middle part of such a
sickle is over-built it becomes hook-like. This

shape is rather a common feature of super sickle fibres in the Plateau arrays on the britch. This problem is more fully discussed from a somewhat different angle in Section V.

(b) Super Sickle A Shape

It must now be recalled that the birthcoat consists of tufts or curls. In N-type animals the curls (see Tables V and VI) are rather large and resemble in general architecture the Scotch Blackface birthcoat (34) or a certain pattern of Karakul birthcoat (Goot, unpublished). In Non-N-type lambs, the tufts are diverse in their shape, composition and arrangement. Hence differences in the general shape of super sickle fibres as well as others depend to a certain degree on the shape of the tuft - in other words the general shape of a tuft is superimposed upon individual fibres.

(c) Super Sickle A abundance on the same body regions of different lambs;

Sutherland (46) pointed out, that the abundance of super sickle A depends on the array rather than on the body regions. That is true, and furthermore, as we will see later, the abundance of all other fibres depends far more on the array than on body regions.

One glance at Table II is sufficient to prove this statement. Let us, however, take a few examples in order to show the abundance of super sickle A fibres in relation both to the body regions and the arrays:

TABLE II.				
		Mean of Super sickle α expressed		
	No. of Arrays	as percentage of total fibres	as percentage of pre-curly- tip.	
Britch:	Plateau	12	3.40	41.5
	Saddle	2	1.62	19.8
	Ravine	1	0;0	0.0
	Valley	2	0.0	0.0
Half Britch:	Plateau	1	1.42	22.2
	Saddle	5	0.76	8.6
	Ravine	7	0.37	4.2
	Valley	4	0.0	0.0
Rump:	Plateau	1	3.78	60.6
	Saddle	3	0.40	4.8
	Ravine	7	0.22	2.7
	Valley	4	0.0	0.0
Side	Plateau	1	0.69	17.1
	Saddle	2	0.0	0.0
	Ravine	3	0.0	0.0
	Valley	10	0.10	0.9
Back	Plateau	1	1.39	27.9
	Saddle	1	0.0	0.0
	Ravine	2	0.20	2.5
	Valley	12	0.15	1.7

From the above Table it is plain that the abundance of super sickle A is mainly due to the array. Moreover, there are considerable variations within arrays on the same body regions, e.g. the percentage of super sickle fibres expressed as the percentage of total pre-curly-tip group in the Plateau arrays on the britch ranges from 18 per cent to 77.4 per cent, the mean being 41.5 per cent. In this light the question arises as to whether the differences in the percentages of super sickle A abundance on different body regions is of any significant importance or not. This question might be of some interest since Sutherland (46) regarded the higher abundance of super sickle A fibres as an indicator of a weak pre-natal check in low grade animals. It is feared that data in hand are too scarce to throw much light on this question. It seems, however, plausible to assume that the strength of the pre-natal check varies within an array. Thus in Saddle arrays the weakest pre-natal check is found on the britch, for this body region has as many as 19.8 per cent of super sickle A fibres, whereas half-britch has 8.6 per cent and rump 4.2 per cent. No super

sickle A fibres were found on other regions in Saddle array.

If we can, then, regard the abundance of super sickle A fibres in a given array with low grade for halo-hairs as an indicator of the pre-natal check, it seems probable that the least checked saddle array is to be found on the britch region.

4. Super Sickle A'

These fibres, Dry (16) described as:

"Chalky throughout the neck except in just a short section grown about the time of birth, the fibre immediately becoming chalky again proximately in the post-natal region".

From the above definition it is apparent that the only difference between super sickle A and super sickle A' fibres lies in the chalkiness of the "neck". If a follicle ceases for a short while to produce medulla and this happens about the time of birth, the fibre growing from this follicle becomes super sickle A'.

Thus, all that has been said in the super sickle A section, as to the length, tip form and shape applies to super sickle A' as well.

(a) Super Sickle A' Abundance

The percentage of super sickle A' fibres varies a good deal. Generally speaking, super sickle A' is numerically one of the smallest pre-curly-tip groups. Super sickle A' may or may not be present in an array. Table III shows that the super sickle A' fibres are rather scarce in the material under investigation, except in the Plateau arrays and some Saddle arrays, especially on the britch. Even in these two arrays great variations of super sickle A' fibres (expressed as the percentage of total Pre-curly-tip Group) were encountered.

For example: In Plateau arrays on the britch the abundance of super sickle A' fibres ranges from 0 to 31 per cent, the mean being 11 per cent. In the Saddle arrays, on the Half-britch portions the data obtained from five lambs is 0-22.4 per cent, the mean being 9.5 per cent; In Ravine arrays on the same position, the data secured from 7 lambs is 0-7 per cent, the mean being 2.5 per cent; finally for Valley arrays on the back (12 lambs) the super sickle A' abundance ranges from 0-15.2%, the mean being 2.8 per cent.

TABLE III			
Means of Super sickle A' expressed as percentage of:			
		Total fibres	Pre-Curly-tip-Group.
Britch	Plateau	1.02	11.08
	Saddle	2.21	22.3
	Ravine	0.0	0.0
	Valley	0.0	0.0
Half Britch	Plateau	2.13	33.3
	Saddle	0.76	9.5
	Ravine	0.65	7.48
	Valley	0.0	0.0
Rump	Plateau	0.38	6.1
	Saddle	0.40	4.8
	Ravine	0.22	2.5
	Valley	0.0	0.0
Side	Plateau	1.26	31.4
	Saddle	0.14	2.3
	Ravine	0.0	0.0
	Valley	0.20	3.0
Back	Plateau	0.33	6.5
	Saddle	0.56	6.4
	Ravine	0.96	10.5
	Valley	0.28	2.8

From the tables concerned and the few examples enumerated, ^{above} it is apparent that there again the abundance of super sickle A' fibres mainly depends on the array, although the body region must not be neglected. For more checked arrays like Ravine or Valley the standard back positions seem to have had a less severe prenatal check, or strictly speaking the beginning of this check, than on the side. It is felt, however, that

in view of such large deviations from the mean within a given array super sickle A' fibres are not good indicators of the strength of a pre-natal check.

Super sickle A' fibres are, however, of great importance from a genetical point of view, because to one who thinks in terms of "small" mutation they indicate the way in which a gene responsible for the existence of super sickle A' fibres works. This point will be discussed in detail in Section V. Here it will be sufficient to point out that, in arrays in which super sickle A' fibres do exist and no super sickle B or sickle fibres are found, namely some "tough" Plateau arrays, as for example all Plateau arrays on the lamb No. 74 (N-type) the very existence of super sickle A' fibres indicates that the genes that govern the pre-natal check have reached their threshold but only for a limited time. On the other hand, in such arrays in which no super sickle A' fibres but super sickle B and/or sickle fibres were found as, e.g. other Non-Plateau arrays, the absence of super sickle A' fibres indicates that this threshold was reached and well maintained at least until the time of birth. Whether the differences in the time in which the pre-natal check acts upon the individual fibres and determines different fibre types, are due to a number of genes or the limitation of time in which a certain gene may act, or perhaps

to still other causes, this is a problem which will be treated in Section V.

5. Super Sickle B.

These fibres are "chalky" in part of the neck, but not chalky in some portions other than, or in addition to, the non-chalky region of type A' (Dry, 16). From the above definition it is apparent that this is the type of pre-curly-tip fibres in which the greatest variations in the fineness at the neck must occur. Therefore it is no wonder that Sutherland (46) in his very minute study on the Plateau array has divided this group into four sub-groups. In view of his study it is considered not necessary to describe the super sickle B fibres as thoroughly as he has done. For the present purpose it will be quite sufficient to stress a few points only, which perhaps bring to light some interesting characteristics. In short, super sickle B is a series of fibres which ranges from super sickle A' to sickle fibres, or from super sickle A' to hairy-tip-curly-tip fibres. The last situation is of course the usual one in Plateau array.

Super sickle B fibres like all large birthe coat fibres may be shed or persistent. The shedding of fibres will be treated in a special section and therefore it will now be enough to say with regard to the shedding of super

sickle B fibres, that usually only chalky super sickle B fibres are shed, although this is not an absolute rule because fine super sickle B fibres are shed as well. The persistent super sickle B fibres may be divided into four classes. This division is based upon the behaviour of chalkiness along the fibre length and therefore has nothing to do with previous classifications (Sutherland, 46), based on the behaviour of the chalkiness in the neck region only.

As we said, the super sickle B fibres may be:

- (a) Chalky throughout;
- (b) Fine throughout;
- (c) Chalky in the distal portion and fine in the proximal portion;
- (d) Chalky in the distal as well as proximal portion, but fine in the middle part of the fibre.

This classification based on the behaviour of chalkiness in the post-natal region is obviously not confined to super sickle B fibres, but holds true for super sickle A and A' - with the exception of "2 class" (fine throughout" as well as for fibres comprising the curly-tip group. Therefore, in order to be able to distinguish super sickle B fibre from other super sickles, it is necessary to bear in mind Dry's definition based on the pre-natal part of fibres. Since the latter definition does not describe the post-natal career of a fibre it is considered justifiable for simplicity's sake to arrange super sickle B fibres into these four classes.

(a) Super Sickle B fibres chalky throughout.

This class of super sickle B fibres is very common in Plateau and Saddle arrays, especially on the britch. After a longer or shorter period of pre-natal check which causes the neck to be fine, the fibre suddenly becomes chalky again and this chalkiness is maintained throughout the fibre length. The one possible explanation is (Dry, 13) that the pre-natal check was powerful enough to cause the part of the neck to be fine, but it was not powerful enough to cause the other region to be fine as well. Genetically speaking one might say that a gene or genes responsible for "neck thinning" reached the threshold for a limited time. After that it subsides and the revival of chalkiness ensues.

This class of super sickle B fibres is of rather rare occurrence, confined to very little checked arrays and curiously enough has almost always a tip not typically sickle shaped. In an array we usually arrange the fibre type in linear order. Usually, too, the left wing of such a series is closely related to the preceding fibre type while the right wing is closely related to the subsequent fibre type. Let us explain this by an example. In an array, say Saddle, the super sickle B series, for instance, we arrange in order so that the left wing is

related to the preceding type, namely super sickle A' fibres, and the right wing is related to the subsequent type, namely sickle fibres. In such arrays two sorts of tip shape are commonly found. The first has a typical sickle shape, the second resembles more the curly-tip shape. The first type is always situated on the left wing and the second on the right wing within the series.

Furthermore, when a super sickle B series comprises chalky fibres, those of them situated in the left wing are usually shed and those in the right wing, chalky too, persist. This is why the persistent chalky super sickle B fibres are to be found on the right wing of this series.

A far more common class of super sickle B is -

(b) Fine Throughout.

This class, however, is confined to well checked arrays like Valley and Ravine and is almost always accompanied by the C class. In fact this class is very much akin to fine sickle fibres, the only difference being in the chalkiness of the neck region, namely super sickle B fibres from this class

have a shorter neck thinning than sickle fibres and this is only one difference. The tips in this class have very typical sickles.

It might be of interest to point out that in a number of Valley and Ravine arrays it has been found that the percentage of super sickle B fibres which are fine was greater than the percentage of sickle fibres which are fine. These two examples support this statement:

No. 60

Britch - Ravine approaching Valley.

	<u>No.</u>	<u>%</u>
Super sickle B, fine	7	100
Sickle, fine	14	87
Sickle, chalky	2	13
<i>Total</i>	<u>16</u>	<u>100</u>

No. 76

Side - Valley

Super sickle B, fine	9	90
super sickle B, chalky	1	10
<i>Total</i>	<u>10</u>	<u>100</u>
Sickle, fine	9	56
sickle, mild ^{ly} chalky	7	44
	<u>16</u>	<u>100</u>

In the last array even a super sickle A'

fibre was comparatively fine. This array, it is pointed out to me, affords as good an example as has ever been found in this laboratory of a pre-natal check becoming intense very early.

Far from common, however, is a series of super sickle B fibres consisting of "C class".

- (c) Chalky in the distal portion and fine in the proximal portion.

Again this class is usually accompanied by at least one of the preceding classes. Since the thinning of the proximal part of a fibre is due to "crisis thinning" (Dry, 13) this type of fibre will be treated in a section devoted to this phenomenon. Now the points will be stressed which are characteristic of super sickle B fibres. If in a given array super sickle B fibres do shed almost always, some proportion of of them persist though there is no difference detectable, at any rate by macroscopic examina-

tion, in the chalkiness or diameter of the fibres. Almost always, too, the shed super sickle B fibres are situated on the left wing of their series, that is, have sickle-like tips, while the persistent super sickle B fibres show crisis thinning after which the fineness is well maintained to the "cut point" (the bottom end of a fibre as well as a sample). The "right wing" is usually closely related either to sickle fibres or to some curly tip fibres standing most early in the array. If the first alternative is the case, some parallel arrangement is to be found within the sickle series. When on the other hand, the second alternative happens to be found, and this is the case in some Plateau arrays of a rather common appearance, the "right wing" is linked up with hairy-tip-curly-tip fibres or if these are lacking with curly tip fibres. Super sickle B fibres comprising this "right wing" of their

series are very similar to the first few fibres of the curly-tip series, and sometimes great care is to be exercised, and someone familiar with "hair-splitting" is needed in order to ascertain properly whether a certain fibre belongs to this or that series. The possible explanations of these happenings will be discussed in the second part, devoted to the evolution of the fleece. Here it will be worth while, however, to add that in a less checked array and particularly on the hind-quarter of the lamb's body a parallel arrangement is not an unusual happening, that is, the arrangement described above was simultaneously found in the same arrays, within super sickle A, or super sickle A', or both of them as well as within the sickle series. In other words, the gradual transition from one type of

fibre to the other was obscured by the presence of fibres linked directly with either hairy-tip-curly tip fibres or curly-tip fibres and thus one might speak of a "double linkage", instead of simple "chain linkage". An example from chemistry will illustrate this point better : - the structural formulae of hypochlorous acid is H-O-Cl. Let the "H" be a super sickle B series, "O" sickle series and "Cl" the curly tip series. This is a simple linkage that occurs in the majority of well checked arrays. Each link (in this case a given fibre type symbolised by a letter) is bound by means of a single bond in a chain in which each link represents a given fibre type.

In structural formula of, say, urea, the arrangement is somewhat different, namely,



Here the letter "C" has as many as four bonds. Let us again denote the hairy-tip-curly-tip as "C"; curly tip fibres as "O" and super sickle B series as well as sickle series as NH₂, even the latter can be shown in the form $\begin{matrix} \text{H} \\ \diagup \text{N} \diagdown \\ \text{H} \end{matrix}$ and thus to denote the left and right

wings as well as the middle part of the fibre type. From these comparisons it is plain that

- (a) in some little checked arrays each series may be linked up directly with hairy-tip-curly-tip series or curly-tip series, and
 - (b) instead of forming a single chain it forms a double one.
- (d) Super sickle B fibres chalky in the proximal as well as distal portion, but fine in the middle part of the fibre (dy class.)

This class was found to be of very rare occurrence, in my material. In fact, it was found only in one array (Lamb No. 82, Ravine, Side). This case may be of some interest in throwing light on the way the follicle works and therefore these fibres should receive some mention here. These fibres, judging from the tip form, belong to typical super sickle B series, that is, the tip shape is typical for super sickle B fibres as well as the "neck thinning". After that the medulla revives and the distal part of the fibres is chalky. This chalkiness extends to "crisis thinning" and then

the fibres become fine for a rather long distance (3-4 cm) and then the medulla reappears and is sustained down to the "cut"bottom.

(e) Tip shape of super sickle B fibres.

It was pointed out earlier that the tip shape of super sickle B fibres does not differ greatly from that of other fibres in this group, no matter whether these are super sickle A, super sickle A' or even sickle. However, looking at tips from the evolution point of view one might make a rather general statement, namely that more perfect tips are found within super sickle B series than within the two preceding series. This is true so far as typical sickle-like tips go. Again, one might be tempted to explain the improvement of the tip form by means of the rate of thickening of the tip as it was already outlined on page 36.

If the thickening is rapid after a while the follicle turns abruptly over to produce the very fine neck, the fibre loses its solid foundation and is apt to have a sickle-like shape, providing that other fibres do not interfere. Very often, however, they

do, and this being the case, the sickle end is entangled in the coils of a spring, for the tips of fibres in well checked arrays are very much like a spring. Sometimes it happens that the chalky part of a tip is comparatively long and rigid, and in this case the shape of the pre-natal portion of this fibre, without being coiled, is curved like the external margin of a tuft. This has already been mentioned on page 37 and will be further discussed in the sickle section.

(f) Super sickle B abundance.

Sutherland (46) pointed out that super sickle B, (if present in Plateau array, may be regarded as an indication of a rather strong pre-natal check, and furthermore he based the judging of toughness or weakness within Plateau arrays on the presence and abundance of super sickle B fibres. Thus if in a given Plateau array no super sickle B fibres are found, that means that this Plateau array is a very tough one, that is, one in which the pre-natal check is so weak, that it can leave a very slight trace of its existence, e.g. super sickle A' only. On the

TABLE IV.

THE PERCENTAGE OF SUPER SICKLE B FIBRES EXPRESSED

		Mean of total fibres	Mean percentage of curly-tip group.
Britch	Plateau	1.4	15.0
	Saddle	3.4	39.7
	Ravine	0.0	0.0
	Valley	0.7	11.1
Halfbritch	Plateau	-	-
	Saddle	2.6	36.5
	Ravine	1.4	16.2
	Valley	1.0	13.1
Rump	Plateau		
	Saddle	1.2	13.0
	Ravine	1.7	19.7
	Valley	0.7	6.6
Side	Plateau		
	Saddle	1.9	22.1
	Ravine	1.7	23.8
	Valley	1.3	22.3
Back	Plateau		
	Saddle	1.8	21.3
	Ravine	2.5	23.4
	Valley	1.1	12.1

other hand, if a certain Plateau array has an appreciable number of super sickle B fibres, the array is a "weak" one because the pre-natal check was strong enough to cause the "neck thinning" and hence the importance of super sickle B fibres in the Plateau arrays. In other arrays than Plateau the key type has been shifted to sickle fibres and curly tip fibres and therefore the abundance of super sickle B fibres is not of outstanding interest in determining the intensity of the pre-natal check but if it should happen that super sickle B fibres are fine, this is taken to show that the check becomes intense early.

Table IV gives the abundance of super sickle B fibres. In studying this data it must be remembered that it is only averages which are given and plus and minus deviations are very great. On the other hand, the actual data collected is too scarce to enable us to draw any inference based on statistical methods. Thus - to give a few examples - the abundance of super sickle B fibres in Plateau arrays on the britch has been computed from twelve animals. Out of these twelve only 3 Plateau arrays lack super sickle B fibres. Thus these three arrays represent the "toughest" Plateau arrays in our lot. The rest arranged from weakest to toughest are as follows

<u>No. of Animal</u>	<u>Percentage of super sickle B expressed as percentage of Pre-curly-tip fibres.</u>
75	2.4
76	4.3
82	6.4
46	16.6
27	28.8
44	26.8
81	30.7
43	36.8
8	38.0

the mean being 15 per cent.

For Saddle arrays on the half-britches the data obtained from five animals, represents a trend which starts on a much higher altitude than in Plateau array. In fact the lowest percentage found in Saddle arrays on the britch is as high as the mean for Plateau arrays and as will be later shown this statement applies to all other saddle arrays.

Saddle arrays on the half-britches

<u>No. of Lamb</u>	<u>Percentage of super sickle B fibres expressed as percentage of total pre-curly-tip group.</u>
8	15.0
11	27.5
65	38.8
27	42.9
48	58.3

Saddle Arrays on other Body Regions

<u>Brit</u>	<u>No. of Lamb.</u>	Percentage of Super sickle B fibres expressed as the percentage of total pre-curly-tip-group.
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<u>Britch</u>	6	33.2
	64	46.2

The mean being 39.7 per cent.

<u>Rump</u>	8	7.0
	11	33.4
	48	0.0

The mean being 20.2 per cent

<u>Side</u>	8	28.4
	81	15.9

The mean being 22.1 per cent

<u>Back</u>	82	21.3
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From the above tables it is apparent that the percentage of super sickle B fibres in the saddle arrays is much higher. This result must have been expected, because the very existence of saddle array depends upon a much stronger pre-natal check than that working in Plateau array.

Therefore a stronger pre-natal check must cause more pre-curly-tip fibres to become at least super sickle B fibres, hence the lowest percentage of super sickle B fibre abundance is at least

(1) as high as the mean for Plateau arrays and furthermore,

(2) the deviation from the mean is appreciably reduced.

The rump regions of lambs Nos. 8 and 48 with none or very low percentage of super sickle B fibres furnish exceptions, but these exceptions are easily understood. As it has been said the pre-natal check determines the arrays. If it is a weak one it is not powerful enough to cause an appreciable number of pre-curly-tip fibres to be sickle fibres and the array is nothing else but Plateau. If it is stronger and does produce sickle fibres, it is understandable that the existence of sickle fibres involves a change in the percentage of other pre-curly-tip fibres; hence the centre of gravity must be shifted. The centre of gravity within pre-curly-tip fibres lies in little checked arrays either in halo-hairs or super sickle A fibres, but in more checked arrays this centre must lie in super sickle B fibres or sickle fibres respectively.

This is the one possible explanation to the above-mentioned cases and of course when analysing these two arrays we can see that these two particular arrays have got a very strong pre-natal check, which has shifted the centre of gravity of pre-curly-tip fibres to the sickle fibre series, for in the pre-curly-tip group only 7 per cent comprises super sickle B fibres and 93 per cent sickle fibres, and in the second case all pre-curly-tip fibres are sickle fibres.

Summarising we can say that :-

- (i) Super sickle B fibres play a very important role in determining the "toughness" within Plateau arrays. In more checked arrays, however, the indicational function of super sickle B fibres has been shifted to sickle fibres or checked curly-tip fibres. That shifting is due to the pre-natal check.
- (ii) In comparisons of the abundance of super sickle B fibres in Plateau and Saddle arrays the latter is found to be appreciably richer in super sickle B fibres.

(iii) With regard to other arrays it might be generally stated that Valley array tends to have less super sickle B fibres than either Ravine or Saddle arrays.

6. Sickle fibres.

This series of pre-curly-tip fibres is of very great importance, for the classification of nearly all arrays of fibre types depends upon the sickle-fibres. It may be recalled that the very definition of Plateau array hinges on the absence of sickle fibres and Saddle array owes its existence to the presence of chalky sickle fibres, whereas Ravine, Valley and Plain arrays are determined by the presence of fine sickle fibres within the pre-curly-tip group. It is thus natural that the career of sickle fibres during their pre- and post-natal development should be studied by Dry. This particular type of fibre is of still greater interest, since other workers in wool zoology succeeded in revealing the existence of sickle fibres in other breeds of sheep. Thus Duerden (18,22) prior to Dry, has discovered sickle fibres in the South African Merino and he states (22) that sickle fibres have been found on the birthcoat of practically all the British breeds".

Here a reservation must be made as to the definition of sickle-fibres, because it seems that Duerden's classification comprises super sickle fibres as well). Galpin (25) had found sickle fibres in New Zealand Merino and Ryeland breeds and finally Sutherland (46) found this fibre type both on the Merino and Wensleydale breeds.

(a) Definition

Dry(13) described this fibre type as follows :-

"Tip region shaped like a sickle and often hairy; portion of fibre below sickle, and grown before birth, fine not hairy".

He also described in different publications the variations within the sickle fibre series and therefore it is proposed to focus attention only on such characteristics as care of most importance, in getting a better insight into the forces at work in the birthcoat of the Romney sheep.

(b) Tip Shape

As it has already been mentioned in the preceding chapters, the shape of the tip of the pre-curly-tip group varies a good deal. In all less checked arrays, that were found especially on the Britch, the half-britch and rump regions the tip shape of sickle fibres is by no means perfect. Sometimes it was very

difficult to ascertain whether a certain fibre belonged to the pre-curly-tip group or curly-tip group. The difficulties encountered were mostly due to non-typical tip shape. Such a non-typical tip approaches in form the tip of the hairy-tip-curly-tip series or curly-tip series, and almost always furnishes the right wing of the pre-curly-tip series. Generally speaking when a fibre starts to grow, and at the same time the chalkiness begins, the distal end of a fibre quickly thickens and becomes sickle or hook-like. If the middle part of the tip curve is rounded, the tip resembles, of course, a hook or curl rather than a sickle. This is always so when the chalkiness starts to thicken immediately; that is, the chalkiness begins to appear practically at the time when the fibre starts to grow, and this chalkiness is well maintained until the pre-natal check comes.

ⁱⁿ
Now/a typical sickle-like tip the medullation behaves quite differently. The fibre starts to grow with a fine tip and the chalkiness begins to appear slowly or even very slowly and gradually the further from the extreme/end the distal

thicker is the fibre. Usually it seems as though the pre-natal check gives the chalkiness a chance to reach its peak and then the pre-natal check comes. It is so powerful that it abruptly causes the cessation of the production of medulla in the neck regions. This transition from the sickle tips to the neck occurs so suddenly and the change in the diameter between the stock of the sickle and neck region is so manifestly and profoundly marked that Dr. Dry (13) could not help remarking "Indeed, one might well regard the roots of sickle fibres as displaying great resource and ingenuity in discovering varied lines of action".

Thus we arrive at the conception that the action of the pre-natal check is not only responsible for the fineness of the neck but also for the bend of the stock of ^{this} its tip. It is reasonable to believe that the pre-natal check changing the diameter impairs the solid and broad foundation of the tip and the stock bends. The differences in the tip shape within sickle fibre series might be as well explained on the behaviour of chalkiness. It has already been said that the time the medullation appears, and the

rate of thickening, play a significant role in determining the different variations in the tip shape, e.g. in the hook or curl like tip off the sickle fibre the chalkiness starts from the extreme distal end and is well maintained until the neck. In typical sickle-tips, however, the chalkiness appears a bit later, thus leaving the extreme distal end fine. Moreover, the chalkiness gradually thickens and thus the diameter is gradually augmented again until the neck, and consequently the tip is a perfect one, and strictly speaking resembles more closely a scythe than a sickle. In dealing with halo-hairs (p.26) it has been emphasised that the same factors might be responsible for halo-hair shape, namely the lack of pre-natal check and the manner in which the medulla begins to thicken. This idea was also emphasised in dealing with other fibre types belonging to pre-curly tip groups and the explanation has been put forward showing how the typical and non-typical form of each series might result from the interaction of these factors. This hypothesis that the tip shape depends upon the interaction of

- (a) the rate of thickening of medulla and
- (b) the pre-natal check, leads

leads to the one conclusion - namely that the differences

in the tip shape are not confined to one particular series of fibre types, but are a common feature of the pre-Curly-tip group.

It is feared, however, that this hypothesis attempts to reveal only one part of the truth, but this is not the whole story. It is realised that behind the force just described there are others, the method of working of which is still unknown. One of these we have mentioned in preceding chapters, that is that the general shape of a tuft is superimposed upon individual fibres. The influence of tuft shape upon sickle fibre will be discussed at the end of this chapter. Now let us consider other features of the sickle-tips, that is -

(c) Length and Hairiness of Sickle Ends.

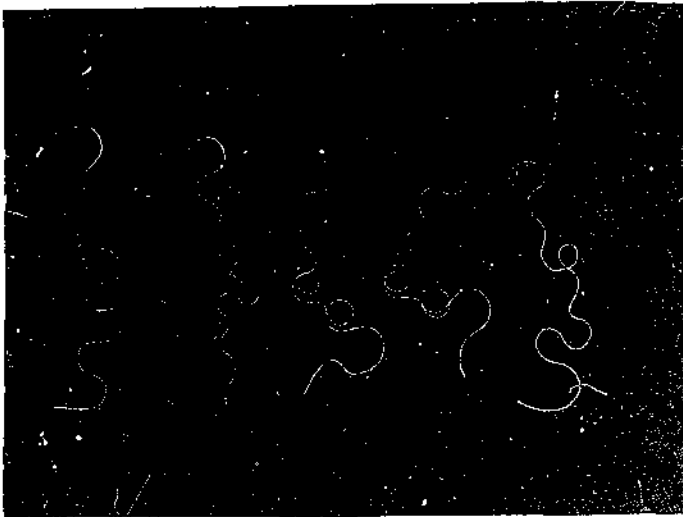
Dry in his publications concerning the birthcoat described the variation in the length as well as in the chalkiness of sickle-ends. In these features there are great differences between wool samples. Within the same wool sample, sickle fibres have been found forming a continuous series, from astonishingly large ended fibres to fibres with very small sickle ends. In different specimens we encountered different gradients as we pass from left to

right along the sickle series. The lengths of sickle fibre ends are of great importance since Dry (16) found a relationship between large-ended sickle fibres and the shedding situation of the successors (G_2) of shed birthcoat kemp. Here it may be pointed out that no measurement of the sickle ends length is available and a comparison may be made within a series of sickle fibres from one array. Some arrays have a sickle fibre series in which it was possible to arrange the sickle fibres in order of the length of the tip from "large ended" on the left wing to "small ended" on the right wing. It is especially interesting that such a series were found in so-called "truncated" arrays, that is, an array in which the first fibres of the pre-curly-tip group were Super sickle B or sickle. The differences in the length of the tip may be explained again in only one way, namely that the pre-natal check which is responsible for forming sickle fibres starts to work at a given time and causes the necks to be fine, but the fibres do not pierce the skin in one short period of time. As Galpin (26) has shown, new follicles are constantly being founded. When the genes responsible for the existence of



fig. 22

A rather large sickle end entangled in the coil
of a spring.



Showing relationships between sickle fibres and curly-
tip fibres:

Fig. 23 : Lamb no. 11, Valley on the back; 2 sickle
fibres and 3 peak curly tip fibres.

fig. 24 : Lamb no. 11, Saddle on the rump; 1 sickle
fibre and 2 curly tip fibres.

> sickle fibres reach their threshold or in other words, when the pre-natal check starts to act, it must act on ^{un-}an/even lot of fibre tips, hence the differences in the length and hairiness of the sickle fibre tips. Indeed the differences are ^{very} great. In some arrays the right wing of the sickle fibre series consists of sickle fibres having very tiny sickle ends and great care must be exercised in order to put these fibres into a proper series. The difficulties will be better understood when we recall that the sickle-end must not necessarily be a chalky one. In the light of the preceding discussion it will be understood that the shorter the sickle end the less chance for it to be chalky. Furthermore, the general shape of a tuft is superimposed upon individual fibres and in very well checked arrays like Valley or Plain, such a tiny sickle end is usually entangled in the coils of a spring and it is very much like the tip of a curly tip fibre (Fig. 22). There are cases in which it was impossible to decide whether these fibres were sickle or curly tip and in such a case we usually speak of a very close association between sickle and curly tip fibres (Figs: 23, 24) e.g. Lamb No. 27, Ravine (in rump), and Lamb No. 44,

Valley on Half-britch, with 9 and 5 intermediate fibres, this being 1.7 and 2.9 per cent of total fibres respectively.

Thus we have discussed the right wing of the sickle fibre series closely associated with the curly tip series. Now the left wing of the sickle series deserves mention as well. It was said that the left wing usually consists of large ended sickle-fibres and therefore it cannot be hidden in the coils of the neck spring. This being the case, no difficulties in recognition of sickle fibres were encountered.

This close association of two types of fibres or linkage between two fibre types has already been dealt with in the super sickle B chapter. The "double bond" has been shown whereby the super sickle B and sickle are linked up directly to the hairy tip curly tip fibres. Now one example of such a linkage will be enough to illustrate that if a tip shape is non-typical this is almost always confined to little checked arrays like some Saddle arrays or to a lesser extent Ravine arrays. This is again Lamb No. 27 with a Saddle array on the half britch region. In this array nine intermediates, between sickle fibres and hairy tip curly tip were found, this being about 2 per cent of total fibres, and it could not be decided

whether they are sickles or hairy-tip curly tip fibres. Such a linkage is a rather common feature of arrays on the half britch regions, when the Plateau array is found on the britch region.

(d) Tuft Shape influencing shape of Pre-natal Part of Sickle Fibres.

As it has already been pointed out, the shape of the tuft or lock has its influence upon the shape of the pre-natal part of a fibre. The tuft of the Romney birthcoat deserves special attention. However, the present study is concerned with fibre types and reference is made to the tuft shape insofar as certain fibres are concerned. Briefly it might be said that manifold variations in tuft shape exist, variations from one lamb to another, as well as on the same lamb but in different body regions. Further, the investigations on the inheritance of the curl shape in Karakul lambs have shown that shapes of curls are very strongly inherited in complicated multifactorial fashion. Thus it is plain that a tuft as an entity exercises an influence upon individual constituent fibres. Figs. 25, 26 and 27 show tufts from the withers. These examples illustrate the profound influence of tuft shape on the shape



Fig. 25



Fig. 26



Fig. 27

the shape of the tuft superimposed in the individual fibres -

Fig. 25 : Lamb No. 74 H-Type (7 weeks old) withers

Fig. 26 : Lamb No. 69 Non-H-Type (7 weeks old) withers

Fig. 27 : Lamb No. 155 Stud Lamb (? 4 weeks old) withers



Fig. 28



fig. 29

The shape of the tuft superimposed on the individual fibres:

Fig. 28 Lamb no. 120, non-R-type (8 weeks old)
Ravine on the withers.

Fig. 29 Lamb no. 46, non-B-Type (8 weeks old)
Plateau on the withers.

of constituent fibres (see also figs. 28, 29). Even in such tufts large ended sickle fibres were found, having rounded sickle ends, this being due to the superimposed general shape of the tuft. There are many other instances in which fibres with shorter necks were found, e.g. super sickle A' or super sickle B, and some of them were practically chalky throughout yet having the identical shape of the tuft, so that one might speak of this fibre as a cast of the tuft contour.

From the few remarks above the conclusions may be drawn that :

- (i) The shape of the pre-natal portion of a fibre is a result of manifold interactions of factors, some of which are known, others are unknown, and
- (ii) the influence of the tuft shape upon constituent fibres must not be neglected.

(e) The Post Natal Portion of Sickle Fibres.

In the super sickle B fibre section a classification was made based on the behaviour of the chalkiness in the post natal portion of a fibre. This classification holds true for the sickle series too. It must be remembered that we are dealing with persistent fibres only.

Here again persistent sickle fibres may be grouped on their post-natal region, in the following classes:

- (i) Chalky throughout;
- (ii) Fine throughout;
- (iii) Chalky in distal part and fine in proximal part of a fibre;
- (iv) Fine in the middle part;
- (v) Fine in the distal part and chalky in the proximal part of a fibre.

(i) Chalky throughout

This class of sickle fibre is of rare occurrence, because it usually happens that if a sickle fibre is chalky in the distal part of its post-natal career, it either sheds or gets a "crisis thinning". Sometimes, however, when shedding is very poor, and "crisis thinning" does not occur, it happens that sickle fibres are found chalky right to the cut butt of the sample. In a series of sickle fibres from the same array there have been found sickle fibres chalky throughout, situated in the right wing of their series, whereas other fibres were

either shed or fine throughout, or chalky to the "crisis thinning"; (for instance Lamb No: 76, Valley array on the back region).

In the tip shape, chalky sickle fibres resembled closely the hairy-tip-curly-tip fibres. Such sickle fibres, chalky throughout, may be regarded as indicators of poor "crisis thinning" and will be discussed later on.

(ii) Fine Throughout:

This class of sickle fibres is of very great importance in determining Ravine as well as Valley array. It will be well remembered that the difference between Saddle and Ravine is that the latter has an appreciable number of fine sickle fibres, whereas the former lacks this class, and the Valley array must have fine sickle fibres too. Therefore this class of sickle fibres is not only the key type of Ravine array, but also the abundance of fine sickle fibres might be regarded as an indicator of toughness or weakness of Ravine array, and thus fine sickle fibres play the same role as super sickle B in Plateau array. Before analysing the abundance of fine sickle fibres a few words may be said about the general mac-

roscopic appearance of these fibres. Usually they are fine throughout, but sometimes a very tiny string of medulla is seen in benzol. Those fibres which do possess a remnant of medulla are referred to as "intermediate" between chalky and fine and are placed in separate columns in the statistical section on fibre -type abundance. On the other hand, it is very easy indeed to find sickle fibres which are extremely fine, usually much shorter and they seem to be very flimsy, without trace of crimp whatsoever, yet the tip form is almost always a perfect sickle-like tip and usually too having the stock of the sickle chalky.

(f) "Toughness" of Ravine Arrays.

In Table V the sickle fibres are arranged in order from toughest to weakest. For simplicity the columns 1 and 2, that is "sickle fibres fine" and "intermediate" were added in column 3 and they are regarded as "total fine sickle fibres". The same applies to column 6, which is a sum of columns 4 and 5, and here again shed fibres are regarded as chalky sickle-fibres.

TABLE V.

Ravine Array.

Sickle fibres expressed as percentage of Pre-Curly-Tip Group.

Body Regions	Lamb No.	Sickle fibres					
		Fine	Inter-mediate	Total Fine	Chalky pers.	Chalky seed.	Total chalky
		(1)	(2)	(3)	(4)	(5)	(6)
Britch	1	20	0	20	80	0	80
Half	6	6	15	21	73	6	79
Britch	82	7	36	43	57	0	57
	81	18.5	18.5	37	52.5	10.5	63
	46	42	0	42	25	33	58
	43	37.5	19	56.5	37.5	6	43.5
	76	75	0	75	25.0	0	25.0
	75	60	40	100	0	0	0
Rump	65	10.5	10.5	21.0	79	0	79
	62	12.8	28.2	41.0	36	23	59
	27	11.4	37.1	48.5	22.9	28.6	51.5
	46	40	0	40.0	54.3	5.7	60
	81	39	17.4	56.4	34.9	8.7	43.6
	76	60	0	60	30	10.0	40.0
	6	81.5	18.5	100	0	-	-
Side	6	28	0	28	72	-	72
	27	9.5	48	57.5	23.5	19	42.5
	82	23	31	54	46	-	46
Back	81	10	14	24	21	55	76
	8	24	31	55	38	7	45

This table enables us to draw the following conclusions:

- (i) the lowest percentage of fine or not chalky sickle fibres expressed as the percentage of total pre-curlly tip group is 20 per cent, and the highest is 100 per cent. The former figure denotes the toughest Ravine array, whereas the latter indicates the weakest ^{Ravine} array. All intermediates of toughness or weakness exist:
- (ii) In light of these intermediates in toughness as well as the scarcity of material under the investigation, it is unsafe to draw any conclusions as to whether some body regions are prone to have weaker or tougher Ravine arrays:
- (iii) None of these arrays has its sickle fibre series completely fine, at least 18.5 per cent of sickle fibres in the weakest Ravine belongs to "intermediate column". This last statement may suggest that if a check is powerful enough to cause all "sickle fibres" to be fine, it causes simultaneously a few curly tips to be fine and the array becomes Valley - in other words, the upper border line for Ravine arrays is about 80 per cent of fine sickle fibres. Up to this point, the array is shifted towards the Valley series. This, however, does not mean that this point is simultaneously the

lower boundary for Valley array because Valley array may have as few as 11 per cent of fine sickle fibres, as Table VI (page 91) shows.

(g) Abundance of Fine Sickle Fibres in Valley Arrays:

Table VI is arranged in just the same order as the previous one, and shows an appreciable increase in fine sickle fibres in Valley arrays, that means, the more checked the array the more sickle fibres. Of course, some overlapping between Ravine and Valley exists, as will be understandable when we remember that the check responsible for determining the arrays comes to expression in at least two phases, namely, a pre-natal phase and a post-natal one. If the effect on fineness is confined to the pre-natal career of a fibre then nothing more depressed is brought about than the Saddle array, although as will be seen later, the pre-natal check has the power to shift the centre of gravity from one side to the other in the pre-curly-tip group by determining the relative abundance of pre-sickle fibres and sickle fibres, and thus change the balance of the pre-curly-tip group. This balance is^a very important factor because it influences the abundance of secondary kemp. In its post-natal effect the check causes the fibre to be fine throughout and this is responsible for determining

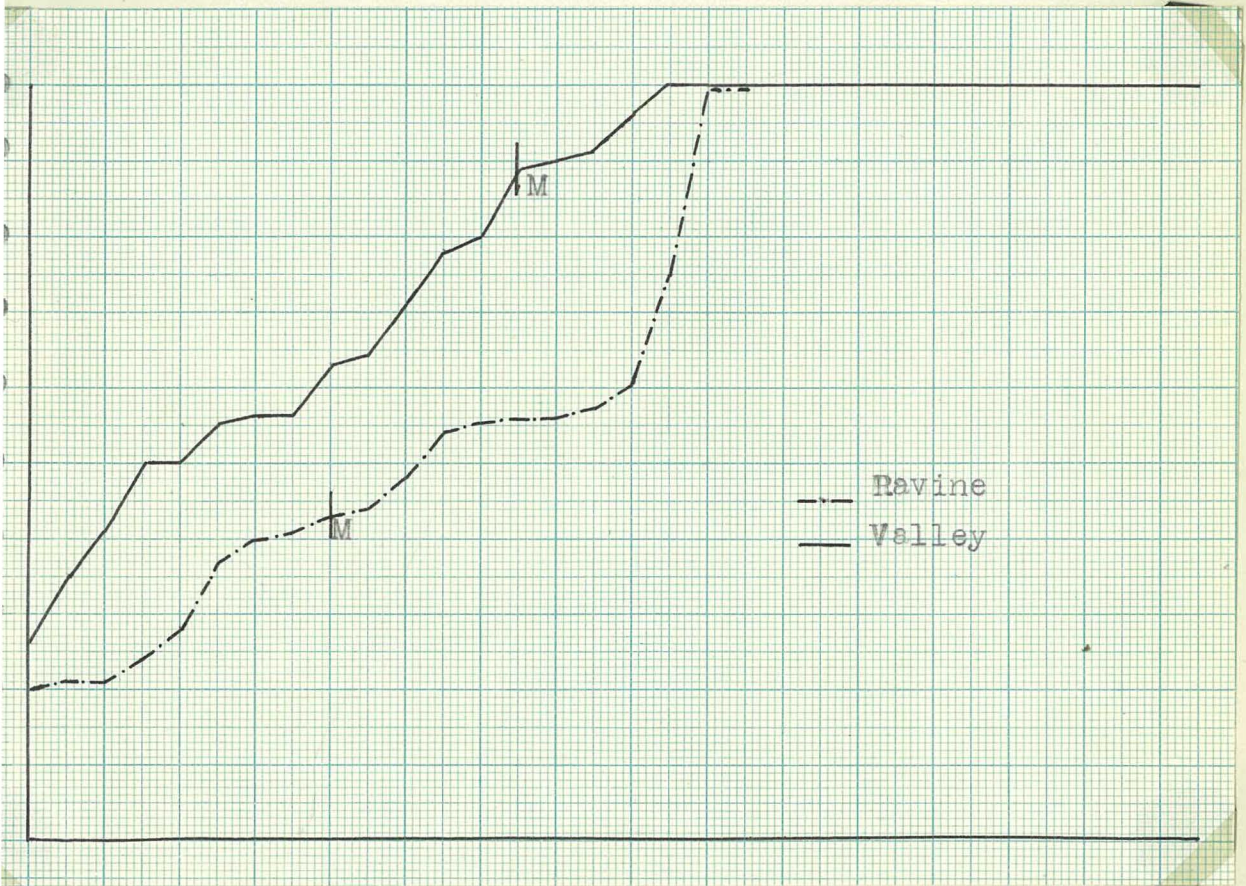
more improved arrays, that is Ravine, Valley and Plain. If the post-natal check is confined only to the pre-curly-tip group, again nothing finer may be expected than Ravine array, but if it also attacks curly-tip fibres it will cause the array to be Valley. Now again we know that the spread of this check varies in a way that can be described in terms of time of action or in terms of space along the series of fibres. If the spread of the check is confined to the pre-curly-tip group it changes chalky sickle fibres into fine but it does not touch the curly-tip group, until a given point, (which was tentatively fixed as 80 per cent of fine sickle fibres) but when the post-natal check catches all the late sickle fibres its effect will spread into the curly-tip group, leaving the left wing of sickle fibres chalky. This is actually what happened in some Valley arrays and in this way it is possible to explain so-called "approaching arrays", e.g. Valley approaching Saddle. This means that the post-natal phase of the check has spread more over the curly-tip fibres than sickle fibres and thus extremely low percentages of fine sickle fibres were found. Such events are however of rare occurrence and coming back in our consideration to these two tables we can see that as a rule the percentage of fine sickle fibre is in favour of Valley array.

TABLE VI.

Valley Array.

Sickle fibres expressed as percentage of pre-curly-tip group.

Body Regions	Lamb No.	Sickle Fibres					
		Fine	Inter mediate	Total Fine	Chalky Pers.	Chalky Shed	Total Chalky
Britch	35	100.0	-	100.0	-	-	-
	84	100.0	-	100.0	-	-	-
Half Britch	1	11.2	67.2	78.4	22.8	-	22.8
	44	90.0	10.0	100.0	-	-	-
	35	100.0	-	100.0	-	-	-
	84	100.0	-	100.0	-	-	-
Rump	43	53.0	11.7	64.7	14.7	20.6	35.3
	75	49.0	51.0	100.0	-	-	-
	1	81.0	19.0	100.0	-	-	-
	84	100.0	-	100.0	-	-	-
Side	65	50.0	-	50.0	50.0	-	50.0
	43	50.0	-	50.0	30.0	20.0	50.0
	76	56.0	-	56.0	44.0	-	44.0
	11	45.5	18.0	63.5	36.5	-	36.5
	48	80.0	-	80.0	20.0	-	20.0
	75	64.0	27.0	91.0	9.0	-	9.0
	46	47.0	53.0	100.0	-	-	-
	1	91.3	8.7	100.0	-	-	-
	35	100.0	-	100.0	-	-	-
	84	100.0	-	100.0	-	-	-
Back	65	26.3	-	26.3	73.7	-	73.7
	27	21.4	14.3	35.7	14.3	50.0	64.3
	11	41.2	-	41.2	47.1	11.7	58.8
	76	55.5	-	55.5	39.0	5.5	44.5
	43	56.8	-	56.8	4.0	39.2	43.2
	48	57.2	14.3	71.5	-	28.5	28.5
	75	46.2	43.6	89.8	10.2	-	10.2
	6	90.6	-	90.6	9.4	-	9.4
	84	96.6	-	96.6	-	3.4	3.4
	1	95.0	5.0	100.0	-	-	-
	35	100.0	-	100.0	-	-	-
	44	100.0	-	100.0	-	-	-



Graph I

Percentage of sickle fibres that are non-chalky.

The Mean expressed as percentage of
total Pre-Curly-Tip Group.

	<u>Ravine Arrays</u>	<u>Valley Arrays</u>
Fine sickle fibres	25.7%	79.95%
Intermediate sickle fibres	16.4%	9.47%
Total fine sickle fibre	<u>42.1%</u>	<u>N 89.42%</u>

From the figures above it is apparent that the differences are striking and Valley arrays are undoubtedly much more checked than Ravine ones. Graph I shows clearly the way in which the curve for fine sickle fibre abundance rises as we pass from toughest to weakest array. It might be pointed out that out of 32 Valley arrays, only 3 arrays have the percentage of fine sickle fibres lower than the mean value for Ravine arrays and the great majority of Valley arrays are situated in the top part of their curve.

Thus, to recapitulate, a few points might be stressed:

- (1) Fine sickle fibres may be regarded as an indicator of toughness or fineness of Ravine arrays. The toughness may be measured and expressed as percentage of total sickle fibres abundance;

(ii) In the present material under investigation, the percentage of fine and fairly fine sickle fibres found ranges from 20 per cent to 100 per cent (the mean being 42.1 per cent) and thus the former figure is regarded as the lowest boundary for Ravine array. As to the latter figure, a reservation is to be made in that the upper boundary for Ravine arrays must be let down to 80 per cent of fine sickle fibres (this 100 per cent comprises fine and intermediate sickle fibres). When this upper boundary is exceeded the array is shifted towards the Valley series;

(iii) The percentage of fine sickle fibres in Valley arrays ranges from 26 per cent to 100 per cent, the mean being 89 per cent. The intermediate sickle fibres in Valley arrays are considerably reduced.

(h) Remaining (c and d) classes of sickle fibres.

The (c) and (d) classes of sickle fibres, namely those chalky in the distal part and fine in the proximal part of the fibre and those fine in the middle part only, respectively, have been described already in the preceding section.

already in the section on Super sickle B fibres and will be further discussed in the section dealing with "crisis thinning". Here, however, may be mentioned that the (c) class is very common in all persistent sickle fibres and the fibres of the Column 4 (chalky sickle fibres) are nearly all class (c). Of course the majority of sickle fibres found in the Saddle arrays belong to this class to.

With regard to the (e) class, it may be said that very few sickle fibres of this class were encountered. The presence of this class may suggest a complicated genetic basis of the check mostly responsible for thinning of chalky fibres. This point may be still more strongly emphasised in the (c) class (fine in distal part and chalky in proximal part of a fibre). Such fibres were found in only two arrays - namely in Saddle arrays on the rump of Lamb No. 48 and on the side of Lamb No. 81. In the first case only one such sickle fibre has been found, the distal part was fine and the chalkiness has revived in the proximal part of the fibre. The second case was of greater importance, because quite a number of such sickle fibres were found, none of them being fine throughout, and this fact has shifted the array, virtually Valley, back to

Saddle series. This array is discussed on page 86

(j) Abundance of Chalky sickle fibres.

(1) Plateau arrays:

Dry and Sutherland have found in some Plateau arrays a negligible number of sickle fibres. In the present study out of 17 Plateau arrays, two such arrays were found, namely Lamb No. 27 and 81 both on the britch regions. The former possessed 1.6 per cent, the latter 7.7 per cent of sickle fibres, expressed as percentage of total pre-curly-tip group. These two arrays border on Saddle arrays and therefore the presence of sickle fibres may be explained in terms of intensity of pre-natal check, which is about to overstep the upper boundary of the Plateau series of arrays or, in other words, the pre-natal check catches a few fibres starting to grow later than the super sickle B fibres and brings about the fineness of the neck. Such Plateau arrays are neither typical nor common, but they are of very great significance from the evolution standpoint and furnish the evidence of a gradual transition of fibre type arrays from Plateau to Saddle. It will be remembered that such borderline arrays likewise



Graph 2.

Percentage of sickle fibres in Saddle Arrays.

(calculated on total number of
pre-curly-tip fibres)

exist linking Saddle with Ravine and Ravine with Valley.

(ii) Saddle Arrays

As it was said in preceding chapters the difference between Plateau and Saddle array lies in the fact that the latter possesses sickle fibres. Further, within Saddle arrays the abundance of sickle fibres varies and these variations must be regarded as due to a weaker or stronger pre-natal check; if this is the case, the abundance of sickle fibres may be measured and expressed as the percentage of the total pre curly-tip group and thus we have a way of expressing the toughness or weakness of Saddle arrays, as was already done for Ravine arrays.

In Table VII the abundance of sickle fibres is given and graph 2 of sickle fibre abundance arranged in order from toughest to weakest Saddle arrays, shows plainly the gradual trend starting from 11.4 per cent up to 100 per cent, The mean being 61 per cent. Thus in the lot of Saddle arrays under present investigation the Saddle array having 11.4 per cent of sickle fibres may be designated as the toughest, whereas the Saddle array having 100 per

cent sickle fibres in its pre-curly-tip group is the weakest, that is the most checked Saddle array. Although theoretically it is possible to picture a Saddle array having all its pre-curly-tip group reduced to sickle fibres, yet a reservation should be made to this particular Saddle array, because as it has already been pointed out on page 85 this Saddle array is virtually a Valley array and only owing to an unusual happening the proximal portion of fine sickle fibres as well as checked curly-tip fibres have become chalky. Thus in the light of these great plus and minus deviations from the mean we cannot expect any outstanding differences in the percentages of sickle fibres in other arrays. One, however, might expect the means to be higher the more certain arrays are checked because the centre of gravity in pre-curly-tip fibres should be shifted towards more depressed fibres in this group. The actual data obtained justified this assumption:

The Means of Sickle fibre population
expressed as percentage of total pre-
curly-tip-Group.

Saddle arrays	61 per cent
Ravine arrays	78.8 per cent
Valley arrays	85.1 per cent
Plain arrays	100.0 per cent

TABLE VII.

Saddle Array.

Sickle fibres expressed as percentage
of pre-curly-tip group.

Body Region	Lamb No.	Total Fibres	
Britch	65	0.75	11.4
	6	2.94	25.0
Half Britch	48	2.02	41.7
	11	3.23	41.5
	27	4.72	45.2
	65	3.75	55.6
	8	5.84	80.0
Rump	11	11.30	61.8
	8	5.24	93.0
	48	6.47	100.0
Side	8	10.39	71.6
	1	10.34	81.8
Back	82	6.31	72.3

Mean = 61 per cent.

TABLE VIII

The Means of Sickle fibres abundance
expressed as percentage of

		Total fibres	Pre-Curly- tip group
Britch	Plateau	0.1	0.77
	Saddle	1.85	18.2
	Ravine	4.31	100.0
	Valley	5.54	88.9
Half Britch	Saddle	3.9	52.8
	Ravine	7.0	70.6
	Valley	5.95	86.9
Rump	Saddle	7.7	85.0
	Ravine	6.8	73.8
	Valley	8.4	93.4
Side	Saddle	7.4	76.7
	Ravine	6.6	76.2
	Valley	4.6	73.4
Back	Saddle	6.31	72.3
	Ravine	7.6	73.6
	Valley	7.5	82.81

(k) Influence of Body Regions
upon sickle fibre abundance

Table VIII tabulates the means of sickle fibre abundance, on different body regions. The first column giving the percentage of total fibres may be omitted since it depends on more than one variable. The second column giving the percentage of total pre-curly-tip group may throw some light on the question whether the body regions have any significant influence on the sickle fibre population. In so far as Ravine and Valley arrays are concerned, no significant influence is shown. However, Saddle arrays show significant differences in the percentage of sickle fibres between Britch and half-britch regions, others do not show any appreciable differences. Thus an inference follows that the toughest Saddle arrays are to be found on the britch region, whereas Saddle on the half britch may be called medium, for the percentage of sickle fibres is a little below the mean for Saddle arrays. Saddle arrays on back, side, and rump regions must be regarded as "weak" because all of them are above the mean. The result above is understandable in the light of Galpin's (25,26) work on the britch-poll fibre-type array gradient.

B. CURLY TIP GROUP

This group has been divided (see page 19) into two series, namely

- (a) Hairy tip curly tip fibres (in short "H.T.C.T.")
- (b) Curly tip fibres (in short "C.T.")

The above classification is based upon two features, that is the shape of a tip and the chalkiness of the prenatal portion of a fibre. In H.T.C.T. fibres part of the prenatal portion can be recognised by eye to be chalky. It is in practice often helpful to examine the tips in benzol. On the other hand, the prenatal region of the C.T. fibre is not chalky to the eye and it is comparatively fine. The apical end of both sorts of fibres has the form of a curl, as distinct from a sickle.

1. Hairy-tip-curly-tip Fibres.

Although in previous publications by Dry and his co-workers the curly-tip group has been considered as one entity rather than as two separate series of fibres, yet the existence of H.T.C.T. fibres in appreciable numbers has been stressed. Sutherland (46), especially studying the Plateau arrays, dwelt upon the structure of these fibres,

for the presence of H.T.C.T. fibres in Plateau arrays is a very usual event.

One could argue the necessity for splitting the curly-tip group into two series of fibres. Of course, a minute study calls for a subdivision. It must be remembered that curly-tip group comprises the bulk of the fleece and this sole fact justifies this division. Moreover, from the evolution point of view, the origin of curly-tip fibres, which, in some arrays, form four-fifths of the total fibres, must be of outstanding interest. Further, there are many features of H.T.C.T. fibres which distinguish them from C.T. fibres, more clearly than (e.g.) Super sickle B are distinguished from sickle fibres and therefore the classification is an easy one.

(a) Tip shape

A number of illustrations (fig.33, 34) show the differences in the shape of H.T.C.T. fibres. All these illustrations show that as a rule the tips of H.T.C.T. fibres become heavily chalky a very short distance from the extreme point of the tip and the chalkiness is well maintained at least until the "crisis level". There

are, however, some exceptional cases. One of the most usual is that the medulla starts later; it thickens rapidly and causes a small portion of the middle part of the tip to be heavily chalky and finally disappears as suddenly as it has appeared.

(b) Length:

Hairy-tip-curly-tip fibres are usually longer than curly tip fibres, and they are at least as long as pre-curly-tip fibres. A few examples showing H.T.C.T. fibre length in comparison with the length of other fibre types are given in Table IX.

In the first example the H.T.C.T. fibres are as long as halo hairs and longer than other pre-curly-tip fibres, and far longer than curly-tip fibres. In other examples some halo hairs are longer than hairy-tip-curly-tip fibres but no fibres of the pre-curly-tip group are longer, and all curly-tip fibres are definitely shorter. To the latter statement a reservation must be made in that an appreciable number of curly-tip fibres have been found to be as long as H.T.C.T. fibres.

TABLE IX.

The length of Birthcoat fibres in cm.
(all fibres cut at skin level).

Cm.	3	4	5	6	7	8	9	10	11
<u>Lamb No. 124</u>									
Plateau on the side									
No. of H.H.							16	7	
S.S.A.					2	13			
S.S.A'						1			
S.S.B.					2				
H.T.C.T.					1	60	30		
C.T.	42	100	95	42					
<u>Lamb No. 89.5 ♀ VI!</u>									
Plateau on the side									
No. of H.H.							6	16	
S.S.A						2			
S.S.A'				1	1				
S.S.B.				1					
H.T.C.T				3	31	48	8		
C.T.	4	73	84	2					
<u>Lamb No. 89.5 ♀ VI!</u>									
Plateau on the britch									
No. of H.H.						1	10	10	1
H.T.C.T.					5	36	27		
C.T.	12	66	12			1	10	10	1

(con)

TABLE IX (con.)

Cm.	3	4	5	6	7	8	9	10	11
<u>Lamb No. 1320 ♀ V</u>									
Plateau on the Britch									
No. of H:H.							4	4	1
S.S.A.						3	3	1	
H.T.C.T.						2	16	2	
C.T.	24	21	16	3					
<u>Lamb No. 86.5♂ VI</u>									
Plateau on the Britch.									
No. of H.H.		1	7	17	6				
S.S.A.	1		5	17					
S.S.A'			6	1					
H.T.C.T.		19	19	22					
C.T.	14	36							

(c) Structure of the Post Natal Portion.

H.T.C.T. fibres seem to be specially resistant to all forces tending to fineness. Consequently if they are not shed, they are chalky throughout and such fibres are very common indeed within the H.T.C.T. series. However, other fibres of this series exist which furnish all gradations from chalkiness

to fineness of the fibres. Hence in very little checked Plateau arrays H.T.C.T. fibres were encountered having a very tiny piece of their length fine and this phenomenon has been called by Dry (13) "crisis thinning"; after this thinning the chalkiness revived to the same degree as before. Very often, however, at least a part of H.T.C.T. fibre population behaves like other fibres already described - that is, the medulla which has undergone this "crisis thinning" never recovers its full strength and becomes at the best a remnant of the past, that is to say the proximal part of the H.T.C.T. becomes fine, but the fineness varies considerably and the medulla can often be detected in benzol. Such a post-natal part of a hairy-tip-curly-tip fibre we can call "chalky in distal part, and fine in proximal part". A still more common feature of a hairy-tip-curly-tip fibre's career is that it is "fine in the middle part and chalky above and below"; that is, the chalkiness undergoes "crisis thinning" and needs a while to recover to full strength. This class of H.T.C.T. fibres is perhaps as common as

the class comprising fibres chalky throughout. One familiar with comparative wool anatomy could easily imagine these four classes of H.T.C.T. fibres, but to find hairy-tip-curly-tip fibres fine throughout seemed beyond comprehension. Chalkiness of H.T.C.T. fibres was a condition sine qua non of the classification of this series of fibre as a whole. However, since fine hairy-tip-curly-tip fibres have been found, it must be described as an unusual happening which stresses once more that the forces at work on the sheep's fleece are very complicated.

The actual array in which all the hairy-tip-curly-tip fibres are fine is Valley on the Withers on the Lamb No. 46 IV

	<u>S.S.B.</u>	<u>Sk.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
No.	2	8	10	206	150
%	0.5	2.1	2.7	54.8	39.9

All super sickle B and sickle fibres fine; out of 100 curly tip fibres are

18.1 checked curly tip

1.0 peak curly tip

80.9 fine curly tip.

No shed fibres.

Benzol test: 7.1% (Ht.)

Thus from the data above it is apparent that :-

- (i) This Valley is a very checked one and approaches Plain;
- (ii) The post-natal expression of the check was very strong and so kept all fibres fine throughout their length, and;
- (iii) Yet an appreciable number of H.T.C.T. fibres was found. Here it is well to remember that all sickle fibres are very typical, having rather large ended and standard sickle tips, and therefore no mistake in judging these H.T.C.T. fibres could be made, and needless to say these H.T.C.T. fibres have a typical curled end.

The very occasional appearance of fine H.T.C.T. fibres may be explained in only one logical way: let us assume that those fibres were compelled for some unknown reason to accelerate their growth, and pierced the skin surface before the prenatal check was at work, or rather suppose the genes

responsible for causing the tip of the fibres to be fine had not reached their threshold at their usual time and hence about 3 per cent of the total fibres or about 5 per cent of the curly-tip population has chalky tips. This explanation is very suggestive when in addition to the above it will be revealed that quite a large part of the curly-tip fibres has visible remnants of hairiness. These tiny bits of medulla in the tips of curly-tip fibres suggest two things:

- (i) the piercing of the skin taking place is somewhat "goose-order", that is the fibres do not jump out ~~in~~ one group but they are steadily piercing the skin at very short intervals of time; and
- (ii) the pre-natal check being about to reach its threshold was powerful enough to cause curly-tip fibre ends to be sufficiently fine in order to be recognised as such, but for earlier germs it was still too weak to cause any visible differences in the chalkiness and the check was not powerful enough to depress the chalkiness of hairy-tip-curly-tip fibres until the threshold had been reached and after that it held throughout the length of a fibre. In other

words, this Valley array is a very good example showing how the gene acts upon the fibres and proves the applicability of the threshold concept to the forces responsible for improvement of wool.

Now the following question arises: It is believed (Dry, Sutherland and Galpin) that fibre types begin their development in the order:

1. Halo hairs
2. Super sickle fibres
3. Sickle fibres
4. Curly tip fibres.

Consequently we should expect to get in such a Valley array in which the growth of fibres was accelerated or the check was retarded, a richer pre-curly tip fibre population and therefore it would be more logical to expect a full array (and not truncated as this one) with much more Super sickle B fibres or even super sickle A' fibres! Why has this not been the case? In Section V this question will find its proper answer. To anticipate the discussion as to "the foundation fibres" it may be necessary to state briefly that there is no evidence that H.T.C.T. fibres develop after pre-curly-tip group fibres and on the contrary there are convincing pieces of

evidence which very strongly suggest that hairy-tip-curly-tip fibres start to develop at the same time as at least super sickle fibres or even halo-hairs, and this one example is a further proof in the chain of the evidence. Thus those hairy-tip-curly-tip fibres have had the same, if not better opportunity to develop as any other constituents of the pre-curly-tip group.

(d) Hairy-tip-curly-tip fibre abundance.

Hairy-tip-curly-tip fibres are an almost indispensable part of the Plateau fibre types because they are very little, if at all, checked. In other more checked arrays, H.T.C.T. fibres are of negligible value except for a few Saddles on the britch and half-britch regions and for a few Ravines on the half britch regions. Table X gives the percentage of H.T.C.T. fibres in different arrays on different body regions.

TABLE X.

The means of H.T.C.T. Fibres expressed as the percentage of

	<u>Total</u> <u>fibres</u>	<u>C.T.</u> <u>Group</u>	<u>per 100</u> <u>C.T.</u>
<u>Britch:</u>			
Plateau	15.4	39.0	63.9
Saddle	5.2	-	10.4
Ravine	0.0	0.0	0.0
Valley	0.0	0.0	0.0
<u>Half-britch:</u>			
Plateau (1 sample)	15.8		62.7
Saddle	3.2		9.4
Ravine	3.2		8.5
Valley	0.0		0.0
<u>Rump:</u>			
Plateau	15.1		61.6
Saddle	0.9	1.3	1.4
Ravine	0.0	0.0	0.0
Valley	0.0	0.0	0.0
<u>Side:</u>			
Plateau	9.8		37.8
Saddle	0.2	0.2	0.4
Ravine	0.0	0.0	0.0
Valley	0.2	-	0.48
<u>Back:</u>			
Plateau	12.8		58.1
Saddle	0.0	0.0	0.0
Ravine	0.0	0.0	0.0
Valley	0.1	0.15	0.1

(con.)

TABLE X (con.)

	<u>Total</u> <u>fibres</u>	<u>C.T.</u> <u>Group</u>	<u>per 100</u> <u>C.T.</u>
Withers:			
Plateau	7.2		25.0
Valley	0.2		0.3

The above Table shows a detectable influence on the body regions upon the less depressed non-plateau arrays, whereas for well-checked arrays the percentage of hairy-tip-curly-tip fibres is negligible. As to the Ravine arrays on the half-britch regions the percentage of hairy-tip-curly-tip fibre is of some importance on ¹/_A when a Plateau array, or "tough" Saddle array is found on the britch region. Hairy-tip-curly-tip fibres in Saddle arrays have still longer range over the body for nearly 1 per cent of hairy-tip-curly-tip fibres have been found on the rump and 0.2 per cent on the side, whereas the means for britch and half-britch are 5.2 per cent and 3.2 per cent respectively. This distribution of H.T.C.T. density within arrays suggests firstly that the better checked an array the lesser the percentage of H.T.C.T.

fibres; secondly, the great decrease in hairy-tip-curly tip fibre density between Plateau and Saddle arrays corresponds in some way with the sudden increase of sickle fibre density within a series of Saddle arrays and may indicate a rather great advance in the intensity of the pre-natal check; thirdly, the further from britch region the less the H.T.C.T. fibre, in other words lambs with an appreciable number of hairy-tip-curly-tip fibres having the same array on all body regions will have the greatest percentage of hairy-tip-curly-tip fibres on the britch and the smallest on the withers (e.g. No. 74) fourthly, H.T.C.T. fibres may be regarded as an indicator of "toughness" within Plateau array and this may be measured and expressed either as a percentage of the curly-tip group or per 100 C.T. fibres. The data arranged in order from toughest to weakest for the Plateau arrays on the britch region is given in Table XI.

TABLE XI

The toughness of the Plateau series of arrays computed on the basis of H.T.C.T. fibre abundance.

Lamb No.	H.T.C.T. fibres as % of C.T. group	H.T.C.T. fibre per 100 C.T.	S.S.B. fibres as % of total fibres	S.S.B. fibres as % of pre-curly tip group.	Percentage of Hairiness.
46	77.6	346.0	1.07	16.6	31.6
48	58.0	141.0	0.0	0.0	63.0
27	56.3	133.0	1.58	18.1	35.0
8	43.7	75.6	3/69	38.0	28.3
74	41.3	70.0	0.0	0.0	93.0
82	40.0	65.3	0.52	6.4	49.2
11	37.7	62.7	0.0	0.0	36.4
75	31.4	45.6	0.18	2.4	24.6
76	30.2	43.0	0.58	4.0	37.0
81	22.0	28.6	4.33	30.7	49.8
44	22.0	28.1	1.12	26.8	30.7
43	7.9	8.6	3.79	36.8	29.3

The table above is very instructive because it shows:

- (i) no relationship between the abundance of hairy-tip-curly tip fibres and S.S.B. fibres;
- (ii) no significant correlation between either of them and the percentage of hairiness.

The first fact is of great theoretical interest, throwing light on the mode of working of the pre-natal check and it favours the conception, mentioned in previous sections,

of the pre-natal check, which is a

of the pre-natal check acting upon individual follicles of each group of fibre types rather than working upon the whole population of fibres, the follicles of which were already laid down at the time when the pre-natal check reached its threshold. However, without further pre-natal studies it is difficult to estimate the truth of such a suggestion.

The second fact is easy enough to understand because the percentage of hairiness is a result of such factors as :

inborn chalkiness (a base upon which the
pre-natal check works),
crisis thinning,
the precipice, and
the abundance of histerotrichs.

All these factors play a very limited part in determining arrays of fibre types. Thus a term "weak plateau 37/8" (37 per cent of super sickle B fibres and 8 per cent of hairy tip curly tip fibres) gives the idea of the strength of the pre-natal check within plateau series only.

The toughness of the Plateau array, a concept derived by Dutherland (46) is tackled in the present study from a somewhat different angle. This is so because it is confined in the Plateau and Saddle

arrays to the work of the pre-natal phase of the check and in Ravine and Valley arrays to both pre- and post-natal phases of the check, leaving all other variables like shedding of fibre, abundance of super sickle A fibres, precipice, etc. out of account, it enables us to measure the intensity and the spreading of the check and to express the characteristics on a comparable basis, for instance as the percentage of a certain type or a given class of fibre types. In other words, the "toughness" of an array expressed as a figure permits us to estimate the quantitative value of genes responsible for this check, as well as its upper and lower limit and in this way it will probably be possible to separate the forces at work on the sheep's fleece architecture. This latter point must be emphasised very strongly, especially when dealing with the evolution of the fleece. Knowing the power and the limitation of each force responsible for the improvement in the course of evolution of the fleece, it is feasible to separate them according to their measurable value.

2. Curly tip Fibres.

Curly tip fibres, as it has already been mentioned comprise the bulk of the sheep's fleece and are therefore

of great importance. Hence very much attention has been paid to the career of these fibres by Dry and his co-workers. Curly-tip fibres were found in this laboratory on the fleece of other breeds of sheep as well. The overseas workers in wool anatomy described fibres found in other breeds of sheep which may be regarded as curly-tip fibres. The differences lay in terminology used rather than in the characters of fibres. Thus we can presume that curly-tip fibres constitute the bulk of every fleece of British sheep breeds.

(a) Tip Form

Curly-tip fibres have the pre-natal portion fine and curled. These two traits vary within curly-tip fibre series. In less checked arrays the tip is usually stronger than in more checked ones. In some Plateau arrays where a gradual transition from H.T.C.T. fibres to curly tip fibres takes place, some C.T. fibres linked with hairy-tip-curly-tip fibres will, of course, show very tiny differences in the general character of the tips and therefore great care must be exercised in order to avoid a mistake. In such a case a drop of benzol on the microscope slide proved indispensable.

The number of curls on the tips varies considerably. A general statement, based on macroscopic judgement may be made - that the stronger the tip the fewer the curls. The word "strong" means a thicker diameter of the tip providing however that the tip is fine. On the other hand curly tip fibres with many curls on the tip seem to have very fine tips. This is clearly manifested in very fine checked arrays, like valley near Plain, or Plain arrays found on the withers region, where the curls form a typical "watch-spring".

Sometimes such a tip has an extreme spiral and like a remnant of a sickle end, especially in Plain arrays on the withers, in which the abundance of sickle fibres is surprisingly small. This suggestion will be discussed later on. Here, however, may be recalled the existence of intermediate fibres linking pre-curly-tip group with curly-tip group (see page 69).

(b) Post Natal Structure

Curly-tip fibres may be divided into classes in just the same fashion as previously described fibres. The classification runs as follows :

- (i) Hairy throughout
- (ii) Fine throughout
- (i) this class has been divided by Dry (13) into two subclasses, namely -

checked curly-tip fibres, and fine curly tip fibres.

- (iii) Chalky in the distal portion but fine in the proximal portion.
- (iv) Chalky in the distal as well as proximal portion, but fine in the middle part of the fibre.
- (v) Fine in the distal portion and chalky in the proximal portion.

Classes (i), (iii) and (iv) are known from previous publications by Dry and his co-workers, as peak C.T. fibres and this term is reserved especially for Valley arrays. Hence curly-tip series in a Valley array arranged in order from left to right consists of :

Checked C.T. fibres
Peak C.T. fibres, and
Fine C.T. fibres.

The last classification will be used henceforth for the Valley arrays only.

All the classes enumerated above will be discussed later on together with "crisis thinning" and "the precipice". Here brief mention will be made as to the general arrangement of the above classes in the Curly-tip fibre series. From the analysis ^{made} it is suggested that -

- (i) the more checked the array the larger is the percentage of fine curly-tip fibres;
- (ii) the sooner the chalkiness disappears;
- (iii) the less the probability of the reversal

of the chalkiness after crisis thinning.

Hence from the point of view of hairiness, the most suitable array is a fairly well checked valley array, that is an array which is not associated with Saddle arrays. It has already been mentioned that the toughness of each array may be measured in terms of the key type or a certain class within a series. This has already been done for Plateau, Saddle and Ravine, and it has been pointed out with regard to Valley arrays that the check was extended to the Curly-tip group, hence checked curly-tip fibres in Valley arrays. This being the case, it will be of great interest to analyse the percentage of checked, peak and fine curly-tip fibres within Valley arrays in order to be able to answer

firstly, how wide is the expansion of the check
in the curly tip series,

secondly, do the checked curly-tip fibres play
a decisive role in the diminution of
the hairiness in Valley arrays.

In Table XII, the data for these fibres expressed as the percentage of the total curly tip group is given. For the sake of simplicity, columns 2 and 3

may be added together and thus the percentage of checked curly tip fibres ranges from 4.9 per cent (Lamb No. 1, Valley on the side) to 24.2 per cent (Lamb No. 75, Valley on the side) the means being:

for the britch	10.5 per cent
" " half-britch	15.6 per cent
" " ramp region	12.8 per cent
" " side	13.8 per cent
" " back	12.0 per cent

With regard to the variations between the means, it is considered that these variations are more due to standard and sampling errors than to any significant differences between given body regions. As to the upper limit of the check which is responsible for checked curly-tip fibres, it must be added that one Plain array has been found which may be deemed an example of the upper boundary of the check, within the curly-tip fibre series. That array is :

Lamb No. 44 - Plain approaching Valley
on the side region:

Sickle fibre	5.56 per cent
Curly tip fibres	56.84 " "
Histerotrichs	37.60 " "
Fine sickle fibre	100.0 " "
Checked curly tip	37.5 " "
Peak curly tip	2.3 " "
Fine curly tip	60.2 " "
Hairiness	3.1 " "

It is worth while to mention that in some Valley arrays it is impracticable to count the actual number of peak curly tip fibres. This is due to the existence of transitional fibres between peak curly tip fibres and fine curly tip fibres (see column 5 in Table XII). Only in Valley or Plain arrays which have a sudden and abrupt change from chalky peak curly tip fibres to fine curly tip fibres like the above Plain array is an accurate count possible and therefore it is not pretended that some figures in Table XII are precisely accurate. The same applies to a lesser extent to checked curly tip fibres in some Valley arrays and in nearly all Plain arrays, owing to the lack of transitional fibres and scarcity of peak C.T. fibres. In such arrays a great deal of difficulty was encountered in distinguishing the checked curly tip fibres from fine curly-tip fibres because the difference lies only in the length and number of curls at the tip of curly tip fibres. Hence the importance of the above array in which the count may undoubtedly be regarded as correct.

TABLE XII
CURLY TIP FIBRES

	No. of Lamb	Checked	Medium	Peak	Medium	Fine	Arrange ment of hairi- ness	% of hairi- ness
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<u>Beitch</u>	35	2.9	10.1	33.6	18.2	35.2	Hc	15.2
	84	8.1	0.0	29.4	0.0	62.5	Ht	9.4
	Mean	5.5	5.0	31.5	9.1	48.9		12.3
<u>Half-Beitch</u>	1	8.0	10.5				Ht	9.3
	35	10.0	10.5	22.5	59		Hb	15.9
	44	18.7	-	22.0	44	15.3	Hb	15.7
	84	6.4	3.4	33.5	27.9	28.8	Hb	10.9
	Mean	11.0	4.6	26.0	33.6	24.8		13.0
<u>Rump</u>	1	8.3	-	28.6	-	-	Hb	10.9
	43	5.0	11.0	22.0	20.3	38.5	Ht	10.4
	75	5.6	5.0	-	-	33.6	Hb	16.5
	84	13.0	3.4	-	-	11.3	Hb	12.8
	Mean	7.9	4.9	-	-	-		12.7
<u>Side</u>	1	4.9	-	9.4	50.7	35.	Hb	10.7
	11	9.1	1.4	20.8	56.7	12.6	Hb	9.7
	35	7.8	10.4	18.2	27.6	36.0	Hb	8.9
	43	16.1	-	3.6	5.8	73.0	Ht	7.0
	46	2.7	12.2	15.1	0	70.0	Ht	9.5
	48	5.8	-	39.0	24.5	30.7	Hb	29.3
	65	10.1	-	25.5	30.3	34.0	Hb	10.1
	75	13.2	11.0	20.8	22.0	33.0	Ht	4.2
	76	11.6	-	9.4		79.0	Hc	15.0
	84	12.4	-	23.1	13.5	51.	Ht	8.2
	Mean	9.4	4.4	17.5	23.1	45.4		11.4

TABLE XII (con.)

	No. of Lamb	Checked	Medium	Peak	Medium	Fine	Arrange- ment of hairiness	% of hairi- ness
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<u>Back</u>	1	12.1	12.6	3.0	40.3	15.0	Ht	4.4
	6	6.8	-	22.5	0.2	70.5	Ht	5.0
	11	20.0	-	17.1	5.7	57.2	Ht	11.4
	27	9.5	-	73.0	14.6	0.7	Ht	18.1
	35	4.5	6.5	21.5	32.5	35.0	Hb	9.8
	43	17.1	9	5.1	0.4	68.4	Ht	6.8
	44	18.6	-	16.8		64.7	Ht	4.6
	48	4.4	4.4	40.7	18.5	29.0	Hb	27.7
	65	4.8	-	26.2	24.0	45.0	Hb	19.7
	75	4.6	5.3	34.2	40.3	15.6	Hb	10.3
	76	7.3	-	9.0	34.2	49.5	Hc	26.7
	84	13.0	2.1	29.4	18.5	37.0	Ht	6.8
	Mean	9.4	2.6	27.2	19.8	46.53		12.7

It follows then that 37.5 per cent checked C.T. fibres may be regarded as the upper limit of the check responsible for causing checked curly tip fibres as well as determining the arrays. There are, however, other factors like the precipice which do not play an important role in determining the array but they are of outstanding importance as far as the diminution of the chalkiness is concerned. These other factors cannot be - for the time being at any rate - properly measured. Sometimes the per-

centage of checked curly tip fibres is relatively small and yet the percentage of peak curly tip fibres is small too, as in lambs Nos. 43 and 44 - Valley on side. These examples show that other factors than the check are responsible for changing peak curly tip fibres into fine ones, and this aspect is discussed in Section III. Here, however, a very important point must be stressed, that is, the limitation of the check, responsible for the determination of the fibre type arrays. This check is referred to by Dry and his co-workers as "pre-natal check" but sometimes it is convenient to speak of the "head check" instead of the pre-natal check. By "head-check" will henceforth be understood the check responsible for the determination of the arrays: since its base is confined to the head of the array it is termed "head-check" distinguishing it from "tail check" responsible for causing the tail of the curly tip fibre to be fine. In this latter at least, two separate factors find expression, with which we will deal later, and for simplicity's sake it is thought better to use these two terms. Thus, in view of the facts now being discussed we can state that the "head check" is limited to about 57 per cent of the curly tip fibres, but some overlapping occurs and the "tail check" may extend its influence so as to invade the realm of

"head check". Lamb No. 76 - Valley on the side - furnishes an example in support of the latter statement.

Lamb No. 76

Checked curly tip fibres	11.6 per cent
Peak curly tip fibres	9.4 per cent
Fine curly tip fibres	79.0 per cent.

In the light of the discussion above it is plain that in order to answer the second question, as to whether the checked curly tip fibres play a decisive role in the diminution of the hairiness it may be tentatively stated that for the diminution of hairiness "head check" as well as "tail check" are responsible and therefore these curly tip fibres which are not checked should be deemed indicators of the chalkiness within curly tip fibre series, and peak curly tip fibres are the very ~~finest~~ fibres upon which the chalkiness depends. A reservation, however, must be made:

Firstly, it was mentioned that the differences between classes of curly tip fibres are not always clear-cut ones, because there are intermediate fibres, and

Secondly, as it has already been pointed out, the total chalkiness depends upon several factors, such as the base of inborn chalkiness, the crisis thinning, the number of pre-curly-tip fibres, and Histerotrichs.

With this reservation in mind, the data tabulated in Table XII give full support to the above statement, that is, the smaller the percentage of peak curly tip fibres, the lower the percentage of hairiness. The factors influencing hairiness are to be discussed from a somewhat different angle in Section III and it will be shown that this very important practical aspect of wool finds its solution in "hair splitting" and it will probably be possible to base the selection against hairiness on the analysis of arrays taken from very young lambs, as was suggested by Dr. Dry in a personal communication.

The third group of fibre types is confined to only one type, namely:

C. POST-CURLY-TIP GROUP (Histerotrichs)

These fibres, as has already been mentioned, are fine throughout, and are not to be found in the pre-natal population of fibre types of Romney lambs.

1. Structure of Histerotrich fibres.

Histerotrichs are always fine, although Dry found a small part of histerotrich fibres mildly chalky for a very short period. However, no such case has been found in my material. The fineness of histerotrichs, judging macroscopically, seems finer than the fine parts of curly-tip fibres. This is especially emphasised in less checked arrays like Plateau or Saddle, where the differences in the diameter of the fibres are astonishing and usually histerotrichs seem to be finer than all the other fibres. In better checked arrays the differences are less pronounced, but without actual measurement it would not be profitable to discuss the question. Perhaps this tiny item may be added - that some extraordinarily checked sickle fibres which are to be found in Ravine, Valley and Plain arrays look much finer than histerotrich fibres.

The tip is, of course, without curl. Some histerotrichs, however, have their tips curved, this constituting one of the greatest difficulties in distinguishing histerotrichs from late (fine) curly tip fibres. This fact has been emphasised by Sutherland (46) too. He, however, pointed out that this difficulty may be easily overcome after a fairly short period of "hair splitting". In the course of the present investigation a number of double samples have been analysed and a few lamb's birthcoats were dyed in order to increase accuracy in judging histerotrich fibres. The result of this investigation supports Sutherland's views that in spite of the slight differences between histerotrich and fine curly tip fibres in some arrays, errors of analysis were negligible.

2. Time of Histerotrich Growth.

By means of dyeing it was possible to ascertain not only the variations in the shape of histerotrich tips but also the time when they start to grow. The lambs' birthcoats were dyed as soon as feasible after birth and it has been found that a small part of histerotrich fibres have had the extreme tips dyed, others being colourless. This dyed part of the tips was a very short one. As will be shown later on it was possible to com-

pute the approximate rate of growth of histerotrich fibres, this being about 0.60 mm a day, hence judging on the dyed tips a conclusion may be drawn as to the time the histerotrich fibres start to pierce the surface of the skin. This time is 2 or 3 days before the birth of the lamb// This last statement confirms previous investigations published by Dry (14) that, practically speaking, the histerotrich fibres start to grow at the lamb's birth. Moreover, the present investigation has given interesting data with regard to the time when the last histerotrich fibre follicles are laid down, in other words - since histerotrich fibres are the last lot of constituent fibres of the sheep's fleece, it was of great interest to find out at what age of a lamb the fleece is complete. In order to answer this question it was necessary to know exactly :

- (i) the time in which the first and last lot of histerotrich fibres pierce the surface of the skin;
- (ii) the date of birth;
- (iii) the date of sampling.

The calculation is a very simple one. The lengths of histerotrichs were measured and dates both of birth and sampling were available, and it has been found that, e.g. Lamb No. 27-Saddle - on the half britch region, the longest histerotrichs were 10 cm. and shortest 2 cm., this lamb being 179 days old

at sampling time, hence in order to compute the rate of growth a day it is necessary to divide:

$$100 \text{ mm} : 179 \text{ days} = 0.56 \text{ mm a day.}$$

Now knowing, (a) the growth a day, and (b) the length of the shortest histerotrich fibres we may compute that it has taken about 36 days to grow 2 cm. length of the histerotrich fibres, that is the shortest fibres found, and hence

$$179 \text{ days} - 36 \text{ days} = 143 \text{ days.}$$

It follows then that Lamb No. 27 being 143 days old has had a complete fleece. The data computed for other lambs runs as follows :

<u>No. of Lambs</u>	<u>Region</u>	<u>The fleece is complete in</u>	<u>The growth per day.</u>
27	half britch	143 days	0.56 mm
27	side	143 days	0.56 mm
43	britch	144 days	0.68 mm
46	rump	141 days	0.63 mm
74	britch	135 days	0.59 mm
	Mean	<u>141 days</u>	<u>0.60 mm</u>

It is understood that the figures calculated above must be considered only approximate and therefore we may say that a Romney lamb about 5 months old has its fleece complete, or, strictly speaking, at this time the last histerotrichs are piercing the surface of the skin.

It must be added, however, that although the actual calculation is based on only 5 examples, the length of the shortest histerotrichs in all other lambs in the present lot is very much the same. Thus we can conclude that at 5 months the NewZealand Romney lamb has its fleece complete. This may be regarded as the upper boundary, since it has not been found in later samples, e.g. hoggett samples, that any new follicles are laid down after the lamb is more than 5 months old. In very well depressed arrays, showing great scarcity of histerotrichs, (see page 131 /) the later starting histerotrichs are probably added earlier. This problem needs further investigation.

3. Growth of Histerotrichs and the Density of the Fleece.

The above discussion seems to be very important since Burns (9) has published a table showing the growth of skin area in sheep. According to this author the growth of skin area is maintained until the sheep reached 12 months of age. Unfortunately the data for the Romney breed is not available and therefore the data for Lincoln and Corridale breeds will be chosen:

TABLE XIII

Three-Quarter Blood Ewes out of one-half
Blood-Ewes, sired by Various Breeds of Rams.

Body area:	Mid-shoulder		Mid-side		Mid-thigh	
Breed of sire:	Line.	Corr.	Line.	Corr.	Line.	Corr.
Age in months: Indices of skin area: first month equals 100.						
2	127	116	124	117	115	116
3	150	141	142	137	134	132
4	162	144	176	160	150	153
5	187	164	216	174	157	157
6	196	170	227	188	157	183
7	205	190	262	207	170	200
8	210	193	264	218	170	206
9	217	195	270	231	174	215
10	229	201	282	243	192	226
11	234	206	289	249	192	230
12	243	201	300	250	192	237

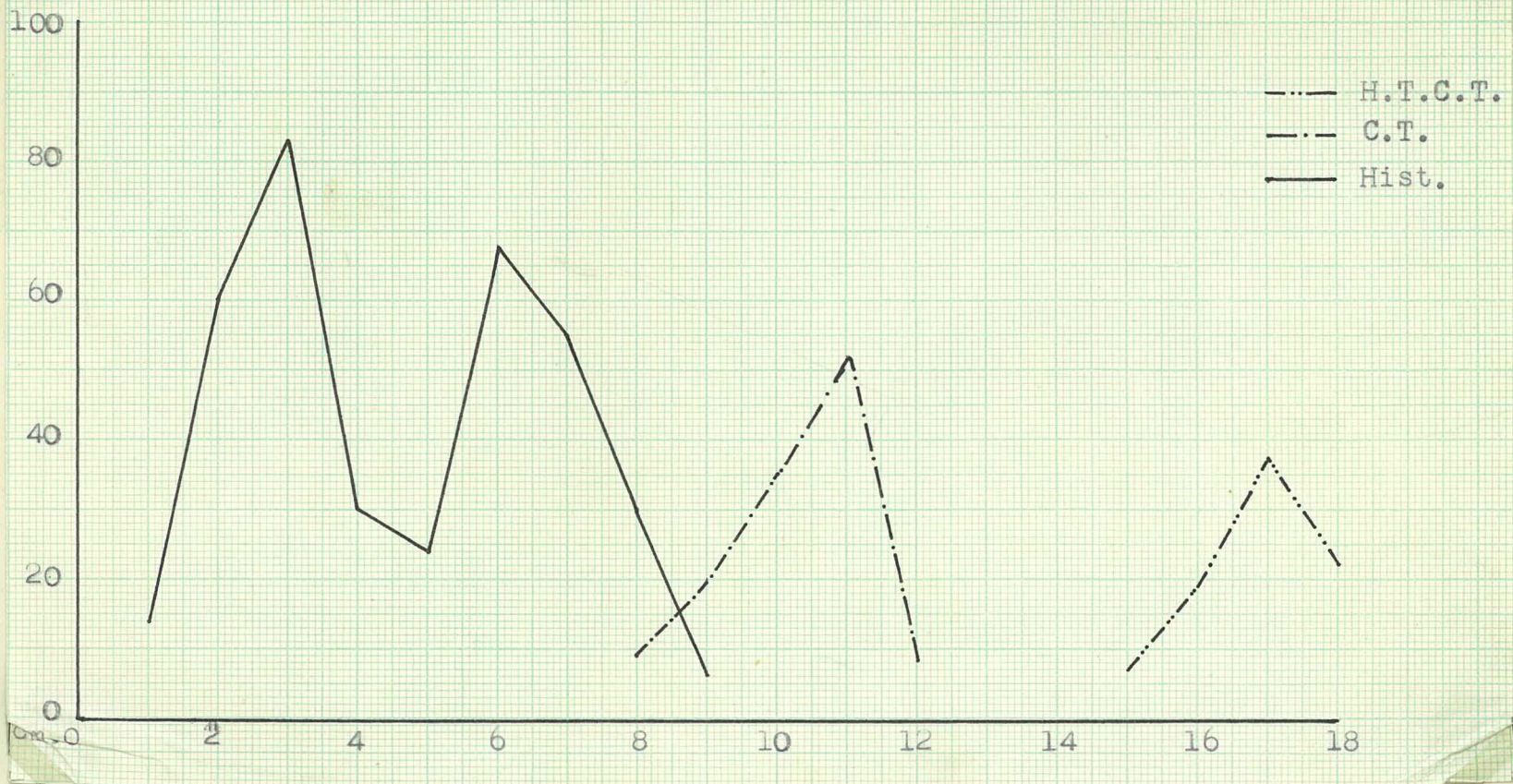
(this Table is after Burns (39)).

The Table above shows an appreciable increase in skin area after 5 months of age and therefore in the light of the present investigation it is apparent that the density, that is number of fibres per unit area is decreasing after five months of age. Therefore, in

speaking of the density of the lamb fleece it is necessary to emphasise the age of a lamb, and it is suggested that the most suitable time for investigation on the density of the sheep's fleece is when the lambs are above five months old, but not older than 6 months. At this time the latest histerotrich fibres are available for counting and the differences in the skin expansion are not very marked.

4. Mode of Histerotrich Growth.

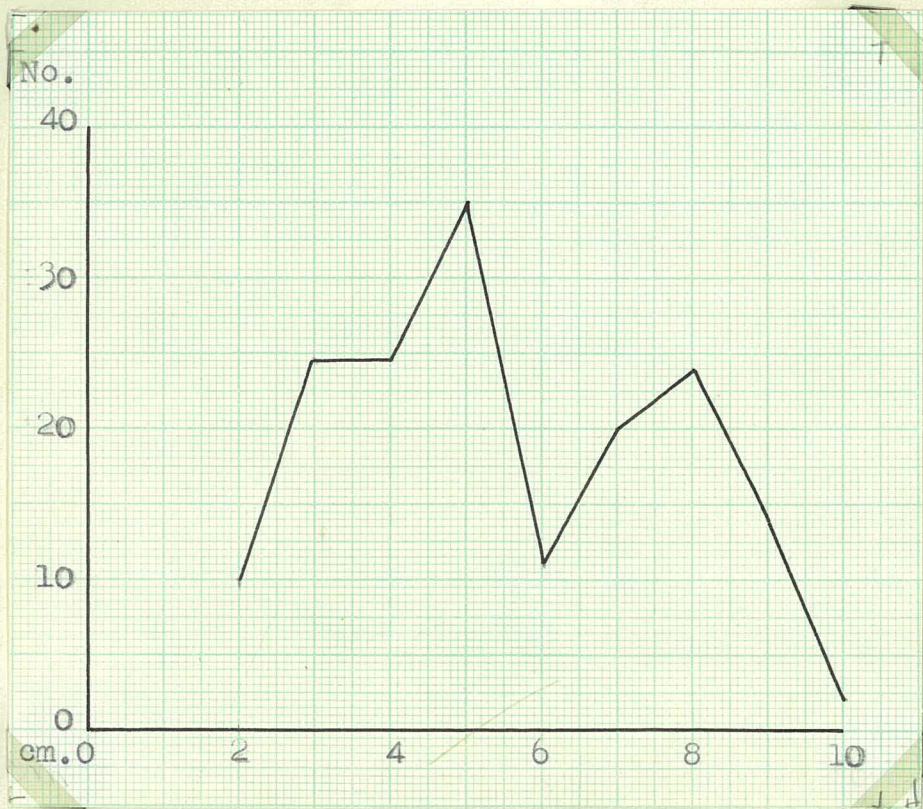
Graphs 3 and 4 (74, 27) show the length of histerotrich fibres. Let us discuss for the sake of example Graph 3, concerning the britch of lamb No. 74 VI!, Plateau. The curve represents two peaks, with a deep gap between. This is the most typical mode of histerotrich fibre growth, which has been checked in other arrays as well. For the reason which will be explained in the section dealing with the evolution of the fleece, these two peaks or at least one of them undergo a reduction and therefore in more checked arrays the gap is not very well marked. However, in all arrays, it has been found that the same main features of development can be recognised - we shall therefore



Graph 3.

length of Histerotrichs, curly-tip and hairy-tip-curly-tip fibres.

Lamb No. 74 (152 days old), Saddle on halfbritch. Note the two peaked curve for histerotrichs, single curve for other fibres; negligible overlapping between first histerotrichs and late curlytip fibres; the deep precipice between hairy-tip-curly-tip and curly-tip fibres.



Graph 4.

Length of Histerotrichs:

Lamb No. 27 (179 days old), Saddle on half-britch.

Note the two peaked curve; the first peak (shorter fibres) is higher than the second.

speak of the wave theory of the development of histerotrichs. In other words, histerotrich fibres do not time their entry into the fleece in a way which may be plotted in simple fashion as a frequency curve, but the curve consists of two distinct waves topped with two peaks. Such a curve indicates that histerotrich fibres pierce the surface of the skin in two waves, either of which may be higher or lower, that is, the first or older (consisting of longer fibres) may be higher than the second while the contrary is quite common as well. This means that at least two phases in the development of histerotrichs must be recognised. The first phase is when the histerotrich follicles are laid down, at first, slowly, then the development of new follicles is accelerated until its climax, denoted by the second peak on the graph, then the foundation of new follicles is withheld until the trough of the gap in the graph is reached. The second phase is identical with the first and lasts until the last follicle is laid down. Sometimes the second phase is further split into two more or less marked peaks with a shallow gap between (see graph 4). Such a curve, with an additional peak in the second phase, will be discussed in the evolution section.

5. Abundance of Histerotrich fibres.

TABLE XIV.

The means of Histerotrich abundance.

	Plateau		Saddle		Ravine		Valley		Plain	
	1 %	2 No.	1 %	2 No.	1 %	2 No.	1 %	2 No.	1 %	2 No.
Britch	51.8	294	38.3	89	43.1	82	31.7	51	-	-
Half Britch	52.2*	206*	38.5	84	36.3	71	31.6	53	-	-
Rump	54.0*	219*	34.8	73	39.9	84	41.3	85	-	-
Side	60.2*	230*	34.0	60	43.2	89	39.3	75	-	-
Back	59.8*	270*	42.6	87	36.2	67	39.5	81	-	-
Withers	63.8*	225*	-	-	-	-	37.3	64	32.5	51.7
Mean	-	-	37.7	78	39.7	79	36.8	68	-	-

Column 1: Histerotrichs expressed as percentage of total fibres

Column 2: Histerotrichs expressed per 100 curly tip fibres

* Only Lamb No. 74

From the above table it is apparent that:

- (i) The highest abundance of histerotrich fibres was found in the Plateau arrays and the lowest in Plain arrays:
- (ii) The differences between Saddle, Ravine, and Valley arrays are of no significance - perhaps Valley arrays are inclined to show a slight tendency to lower histerotrich abundance;
- (iii) Very marked drop in the histerotrich fibre abundance from Plateau arrays to more depressed ones.

It must, however, be pointed out that the great majority of the lambs concerned were chosen with the britch standard region heavily hairy with great abundance of halo hairs. In dealing with halo-hair abundance the way in which the decrease of halo-hair abundance takes place has been mentioned and it was said as well as shown in plates that already a few centimeters above the britch the birthcoat may be entirely free of halo-hairs and this means the other regions have more checked arrays. It seems, therefore, that the drop in

halo-hairs abundance is not only related to the better or more severe pre-natal check, but also this drop brings about a simultaneous drop in histerotrich abundance. Data given by Sutherland (46) supports the last statement. The analysed Saddle arrays were closely associated with Plateau arrays on Romney lambs of Grades V and VI. If the sudden drop in halo-hairs abundance is correlated with a simultaneous drop in histerotrich fibre abundance, we should expect an appreciably higher percentage of histerotrich fibres in high grade lambs. In Saddle arrays of Grades V and VI the mean percentage of histerotrichs is 46.33 ± 2.12 S.E. with the co-efficient of variation 11.16.

It may be added, too, that Sutherland's mean for histerotrichs in Plateau arrays, all the lambs being Grade VI! is 51.43 ± 1.31 S.E. with the co-efficient of variation 12.286. This mean is almost identical with the mean found in the present investigation, this being 51.8 per cent. The relatively small coefficient of variation shown in Sutherland's figure strengthens the real value of the means, although tables of the appendix show much

greater variability of histerotrich abundance in my material, hence this variability rather suggests multifactorial inheritance of histerotrich abundance. Thus we may conclude that a sudden drop in halo-hair abundance is correlated with a simultaneous drop in histerotrich abundance. This drop is still better emphasised by computing the number of histerotrich fibres per 100 Curly tip fibres (column 2 in Table XIV)

There is another inference to be drawn from these data as to the correlation of histerotrich abundance with arrays. It has been said that Valley arrays tend to have very low histerotrich abundance, this being still better marked in Plain arrays. In a previous discussion it has been pointed out that Valley arrays as well as all the others should be considered as a series of arrays having common characteristics which allow the classification, and this classification is based upon the results of the action of the "head check" but as it has already been pointed out the head check has its limitation, leaving at least 63 per cent of curly tip fibres under the influence of the "tail check". This tail check must not necessarily be confined too, say Valley array. The trace of its work may

be found as early in Saddle or even Plateau arrays and hence the variation in the percentage of hairiness. It is true, nevertheless, that the fullest development of this "tail check" may be watched in Valley arrays. In other words, in my material the "tail check" is almost always found when the array is Valley and always when the array is Plain. Now, both head and tail checks are responsible for improvement of the fleece, the first by causing all pre-curly-tip fibres and an appreciable number of curly-tip fibres to be fine; the latter by causing all remaining curly-tip fibres to be fine as well, hence without interaction of these two checks marked improvement of the fleece could not be made. It is, of course, only in Valley and Plain arrays that these two checks are joining forces and therefore we feel on surer ground in looking for wool improvement on these more depressed arrays. Now, instead of speaking of "tough" or "weak" Valley arrays, we are justified in saying "more or less improved" Valley array - that is a Valley array with a smaller percentage of peak curly tip fibres will be more improved than one with a greater number of these fibres, and still further

when a Valley array reaches a stage when all fibres are fine or nearly so there is still left ample room for further improvement in the length and diameter of fibres, at least. Now coming back to histerotrich abundance and keeping in mind the tendency to decrease the histerotrich population as was concluded from the mean of histerotrich abundance within Valley arrays, we may suspect that this diminution would be better marked in more improved Valley arrays. Here again, Sutherland's data furnishes the evidence that the above supposition is correct. He analysed low grade lambs from Dry's experimental stock as well as from stud stock of the Romney breed and Wensleydale breed. It is understood that Romney stud stock of Massey Agricultural College as well as pedigree Wensleydales may undoubtedly be regarded as well improved sheep as far as the present discussion is concerned: Sutherland's data are as follows:

Dry's Experimental Romney Sheep: - Valley Arrays

22%	Grade I
56%	Grade II
22%	Grade III
Histerotrich mean	31.11%
Curly tip fibre mean	58.44%

<u>Romney Stud Ewes:</u>		Valley arrays
Histerotrichs	Mean	21.15 %
Curlytip fibre	mean	58.44%

<u>Wensleydales:</u>		Valley Arrays
Histerotrichs	Mean	20.6 ± 3.0 S.E.
	Coefficient of variation	65.25
Curly-tip Fibres	Mean	73.95± 2.93 S.E.
	Coefficient of variation	17.83

Thus we can safely state that the more improved the Valley array the lower the Histerotrich fibres.

Histerotrich fibres will be further discussed in the "evolution section" from a somewhat different angle. Nevertheless it is not possible to escape the question of the importance of the enormously high coefficient of variation of the percentage of histerotrich fibres shown in Wensleydales as well as in Stud Romneys (the latter being 55). It will be suggested that this high variability, apart from its genetical aspect, is due to the foundation of new histerotrich follicles. This process, though, obscures the distinct trend of histerotrich evolution and at the same time makes one rather doubtful about the conclusion reached by Bell, Spencer and Hardy that the later

density of the fleece could be judged in the early weeks of the lamb's life. The authors have stated that after birth, an increase of about 20 per cent of new fibres is to be expected. In view of the high variability in the percentage of histerotrichs found by Sutherland and myself, one might doubt very much whether such an estimation has any practical value for the Romney Breed.

SECTION II.

I. SHEDDING OF BIRTHCOAT FIBRES AND THEIR SUCCESSORS.

The Pre-Curly-tip group plays the decisive role in kemp hairiness. Save that just occasionally Dry has found some secondary kemps to succeed hairy-tip-curly-tip on the back, it is on the pre-curly-tip group of birthcoat fibres that the presence and abundance of the secondary kemp depends. Dry (16) called the birthcoat Kemp " G_1 " and their successors in the same follicle, whether shed or not " G_2 ". These terms will be used henceforth. Thus if the shedding of birthcoat fibres is very poor, the abundance of G_2 will also be very poor. This is the rule which may be expressed in the following statement: No G_1 no G_2 . From this simple statement it is not to be understood that selection against shedding should be advocated in the Romney breed. Of course, a fibre does not cease to grow and instead of G_2 the fleece will contain persistent chalky fibres, which have been described earlier. From a manufacturing standpoint this "non-kemp-hairiness" as Dry (16) has called it, is undoubtedly undesirable. It must be emphasised that the difference between "kemp-hairiness" and "non-kemp hairiness" hinges simply upon whether the fibre sheds or persists.

Necessarily a fibre must do one or the other. We have here an "all or none" situation, but in other respects shed or persistent fibres of the same type may be quite indistinguishable.

1. Shedding in the Pre-curly-tip group: its variations in different body regions and arrays.

From Table XV which gives the means of shed fibres (G_1) expressed as a percentage of fibre types (see also the appendix) the following conclusions may be drawn:

- (a) All Halo-hairs are shed, this being the rule, yet it must be remembered that both Dry and Sutherland found very occasional persistent halo-hairs.
- (b) In the remaining constituents of the pre-curly-tip group, the shedding situation varies according to the array and the region of the body. With regard to the arrays it is clearly shown in Tables XV and XVII that the Plateau arrays have the highest percentage of shed fibres and the Valley arrays the lowest. A comparison within certain arrays over different body regions suggest

that in some regions the shedding is stronger and in others weaker. Thus the shedding in all arrays, in order from strongest to weakest, may be arranged as follows :

- (a) Back
- (b) Rump
- (c) Half-britch
- (d) Britch
- (e) Side
- (f) Withers

Attention may be drawn to the sudden drop in the shedding between the back and side, and back and withers positions. Again if different arrays are compared on the same body region it is apparent that the more checked the array the less the percentage of shed fibres in a given type. Further, fibres more closely related to halo-hairs show a greater percentage of shedding, while sickle-fibres show a smaller percentage of shedding. This general statement holds true for all arrays and body regions. The very important point which must be remembered is that the balance in the pre-curly-tip group varies according to the array. As it has already been mentioned in the sickle fibre section, the centre of gravity is in more checked arrays shifted towards the sickle fibre type, hence in Plateau arrays with no sickle fibres it may be expected that the relative and absolute percentage of shed fibres will be much

greater than in Valley arrays, because in the latter the balance of the pre-curly-tip group is so shifted to sickle fibres, that in extreme cases the pre-curly-tip group consists entirely of sickle fibres. Sickle fibres, according to previous statements, show :

- (a) the smallest percentage of shedding, and
- (b) a still further reduction in the percentage of shedding is the accompaniment of more pronounced depression in the array, that is a Valley array with a strong "head check", will have nearly all its sickle fibres fine, and fine fibres are almost always persistent.

It follows then, that there are two ways of decreasing the shedding of fibres:

- (a) the shifting of the centre of gravity of the pre-curly-tip group towards sickle fibres;
- (b) stronger "head check" causing the sickle fibres to be fine.

These two phenomena come together in the course of an evolutionary process causing the shifting of arrays from Plateau to Saddle, Saddle to Ravine, Ravine to

Valley and Valley to Plain, hence if selection is based on weak (intensely depressed) and truncated arrays, this selection is directed ipso facto against the shedding of fibres. The last statement is not to be understood to mean that I am convinced that the "head check" is as influential (or is even responsible at all) in preventing shedding as my co-workers believe. The "head check" changes only the balance in the pre-curly-tip group and causes the fibres to be fine. It seems that with the "head check" is closely correlated the shedding so that we can speak of the correlation without regarding the genes responsible for the "head check", as simultaneously responsible for the shedding situation. This point, however, calls for further investigation.

TABLE XV

SHEDDING OF FIBRES EXPRESSED AS PERCENTAGE OF FIBRE TYPES.

(N. = normal shedding; S. = Smoky shedding; Pers. = persistent)

	<u>PLATEAU</u>			<u>SADDLE</u>			<u>RAVINE</u>			<u>VALLEY</u>		
	Shed		pers.	Shed.		pers.	Shed		pers	Shed		pers.
	N.	S.		N.	S.		N.	S.		N.	S.	
<u>BRITCH:</u>												
Baby	100											
Halo-hairs	100											
S.S.A.	64.8		35.2	10		90						
S.S.A.	34.7		65.3			100						100
S.S.B.	39.4		60.6			100						100
Sk.	50.0		50.0			100			100			100
H.T.C.T.	6.3	1.2	92.5			100						
C.T.		0.1	99.9			100			100			100
<u>HALF-BRITCH:</u>												
Halo-hairs			100			100			100			
S.S.A.			100			60			40			
S.S.A.			76.5			23.5			65			
S.S.B.			56.8			43.2			18			100
Sk.			28			72			8			100
H.T.C.T.						100			100			
C.T.				0.1		99.9			100			100

TABLE XVI.

G₁ (Shed) G₂ (coarse fibres shed and cut)
expressed as the percentage of total fibres.

	<u>Plateau</u>		<u>Saddle</u>		<u>Ravine</u>		<u>Valley</u>	
	G ₁	G ₂	G ₁	G ₂	G ₁	G ₂	G ₁	G ₂
Britch	6.7	6.3	0.5	0.5	-	-	-	-
Half-britch	5.5 *	5.5 *	3.5	2.6	1.4	1.0	-	-
Rump	8.7 *	7.8 *	3.1	2.7	1.5	1.1	0.8	0.8
Side	2.6 *	2.6 *	0.8	0.6	0.6	0.6	-	-
Back	7.9 *	7.5 *	10.9 *	1.0 *	4.0	4.2	1.8	1.3
Withers	-	-	-	-	-	-	-	-
Mean			3.8	1.5	1.6	1.4	0.4	0.3

* From one lamb only.

Looking on the shedding situation as it can be seen from Tables in the appendix, one is struck by the great variations within the array on the same body region. For the sake of simplicity let us take three examples of shedding in Plateau array on the britch.

	<u>Lamb No.</u>					
	<u>27</u>		<u>76</u>		<u>65</u>	
	No.	%	No.	%	No.	%
Baby H						
Shed	4	6.6	2	4.3	0	0
Pers	0	0	0	0	0	0
H:H.						
Shed	11	18.0	17	36.2	10	24.4
Pers.	0	0	0	0	0	0
S.S.A.						
Shed	29	27.6	11	23.4	3	7.3
Pers	1	1.6	10	21.1	23	56.1
S.S.A'						
Shed	4	6.6	2	4.3	0	0
Pers	0	0	3	6.4	4	9.8
S.S.B.						
Shed	11	18.0	0	0	0	0
Pers.	0	0	2	4.3	1	2.4
Sk.						
Shed	1	1.6	0	0	0	0
Pers.	0	0	0	0	0	0
TOTAL						
Shed	60	98.4	32	68.2	13	31.7
Pers.	1	1.6	15	31.8	28	68.3

pers = persistent
 No. = number of fibres in a given fibre type
 % is expressed as percentage of total pre-curlly tip group.

The first and third examples show the extremes, the second is intermediate. Now the question arises why arrays vary as to the percentage of shed fibres. The full answer to the above question would involve a detailed discussion upon the forces at work causing the fibres to shed. It was not my purpose to extend the present investigation into the shedding situation, and therefore only a few points will be stressed, points which may be of some help in the future investigation of this subject.

The present investigation seems to indicate that there are at least two causes bringing about shedding or persisting:

- (i) the quantitative effect of genes responsible for shedding varies just as all the other quantitative effects of genes working upon every other quantitative trait, e.g. the number of sickle fibres, the number of curly tip fibres, etc.
- (ii) as it has already been mentioned in preceding sections, fibres comprising the pre-curly-tip group have two different shapes of tip (since halo-hairs are all shed they may be left out of account). The typical sickle like shape of fibre tips usually furnishes the left wing

of each fibre type and the non-typical hook or curl-like shape furnishes the right wing (see fig. 23). It was said, too, that the left wing is associated with halo-hairs, whereas the right wing is associated with hair-tip-curly-tip or curly-tip fibres.

The statements now made have references especially to plateau and also to Saddle on the britch, bordering on plateau. Sometimes, of course, it might happen that fibres on one wing are lacking or the number of fibres on the one wing or the other varies, eg. S.S.A. fibres having typical sickle ends may furnish the whole series of S.S.A. fibre type; on the other hand, there are cases in which only a few typical S.S.A. fibres are found, the others in this series being non-typical. Now if shedding takes place, it will be almost always found that the majority of typical sickle-ended fibres are shed, that is, the left wing of a fibre type will be shed, whereas the right wing comprising the non-typical sickle-ended fibres is persistent. A situation has never been found in which the left wing is persistent and the right wing is shed. Let us come back to these three examples. Lamb No. 27 shows very free shedding

In such a case we should expect that all the super sickle fibres will be shed, and, if a persistent fibre was found, this should be, at least, a sickle fibre. However, this single persistent fibre is a S.S.A. fibre and it may be added at once the only one placed on the right wing and closely associated with hairy-tip-curly-tip fibres. The same story repeats itself in the two remaining examples, the differences being that the right wing of the fibre types is longer, hence the percentage of persistent fibres is bigger. This is particularly clearly distinguishable in the second example. Notes are made in the course of analysis describing this array, point out simply that "all shed fibres are typical, all persistent are linked up with hairy-tip-curly-tip fibres". It may be worth while to show the shedding situation within hairy-tip-curly tip fibre series in these particular cases:

	<u>H.T.C.T.</u>	
	Shed	Pers.
<u>Lamb No. 27</u>		
No.	10	101
%	9	91
<u>Lamb No. 76</u>		
No.	6	33
%	15	85
<u>Lamb No; 75</u>		
No.	0	60
%	0	100

The above figures show that shedding in H.T.C.T. fibres is very much less free than in pre-curly-tip fibres.

It has been said that the fibres comprising the right wing of the pre-curly-tip series are very similar to H.T.C.T. fibres, the similarity lying not only in the tip shape, but also in the post-natal structure of the fibres, that is, the post-natal structure of the right wing fibres is almost identical with that of hairy-tip-curly-tip fibres. In other words, if H.T.C.T. fibres have a "crisis thinning" so will the "right-wing" fibres have this "crisis thinning". If medullation revives it does so in both types, etc. One might, therefore suspect the non-typical constituents of the pre-curly-tip group of having originated from a different stock of fibres, a stock which is not apt to shed. Thus it is suggested that fibres furnishing the right wing of every pre-curly-tip fibre type have evolved from hairy-tip-curly-tip fibres, and in this way it is possible to explain the different behaviour of shedding within the pre-curly-tip group. It must be kept in mind that the above explanation holds true in all cases in which non-typical sickle-ends were found. This does not mean that chalky fibres with non-typical ends never shed, or that chalky fibres with typical ends never persist. Of course, a small proportion of non-typical fibres do shed and a relatively larger proportion of typical chalky fibres of the pre-curly tip group persist, but the outstanding feature of

typical sickle-ended chalky fibres is shedding and for non-typical, non-shedding.

2. Shedding in Curly-tip Group

The type of shedding which has been discussed in the preceding chapter may be termed "normal shedding" or briefly "shedding". This is, however, not the only type of shedding found in the sheep's fleece. The abnormal shedding has been termed by Ruddall (42) and Sutherland (46) "smoky" shedding. The latter will be discussed in the next chapter. Here a brief mention may be made that "smoky" shedding is to be found almost always within the curly-tip group, the mean being about 1 per cent in H.T.C.T. fibres and about 0.5 per cent in C.T. fibres. The percentage is expressed as percentage of total fibres of the particular type.

The amount of normal shedding within the curly-tip group is negligible. As can be seen from Table XV only hairy-tip-curly-tip fibres in Plateau arrays on the britch regions have an appreciable number of shed fibres, the mean being 6 per cent. In all other arrays, in all the standard positions over the lamb's body if hairy-tip-curly-tip fibres were encountered they were persistent fibres, with one exception, this being the back position in Valley arrays that shows a trace of shed hairy-tip-curly-tip fibres, namely 0.2 per cent.

Within the Curly-tip fibre series, normal shedding takes place very seldom indeed. In fact, here again only in Valley arrays on the back have shed curly-tip fibres been found, the mean being 0.5 per cent. One Valley array, however, had as high as 3 per cent of shed curly tips. One Saddle array, too, found on the back position had 5.7 per cent of its curly tip fibre population shed. Thus from the data in hand, a conclusion may be drawn that the curly-tip follicles, showing a very low percentage of shed fibres, play a very unimportant role in the production of G₂ hairiness.

3. Shedding of Histerotrichs.

Histerotrichs are always persistent. This is the rule. However, one odd histerotrich has been found which was shed in normal fashion. This was found on Lamb No. 44 in the Plain array on the side region. This shed histerotrich has been found by mere chance because in the course of sorting the fibres one's attention is drawn to the butt end of the chalky fibres in searching for shed fibres and very little, if any, attention was paid to butt end of histerotrichs. It has been taken for granted that histerotrichs, being fine, must automatically be persistent. On the other hand, searching for shed histerotrichs is very tedious because it cannot

be detected macroscopically that such fibres are shed. Since ^{no} ~~in~~ investigation has been made of the shedding situation within histerotrichs no conclusion as to the frequency of shed histerotrich fibres can be drawn from an accidental finding of shed histerotrichs.

II. THE MODE OF SHEDDING.

A few observations upon the mode of shedding of fibres in the Romney fleece may be worth while. These observations were made in a rather sketchy way and should be looked upon as a by-product of the investigation.

As it has already been mentioned in the preceding chapter, two types of shedding have been found - normal and smoky. As to the latter, Sutherland (46) found all intermediates between "smoky" and normal shedding, yet he writes (p.31) "

"That this type of shedding (smoky shedding) is peculiar to fortuitously shed fibres, and is, therefore, the result of a different set of circumstances from those responsible for normal shedding'.

In the present investigation this matter was not studied seriously. However, one familiar with these two types of shedding may accept Sutherland's view. In the course of the present study curly-tip fibres were found which



Fig. 30



Fig. 30a

Fig. 30 : A curly tip fibre which has a swelling typical of smoky sheathing some distance from the shed end.

Fig. 30a: A sheath of a shed fibre.

have a combination of these two modes of shedding, that is a fibre starts to shed spikily and after a little while it sheds in normal fashion. Such a fibre is pictured in fig. 30. The above described combination of shedding supports Sutherland's view again.

It may be worth while to mention that one super sickle B fibre was found with a "smoky" shedding (Lamb No. 76 - Valley on the back).

The basal ends of shed fibres have been described firstly by Dry (13) and later by Sutherland (46). Generally speaking, the shed butt is ended with a brush or a club. These basal ends are sometimes enclosed in a sheath. This sheath, as it has already been mentioned, takes Orange G very easily, whereas the fibre itself does not. We thus have a very simple method for dyeing and distinguishing under the microscope the sheath from a brush or club, and it is even possible to see very clearly the enclosed brush. Sutherland has already described variations in shedding without the sheath. The sheath of shed fibres may be long or short, narrow or broad. The basal end of such a sheath is usually circular but a sheath has been found with a bottom split longitudinally in a somewhat root-teeth fashion.

It may be worth-while to mention the relative frequency of shedding with and without a sheath. The microscopical analysis of shed fibres of twelve different arrays on different body regions is given below in Table XVII. This Table shows that "sheath shedding" is more common than non-sheath shedding. This statement is in contradiction to Sutherland's opinion (p.94) -

"Shedding with a sheath appears less common than without the sheath".

TABLE XVII
TYPES OF NORMAL SHEDDING.

	<u>No.</u>	<u>%</u>
Halo hairs		
Brush end	22	33
Sheath end	44	67
S.S.A.		
brush end	20	35
sheath end	38	65
S.S.A'		
brush end	25	47
sheath end	17	53
S.S.B.		
brush end	13	42
sheath end	18	58
Sk;		
brush end	14	39
sheath end	22	61
H.T.C.T.		
brush end	0	0
sheath end	7	100
C.T.		
brush end	0	0
sheath end	11	100

III. G₂

Dr. Dry understands by G₂ all successors of birth-coat kemp, whether shed or persistent. In the course of the present study it was impossible to ascertain whether G₂ was shed or persistent because the samples were still too short and quite a number of G₂ were cut. Of course such G₂ could be shed later on. Generally speaking all the data collected upon the behaviour of G₂ give the fullest support to Dry's views and conclusions reported in various publications of his, and therefore it is considered necessary to stress only a few points.

1. Relation between G₂ and arrays.

In Table XVI, the data are given to show that there is a relationship between the arrays and the abundance of G₂. As a rule we can state that the less checked the array, the greater the proportion of G₁ fibres succeeded by hairy G₂ fibres. This is understood in the light of previous discussion, when it was pointed out that the balance of the pre-curly-tip group is in more checked arrays shifted towards sickle fibres.

2. Relation between G₂ and body region.

corresponds with that of G₁.

3. Relation between kemp-hairiness (G_2) and non-kemp hairiness (persistent chalky fibres):

Such a division is an arbitrary one.

The following is an example of a common way in which the two kinds of hairiness are united. I have been particularly impressed by super sickle B fibres, chalky until "crisis thinning", then having a fine portion of about 3 cm long, after which the chalkiness revived. The latter chalkiness corresponds in every respect with kemp chalkiness. Again the division within G_2 is an arbitrary one. Especially in Non-plateau arrays, the successors of halo-hairs have a distinctly better chance of shedding than the successors of other pre-curly-tip fibres. As a rule the chalkiness of G_2 is a reflection of the general chalkiness of a given sample. If the chalkiness of persistent fibres or strictly speaking of the head part of an array is well maintained down the samples the G_2 will be very chalky too.

Let us give a few examples.

		<u>Hairiness</u>
		<u>%</u>
1.	Lamb No. 11 Britch, Plateau	36.4
2.	" " 11 Half-britch, saddle	34.2
3.	" " 74 all regions	+ 100.0

4.	Lamb No. 76,	Britch, Plateau	37.0
5.	" "	81, Britch, Plateau	49.8
6.	" "	82 Britch, Plateau	49.2

The first, second and fourth examples show a considerable number of pre-curly-tip fibres and hairy-tip-curly-tip fibres, chalky throughout.

The fifth and sixth examples show a still greater number of fibres chalky throughout, and Lamb No. 74 has extremely chalky fibres. In these six examples G_2 was very chalky. On the other hand there are arrays which, though still hairy after "crisis thinning", are comparatively fine and then G_2 shows an appreciable reduction in coarseness. Such arrays are:

Hairiness

1. Lamb No. 75, Britch, Plateau 24.6
2. Lamb No. 44, Britch, Plateau 30.7

In the first example only, few G_2 were really chalky, others were rather fine. In the second example not a single G_2 was found to be heavily chalky. To the above generalisation a reservation must be made, namely, that the successors of birthcoat fibres well to the left of the array, and especially halo-hairs, usually escape from the check and usually they are chalky; e.g.

Lamb No. 27,

Britch - Plateau.

	<u>No.</u>	<u>%</u>
Baby hairs		
Shed	4	6.6
pers.	0	0
Halo hairs		
shed	11	18.0
pers	0	0
S.S.A.		
shed	29	47.0
pers.	1	1.6
S.S.A'		
shed	4	6.6
pers.	0	0
S.S.B.		
shed	11	18.0
pers.	0	0.6
Sk.		
shed	1	1.6
pers.	0	0
G ₁	70	10*
G ₂	58	8*
Hairiness.		35%

* Expressed as percentage of total fibres, others expressed as percentage of pre-curly-tip group.

G₂ found in the above array varies as to the chalkiness length, shedding, etc, and it may be assumed that the successors of early fibres are more dangerous than the successors of later ones, because

the former can escape the pressure of the check and the latter cannot. A very striking example that the successors of late fibres, that is super sickle B and sickle, fibres, are almost always in the orbit of a check responsible for after-crisis-level fineness (Section III) is that of lamb No. 82, Saddle on the back.

	<u>No.</u>	<u>%</u>
S.S.A'		
shed	3	6.4
pers	0	0
S.S.B.		
shed	9	11.2
pers.	1	2.1
Sk.		
shed	32	68.0
pers.	2	4.3
G ₁	44	11 *
G ₂	0	0
Hairiness		16.4

* Expressed as percentage of total fibres, others expressed as percentage of pre-curly-tip group.

Thus this latter array in spite of having 11% of total fibres shed has no single chalky successor!

With regard to the structure of G₂ it may be said that there are a hundred and one variations. A G₂

fibre may start to grow with a chalky tip and after a while the chalkiness is diminished and a fine portion of G_2 follows or a G_2 fibre may start with a fine tip and becomes chalky after a while for a longer or shorter period and later on the chalkiness disappears. Also the general crimp of a staple is superimposed on G_2 fibres, e.g. Lamb No. 74 has crimps only in the back and Britch. On these regions G_2 is crimped too, but on the side where no trace of crimp is detectable the G_2 fibres are as straight as all the others.

Thus, to sum up, emphasis must be laid upon the following factors:

- (i) in kemp production the follicles of the first fibres, that is halo-hairs and their closest associates play a very important role;
- (ii) there is a correlation between kemp hairiness and non-kemp hairiness;
- (iii) the relation between shedding in G_1 and G_2 has been found in this laboratory to be orderly, but a little elaborate. To be sure, the successors of halo-hairs may be

non-hairy persistent fibres, but they may be hairy fibres or kemps. Consequently in a breed in which halo-hairs in the birth-coat confer no advantage on the lamb, it is simplest to base selection on truncated arrays with the hairiness of persistent fibres never sustained below the crisis level. Such an array may be sometimes a weak "Saddle" providing however that the post-crisis-level-check is strong enough, but it seems much safer ideally to chose as a standard array a weak Ravine or weak Valley. One could object that here is a method advocated which leads to selection against hairiness. Exactly. As long as the conviction prevailed that kemp is a remnant of the outer coat and all other hairiness had originated from the inner coat, such a division was tenable. This view is, however, wrong.

persistent

of the coat

As our knowledge/of the Romney lamb has advanced it is more and more realised how intimately related are those supposedly different kinds of hairiness. Both sorts of hairiness may be regarded as belonging to the same substratum acted upon - carved or sculptured - bby the pre-natal check or other forces.

Later more will be said about selection against that aspect of hairiness which it is convenient to call non-kemp hairiness.