A STUDY OF THE PLATEAU ARRAY.

Thesis Submitted by

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A STUDY OF THE PLATEAU ARRAY

SECTION I

SECTION II

Page

FIBRE TYPES

SECTION III

Page

Page

SECTION IV

A STUDY OF THE PLATEAU ARRAY.

Introduction.

A brief historical survey of the work leading up to the present study.

The world sheep population is in the vicinity of seven hundred millions and the vast majority of these animals are kept, to a greater or a lesser degree, for their wool. It is, therefore, not surprising that Wool Research is by no means new. The production of sheep for their coat has been, as Barker points out (1), of importance since Biblical times and, although during the last epoch, with the perfection of methods for meat preservation, the importance of wool to the sheep industry has decreased, the need for wool research has been increased by the ever growing perfection of synthetic fibres.

Wool research as such can possibly be dated from Dr. Hook who, in 1664, presented a paper to the Royal Society on the subject of wool and hair structure, but it was not until the advent of the compound microscope that the study of wool gained sufficient precision for measurements to be made. Such measurements opened the door for the wool physicist who, by the application of X-rays and other physical methods, has been able to explore with considerable success the ultimate structure of wool and hair.

The value of wool has been determined, at least partially, by its length and thickness (or width), and thus measurements of wool in three dimensions have been important sections of wool research. As other valuable characters were recognised and evaluated they also were measured and correlations worked out. Thus it has come about that wool research has collected about itself innumerable patient measurements - measurements that have often merely evidenced the complexity of the fleece of the sheep as a subject of research. Workers have often been unable to check their measurements with those of other workers because of the great variation, not only between sheep of different breeds in different environments but, between animals of the same breed and even between adjacent areas on the same animal. Thus it is, that similar series of measurements have led to different conclusions, bringing about confusion which still exists in certain sections of wool research.

The concept of the fibre as an individual entity and not merely as an individual in a population is relatively new in wool research. Barker (1) as late as 1929 writes that, from the point of view of Biology, the unit of study is the complete fleece, pointing out that differences between fibres while marked in extreme cases are yet not absolute, as fibres can be found that represent every graduation between extremes. He does, however, make a distinction for Kemp.

The fact that the wool fibre is an accretionary product showing in its structure the happenings in the follicle that grew it, has been rather neglected by overseas wool workers. That different types of fibre existed has, of course, been plain but anatomical and environmental relationships between them have been overlooked.

Perhaps the economic importance of wool as a product has, by laying too much emphasis on the practical value of the work, rather confused wool workers, perhaps the difficulties confronting the wool manufacturer were so obvious that those available for wool research must first attack the problems ready to hand. This has resulted in the neglect of wool biology in those countries where manufacturing is of major importance. In producing countries which are relatively new or relatively backward the long established seats of learning apparently necessary for relatively long range pure biological research are practically non-existent, with the result that wool as a biological subject for pure science research has not been given the attention it warrants. A further point of importance is that the manufacture of the product is largely divorced from its production, with the result that the producer is unable to appreciate the relative importance to the manufacturer of the faults in the wool and is therefore unlikely to give support to long range schemes for wool improvement. Also the producer countries have been greatly troubled with environmental effects and have concentrated on these as giving the greatest returns.

The difficulties such a large animal as the sheep presents for experimental purposes makes the work expensive and rather cumbersome. Thus it is that wool research from a biological point of view is of relatively recent origin. Happily, however, the biology of hair has been studied in other mammals - animals more amenable to breeding and laboratory work, and this work has established principles and methods that have been found applicable to wool research.

Thus biological wool research as such is a relatively new field and a cronological survey of that section which deals with kemp, followed by a brief resumé of biological work on the coats of smaller mammals of importance to fibre types in the sheep, is proposed.

Work on kemp has always recognised that at least two types of fibre exist in the fleece of the sheep. The term Kemp is taken from the trade where it serves a useful practical purpose in distinguishing excessively coarse fibres from the bulk of the fleece. Thus, although it supplies the research worker with a very useful term, it requires to be defined before it can be used in scientific work.

Wool research has been greatly hampered by the lack of efficient scientific definitions for terms borrowed from the wool trade - terms that served a very useful purpose for rough practical distinctions, but when applied to the results of minute study tended more to complicate than to clarify.

In research on wool, the work has been mostly descriptive and the descriptions have perhaps been too close to get a view, as either locks or parts of single fibres have been studied. A complicating factor is that the fleece is clipped each year and the fibre growing, as it does, throughout life, is incomplete except in the first fleece. Also in the first fleece the fibre is exposed to external conditions with the result that the tips are damaged early in life.

Descriptions of fibres in the fleece of the sheep have revealed the wide differences in structure, but the intermediates have proved so numerous that separation into definite types has been found difficult. Thus it is, that until recently the study of kemp has been greatly hampered by the lack of definition of a Kemp. Before a definition can be given, however, a study must be made and this study was started early in the century when Bowman 1908 (2) and Priestman 1911 (3) described kemp fibres occurring in cloths, the latter succeeding in tracing them back to East Indian raw wools.

The word kemp is a practical term used by the sheep breeder and manufacturer to describe certain coarse fibres occurring in wool. These fibres have proved to be a nuisance to the manufacturer in both dyeing and working, thus decreasing the value of the wool. The trade idea of kemp has, however, given rise to many difficulties when an endeavour has been made to study it in the laboratory. There is no doubt that workers were agreed on the general idea of what kemp was but there appeared to be some difference of opinion as to how to regard kemp.

Bowman (2) and Priestman (3), possibly the first to describe kemp, both regarded it as a faulty wool and failed to distinguish between true short kemps and kempy or medullated wool. Priestman (3) in disagreeing with Bowman (2) that the brightness or silveriness of the kemp by reflected light and its density and opacity by transmitted light were due to a scale modification, held that it was due to the inclusion of space or air bubbles within the fibre and that if these spaces be filled by soaking in benzol and oil or by boiling in oil, then the fibre becomes transparent. He published interesting micro-photographs showing clearly the characteristic round and square cells of the kemp medulla.

Barker and King (4) and later McMahon (5) conclusively proved that density of the medullated fibre, and therefore kemp, is considerably less than of pure wool and thus the large cells illustrated and described by Priestman probably contain air.

Duerden and Ritchie (6) describe kemps as they occur in the South African Merino. They note that they are when found in the fleece, always single and isolated, never in staples, and are intermingled with the denser growth of wool. Usually, they observe, "kemps are not more than an inch or two in length". The shed butt is then described as is the whip tip, typical of new fibres. Further study of the medullation leads them to neglect shortness and shedding as unimportant and to suggest that for the sake of terminology, any fibre containing air should be classed as a kemp, or at any rate kempy. Their consistency with this definition however breaks down when they hold that kemp is the remnant of the outer coat of the ancestral sheep. They thus remark the essential continuity between kemp or kempy fibres, as defined by themselves, and wool, while pointing out that the essential discontinuity between the outer and inner coat when they say, "by breeding the fine fibres have been increased and instead of being shed at intervals now grow continuously for the lifetime of the sheep". They were, however, unfortunate in their choice of sheep as the Merino is less adapted for kemp and medullation study than the coarser sheep in which all kinds of medulla occur more or less abundantly.

Roberts (7) in 1926 raises the question of definition and from observations made on the Welsh Mountain breed, lays down conditions that an adequate definition of kemp must satisfy. Since an adequate definition is of major importance if a scientific study of kemp is to be made these conditions might well be quoted in full.

"(1) The distinction between kemp and other fibres should be both sharp and qualitative.

(2) The distinction, if it is to be used practically,

should permit rapid and accurate naked-eye separation into the two groups - kempy and non-kempy.

(3) It is desirable that the separation into the two groups should be one that would correspond to the technical opinion of what constitutes a kemp.

(4) It would be highly satisfactory and an indication of profitable biological discussion in the future if the definition were to represent a real biological distinction".

Above all then a kemp is a fibre that sheds".

Those fibres that exhibit medulla and were included with kemp by Duerden (8) and previous workers generally, he considers to resemble the kemps as defined above.

This distinction has become most important with the discovery and use of the benzol test by Elphick (9) and later McMahon (5). The importance lies in the fact that even fine medullation that is difficult to detect with the naked eye is shown clearly by this test and it is abundantly evident that all fibres showing medullation are by no means all kemp as described by workers on kemp.

The discontinuity of the kemp series is therefore definite - either a fibre is shed or it persists. If it is shed it is a kemp and thus the problem of kemp is the elimination, according to Roberts, Duerden, Barker and others, of a totally distinct coat of the sheep. That the distinction is as clear cut as Roberts believed is doubtful in the light of more recent work by Duerden and Seale (10), Duerden (11), and particularly Dry.(12) and others. Roberts (7) however, later remarks the macroscopic and microscopic similarity to kemp of one persistant fibre which he classifies as anomolous.

The definition does, however, despite exceptions, give a very useful working distinction in the coat of the sheep and as such is of the utmost importance to the research worker who recognises it as a working definition and by no means the final word. That kemps are too complicated for such a simple definition is now obvious. Fine fibres with no macroscopic or microscopic kemp characteristics have been found loose in the fleece with the bulbous swelling typical of shed fibres, while coarse fibres closely resembling kemp both macroscopically and microscopically have persisted, but as a working definition this shedding distinction has yielded valuable results and paved the way for a better understanding of the biology of the fleece of the sheep.

Blyth (13) in a study of kemp fibres of the British breeds of sheep, designates kemp as 'fibres distinct from all other fibres on account of coarseness and because they are usually found loose in the fleece, that is, they are shed at least once a year'. A minute study of structure is made from which there appears to be a definite distinction between kemps and non-kemps in scales as well as medulla. These structures in the kemp resemble similar structures in the hairs of primitive breeds and thus lend weight to the theory of the homology of kemp and hair.

Roberts (7) also found an absence of relationship between kemp and length of fleece, density of fleece, lockiness, and fineness. and remarks animals that had much birth coat kemp and relatively pure fleeces. Later in his work on the Welsh mountain breed he speaks of fibres which appear to be wool fibres for the greater part of their length, but exhibit portions (usually the tip) of a "kemp like nature".

Grew and Blyth (14) observed in the fleece of the wild sheep, Ovis vignei, and also in Ovis musimon, fibres of a character intermediate between the usual coarse kemp and the wool. These they describe as "fibres indistinguishable from wool in their fine proximal part, but showing a stiff, straight distal portion, white or pale brown in colour". They again refer to similar fibres that they found in the fleece of the Blackface (15).

Duerden and Seale (10) fully describe fibres of a similar nature in the fleece of the South African Merino which they call heterotypes. These fibres, they describe as "medullated in their upper parts, usually of a sickle shape and non-medullated below this tip region." They occur only in the first fleece and are ordinarily shed from about three months onwards. They were explained as modifications of wool fibres.

Barker (1) in referring to 'heterotypes' writes "it is possible to draw distinctions between types of fibres occurring in the same fleece, and separation of samples into these types is occasionally useful; but up to the present (1929) except in the case of kemp rigid distinctions cannot be drawn. The differences, while marked in extreme cases are yet not absolute as fibres can be found that represent every graduation between extremes. Separation of fibre types, therefore, except in the case of kemp, must depend on the establishment of arbitary standards and involves an individual judgement that limits useful analysis on these lines".

This then was the position in 1929 but work since then has, on the one hand, shown that kemps are not as distinct from wool fibres as was then supposed, while, on the other hand, that definite steps from Curly -tip fibres (those fibres that are typically wool) to the coarsest birthcoat kemp can be traced and fibres that fall in each group classified on macroscopic appearance that is dependent on developmental happenings.

In 1933 Dry, fresh from work on mouse hairs (16), and confident that some order existed in the coat of the sheep comparable with that which he had found to exist in the coat of the mouse, published a series of papers on fibre types found in the coat of the New Zealand Romney lamb. This work was the outcome of that type of outlook pioneered by Toldt (17) working on mammalian hair form, and by de Meijere (18), working on the arrangement and development of mammalian hair. These men were able to lay down principles which are still an inspiration to those concerned with the study of the architecture of the fleece.

About the same time Elphick perfected the benzol test and was able to show that fibres could be classified as either medullated or non-medullated. He thus alleviated the confusion between the terms, "Kemp" and "Kempy." Dry also simplified the problem as much as possible by working on the first fleece and covering the animals so as to prevent fibre damage and loss of any fibres that shed. Halo-hairs, as the most notable feature of the first pelage, were first studied, a grading system was evolved and the Halo-hair relationships between different grades established.

Other fibres, termed Heterotypes by Duerden and Seale (10), were discovered and studied from a somewhat different point of view from similar work overseas. Fibre form was of major importance with length of medullation often distinctly secondary. The classification was thus an easy macroscopic one and where medullation was taken into account chalkiness was regarded as the criterion. Working on these lines the study of heterotypes gave rise to the recognition of many different groups present in the first pelage, groups that could be classified on their macroscopical appearance and groups that formed intermediates between the coarsest Halo-hairs and the smallest wool fibres.

All the groups were, by no means, present in all animals, nor were there similar numbers of each group in all animals or in parts of the same animal. In many animals the Halo-hairs were absent altogether, in others only partially so; in some there was an absence of intermediates between the Halo-hairs and those fibres called Curly tips. (The Curly tips are those fibres that give rise to the bulk of the improved fleece or, as workers overseas would have it, the developed undercoat of the wild sheep).

Such differences were by no means new in the mammalian coat. Toldt (17), the pioneer, had been able to classify into Woolhaare, Grannenhaare and Leithaare, the hairs from the coats of many mammals. Dry (16) himself had fully described what he recognised as real differences in the details of pigment and structure of individual hairs in the coat of the mouse.

Duerden, working on Sickle fibres in the Merino and other breeds writes, "they are best regarded as down fibres or prototrichs, comparable in many respects with the down which occurs at the apex of the definite feathers in birds. The entire covering of the lamb at birth (including Halo-hairs) would then be regarded as a down coat composed of prototrichs or down fibres, persisting for a time at the tip of the staples of the later woolly coat".

Heterotypism is, he considers, to be regarded as the primary condition of the hair fibres in most mammals, carrying with it a physiological significance repeated in a simplified form in the down fibres or prototrichs of the Ovidae. The curly tipped prototrichs, he regards as fibres which have lost their medullated thickening and thus are connected through intermediates to the 'Heterotype Sickle' fibres. Similar intermediate stages were found to exist between Sickle fibres and the Halo-hairs, the acme of birthcoat fibre medullation.

This type of speculation has not been advanced in this present work, not because of a failure to realise its importance in regard to Biological theory, but because it is considered that before such speculation is of value there needs to be a further capital of facts pertaining to the explanation of the architecture of the fleece.

Dry, believing that the coarse fibres of a mammal tended to be more primitive than the fine ones, quoted (16) the occurrence of the fine specialised zig zag fibres found in mice, the type of broad primitive scale found on the wide apical region of the fibres from Ornithorynchus and the general rule established by de Meijere that in the original pelage the earlier a fibre begins growth the stouter it is. Thus he states the problem when he says (19) "in fibres starting their development relatively early comparative fineness of a portion or of the fibre as a whole therefore calls for explanation".

In the same paper Dry (19) describes the fibre type arrays in the birthcoat of Romney lambs, explaining that the classification centres on the kind of transitional series into which fibres can be arranged in order to link by gradual steps the coarsest kemps, Halo-hairs, possessing big Sickle ends with the coarsest Curly tip fibres.

Thus the idea of a check in growth of a fibre from the follicle, first suggested to Dry by Duerden, who called it the "Birth check", began to bear fruit. This conception as Dry says in a letter to Nature in 1931 (20) "is the guiding idea in the work ...." In the light of the "birth check" the structural differences displayed by the array of fibre types that begin their growth at different times fall simply into line" The conception of the birth check thus explained the numerical variations in different types of fibres and also variations in shedding. This latter involves the conception of shedding as evidence of vitality of the follicle, a concept later to be established by Galpin (21).

An intensive study of the pre-natal check was made, using the data afforded by variations in the individual fibres and the idea was evolved that a pre-natal check is superimposed on a basic inherent fineness or coarseness of the animal. Dry (unpublished paper) from birth weight data and breeding experiments was able to show that the arrays were due largely to inherited factors as contrasted to environmental effects. Dr. Galpin (22) working on Romney foetuses, obtained sufficient evidence to say, "pre-natal work suggests that these two phenomena, (which she terms (a) the pre-natal check (b) the reduction in inherent coarseness), are the results of the same physiological factor in the development of the fibre population, viz. overcrowding of available skin space, due to rapid follicle formation - the first occurring at the trio and the second at the nine stage." The pre-natal check it is suggested might be regarded as a trio depression and the reduction of inherent coarseness as a nine depression.

It is thus apparent that although useful, the former conditions regarding kemp must perforce be revised. Whereas Roberts (7) in 1927 writes, "the problem of kemp involves the elimination of a totally distinct coat of the sheep" and further, "terming kempy all fibres that have an air filled medulla, destroys the most useful distinction that can be made in the fleece". Dry in 1932 was able to write of associations of fibres in the first pelage which he termed arrays, based on an essential continuity between the coarsest shed fibres - the Halo-hairs - and the finest wool fibres - the histerotrichs, or post curly tip fibres.

Further, he was able to link up the features of these arrays - due as Galpin showed to differences in pre-natal developmental rates - with the continued appearance in the fleece of kemp identical with those fibres described by previous workers.

Thus it is apparent that some measure of understanding has been obtained towards a more complete study of the architecture of the fleece of the sheep.

Material and Methods.

General.

This section is not divided into the classifications of materials and methods, due to the fact that in the descriptive, and particularly in the Genetical section, they are so intimately connected that such a division would be essentially artificial.

The materials, consisting in the main of Back samples from experimental sheep, are described in the light of the animals which grew them. This has enabled a classification to be made but it must be remarked that the bulk of this thesis depends on samples from Dry's experimental flock. These animals have been described previously, both by Dry (19) and Galpin (21), but for completeness a repétition of these descriptions is considered necessary. The work has not been confined to these experimental sheep and descriptions of these other sheep are included.

The methods used are simple in the extreme, and accuracy depends largely on care and judgement. The differences between fibres that provide a criteria for this classification are not treated in this section as they are dealt with in detail later.

Breeds.

The breeds of sheep used in this work are :-

A. Romney.

B. Wensleydale

C. Merino.

A. Romney. The Romney constitutes the main breed of sheep studied and the other breeds, together with the Romney Stud Sheep, have merely been used as extremes for comparative purposes. Thus it is apparent that a real classification within the Romney sheep can be made. These are :-

(a) Experimental

(b) Romney Stud Sheep.

(c) Miscellaneous Romney Cross-breds.

(a) Experimental Romney Sheep. These are sheep in Dry's (19) experimental flock and free use has been made of these by using stored samples as well as samples actually taken for the present work. This use of stored samples has made it possible, for purposes of illustration, to include animals that have been long dead. In using such samples free use has been made of Dry's files of analyses, but whenever possible Dry's analyses have been checked from a stored sample and experience of an array upon which Dry himself has done little work has made it possible to recognise much new detail. This use of stored as well as contemporary material has permitted the study of large numbers of sheep and the writer has been very fortunate indeed in having such a large number of dated and pedigreed samples available for study.

Actual breeding experiments have been taken over in toto for the genetical section. New experiments designed to further elucidate problems arising from these particular experiments were laid down in 1939 and preliminary results of these have been included.

The types of experimental animals used have been described by Dry (19) and are treated later in this work, so that it is not considered necessary to treat them here except to briefly state that they can be roughly divided into two classes, The Dominant N-type and the recessive non-N-type. Intermediates occur between these and wide variations of the two types occur but on the whole the N-type is typically Grade VI: (Dry unpublished) with a Plateau Array on the back position, while the non-N-type is typically Graded I, II or III for Halohairs and may have a Plain or Valley or less commonly a Ravine or Saddle Array.

As will be explained later, Dry has in his flock two strains of the N-type sheep. These are, however, apparently phenotypically similar and the distinction between them, although of prime importance in the genetic section, has been neglected in the descriptive section.

In relation to the non-N-type a rather similar situation exists and although the non-N experimental animals can be classified into recessives of different N-type strains, (see later,) and those unrelated to N-type animals, these differences have been neglected due to their phenotypical similarity.

(b) Romney Stud Sheep. Only a few analyses of these animals were made and these from samples taken early in November before the fibre tips had deteriorated. The sheep were Massey Agricultural College Stud Romneys, which stud has been selected for some years on medullometer test (5) and Halo-hair grading. The gradings of these animals for Halo-hairs were grades I and II, and they varied in medullometer test from Es. to AAs. on McMahon's (5) medullometer gradings. Thus it is apparent that no particular care was taken to ensure that these animals were extreme types and it may well be said that they constituted a random assortment.

(c) Miscellaneous Romney Cross-breds. These animals consist of College flock ewes that were being used for nutritional experiments quite unconnected with the present work. They are, therefore, sheep with unknown birthcoats. However, each was tested in the benzol tray and it was in this way ascertained that none of them had medullation that was comparable with that associated with the N-type condition. These ewes, commonly designated as cross-breds, are virtually pure Romneys as they are the result of a number of top crosses by the Romney ram. They were used for back crosses to augment the numbers of low grade experimental sheep. Their use provides room for criticism of the backcross results, but as the N-type is always associated with extreme medullation in the fleeces later than the Hogget, and as none of the animals used were unusually heavily medullated it is reasonable to use them failing enough ewes graded for Halo-hairs at birth.

Thus it is apparent that a fairly wide range of Romney types has been used, each aiding in the elucidation of a different aspect of the study of the fleece, while collectively demonstrating the wide fields of research leading towards a better understanding of the growth and architecture of the fleece.

B. Wensleydales. The study of these was made possible by Dr. K.M. Rudall who, at considerable personal inconvenience, obtained a large number of samples from Wensleydale Stud lambs in the North of England. These samples merit considerably more study than it was possible to give them in this work.

The reasons for obtaining these samples will be discussed later.

The samples are from lambs and were taken from the Standard sampling positions when the animals were about six to eight weeks old. They are heavily conditioned and due to the setting of the yolk the samples were occasionally gently washed in benzol to enable each fibre to be removed separately with the minimum breakage. Otherwise the samples were analysed in exactly the same way as the Romney samples. In washing the sample was held firmly by the butt end thus preventing the loss of Histerotrichs.

C. Merino. The Merino samples used were obtained from Otago Stud Sheep by Mr. M.B. Rowlands, late of the Fleece Testing Department of Massey Agricultural College. They were taken from uncovered hoggets and were unfortunately rather late samples with relatively imperfect tip form.

Covering.

The experimental animals of the N and near-N-type, were all covered as described and discussed by Dry in a letter to Nature (20) and later illustrated and again described in a further publication (19). Thus a description of the type of cover used and the reasons for covering is considered unnecessary. A quotation from Dry (20) is, however, of interest in regard to comparisons between covered N and uncovered non-N-type sheep. Thus he states: "as far as it has been possible to tell, the use of covers has no effect upon any feature of wool growth that has been studied, though, by preventing the washing out of yolk, covering does, of course, keep the fleece in a very pleasing condition". In support of this it is notable that the first samples taken previous to covering are, when analysed, in complete agreement with later samples taken after the sheep has been covered for a considerable time. Further, the covers are first placed on the animals when the first sample is taken and thus as regards analyses of these samples there can be no question of the validity of comparison on the score of covers.

Sampling.

The actual sampling of the lambs can best be treated under three distinct headings. These are:

(a) Sampling positions.
(b) Sampling methods.
(c) Sampling times.

(a) Sampling positions: These, along with numerous other positions which were neglected in this work, have been fully described by Galpin (21), but for completeness a repetition of the sampling positions actually used is considered to be necessary.

Practically the whole of this work is based on one sampling position but, for certain particular reasons, samples from other positions have been analysed. The major position is termed: (1) The Standard Back position. On the mid-dorsal line level with the last rib. The positions of lesser importance are:

(2) Withers. On the mid-dorsal line level with the fifth rib.
(3) Side. On the right side at the distal end of the last rib.
(4) Britch. Immediately posterior to the stifle joint and mid-way across the thigh.

(b) Sampling methods: These are simple in the extreme. The covers are first completely removed and the sampling positions accurately determined. The actual sample is removed with a pair of fine nail scissors. This permits the sample to be cut very close to the skin. The cut sample is stored in an envelope suitably marked with the date, sheep number, sampling position and any other notes that from time to time are considered important.

(c) Sampling times: The sampling times are primarily determined by shedding. Thus, in the light of the fact that previous to taking the first sample animals are not covered, the first sampling time must be before any of the birthcoat fibres are shed and thus liable to loss. However, samples must not be taken too early as for array determinations, a certain minimum length is necessary. The sampling dates of the first samples from the two lamb crops that have been studied particularly are 26th. October, 1937: 14th. October, 1938: and the 16th. November 1938. The two sampling dates for the 1938 season were made necessary by the unusually prolonged lambing season due to the eczema trouble at tupping. The early lambs were run separately from the latter lambs and it was, therefore, possible to sample them at a different time to the late lambs, thus permitting the samples to be more comparable as to age than would otherwise have been the case.

Later samples were taken from covered animals only, and as it is considered unnecessary in the light of Dry's work on succession to cover any but the higher Halo-hair grade animals it is apparent that analyses of low grade animals is confined to the October sample. However, certain of these non-N-type animals have been covered and subsequently sampled at the same time as the covered Hoggets.

The actual times of taking these later samples is determined by shedding and crisis thinning. Thus samples are not taken till all G_1 fibres have shed and usually G_2 fibres are well advanced in growth. This also permits the addition of

Histerotrichs to be completed and crisis thinning with or without recovery to be observed. This time is regarded as being about six months after birth and therefore sampling takes place in February or March. Thus in the 1937 and 1938 lambs samples were taken on the 10th. February and the 15th. March respectively.

A late sample is taken mainly for succession studies immediately previous to shearing. These samples have not been used in the present study except on odd occasions to check an earlier sample.

Stored Material.

"Hair splitting", as Dry so aptly describes the type of sorting done in the laboratory, is simple in the extreme. The complete cut sample is removed from the packet and a small sample of about 500 Curly tip fibres is selected therefrom. In the separation of this selected sample a considerable amount of care is necessary or small Histerotrichs will be lost and tip breakage will be excessive. To minimise these sources of error the sample for analysis is removed, butt end first. The method is to select the size required from the butt and grasp it firmly, peeling it down to the tip. Where the sample is a late one and therefore of considerable length with possibly both shed G_1 and G_2 fibres present this peeling process must be carried out with care or trouble will be experienced in obtaining accuracy as judged by duplicate samples.

The actual sorting is done on black velvet with two pairs of sharp pointed tweezers. These enable one to grip the fibres singly and with sufficient security to stretch them along a ruler if necessary. The fibres are then classified and if necessary the eye determinations are checked with the microscope or by making a benzol test with a drop of benzol, a microscope slide and a cover slip. The samples, except in the case of the Wensleydales (see above), are not scoured.

Methods used in measuring the fibres are discussed in their appropriate sections and will not therefore be treated here.

A certain number of benzol determinations were made and the same method as that used by Elphick (9) was employed.

DESCRIPTION OF THE PLATEAU ARRAY.

Introduction.

Before a description of the Plateau Array can be given it is considered necessary to describe in detail the various types of birth-coat fibres that have been recognised in the coat of the New Zealand Romney Marsh. These fibre types were discovered and named by Dr. F.W. Dry and have been described by him in various publications. Due, however, to their importance in this study a review of these descriptions, together with minor additions as to detail of some of the fibres, is thought necessary

The justification of the classification into distinct types may be questioned on the grounds that the fibres fall into an essentially continuous series - that the differences although marked in extreme cases are not absolute, as fibres can be found that represent every graduation between extremes. This in part is true, but the classifications are broad and therefore, although intermediates do occur, they are relatively scarce. In practice intermediates are often surprisingly scarce with the result that arrays can seldom be questioned on the score of fibre type classification.

The existence of real differences in macroscopic appearance between fibres of the birth-coat of the sheep was probably first recognised by Nathusius and McMurtrie before the close of the last century, while still more recently Crew and Blyth (14), working on the birthcoat of Ovis vignei, described three different types of fibre. Later Blyth (13) found fibres that she described as "indistinguishable in their fine early proximal portion but showing a stiff, straight distal portion"; these she termed "intermediate (b)".

Roberts (7) in studying kemp in the fleece of the Welsh Mountain sheep called "anomalous" fibres which he described as "wool fibres for the greater part of their length but exhibiting portions (usually the tip) of a 'kemp like' (medullated) nature". Duerden (10) later observed similar fibres in the coat of the South African Merino lamb and in a letter to Nature (11) featured their Sickle shaped tips. These fibres he termed

Heterotypes. Lochner in his thesis on "The Development of the Blackface Fleece" distinguishes the same three fibre types that Crew and Blyth (14) recognised and used the same nomenclature - namely 'Heterotype A, Heterotype B, and Wool.

In the birthcoat of the New Zealand Romney Marsh lamb Dry recognised the following :-

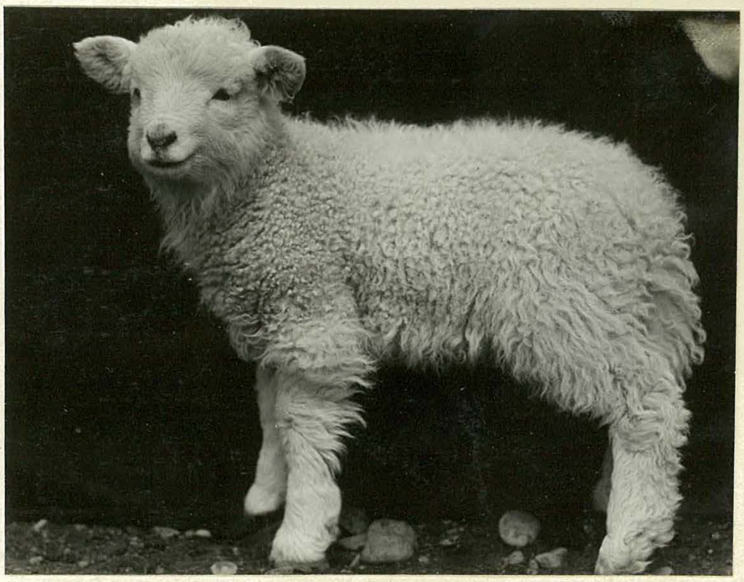
1. Halo-hairs.
2. Super-sickle-fibres.
3. Sickle-fibres.
4. Curly -tip fibres.
5. Histerotrichs.

HALO-HAIRS.

These fibres have been briefly described by Dry (19) 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". Differences between britch and back Halos are noted; britch Halo-hairs being often noticeably longer than back Halo-hairs and also showing no thinning in the pre-natal region, grown immediately prior to birth. This thinning is a variable although common feature of back Halo-hairs. In a later unpublished paper Dry again describes Halo-hairs but somewhat more fully, remarking that Halo-hairs have always been found to shed freely.

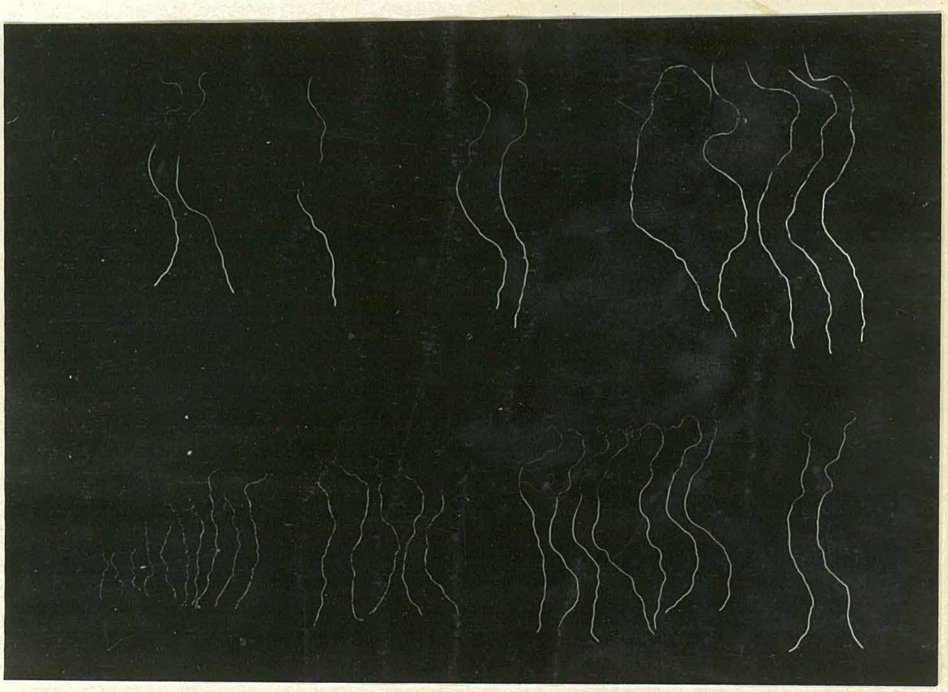
The name Halo-hair is derived from the appearance these fibres have in the young lamb - appearing as a Halo about it. This is due to their great length when compared with the remainder of the early lambs fleece. In animals that are not of the N-type but have Halo-hairs in quantity this halo effect is very marked due to the excessive coarseness and length of the Halo-hairs when compared with the rest of the early lamb's coat. Figure I. In N-Type animals the halo effect is often masked due to the close association between the Halo-hairs and the excessively coarse 'Hairy tip Curly tip' fibres. This association

FIGURE. I.



Grade VI. lamb.

Typical N type lamb without a drop on the withers. Apparent close relationship between the Halo-hairs and the Curly-tip fibres which represent the bulk of the fleece.

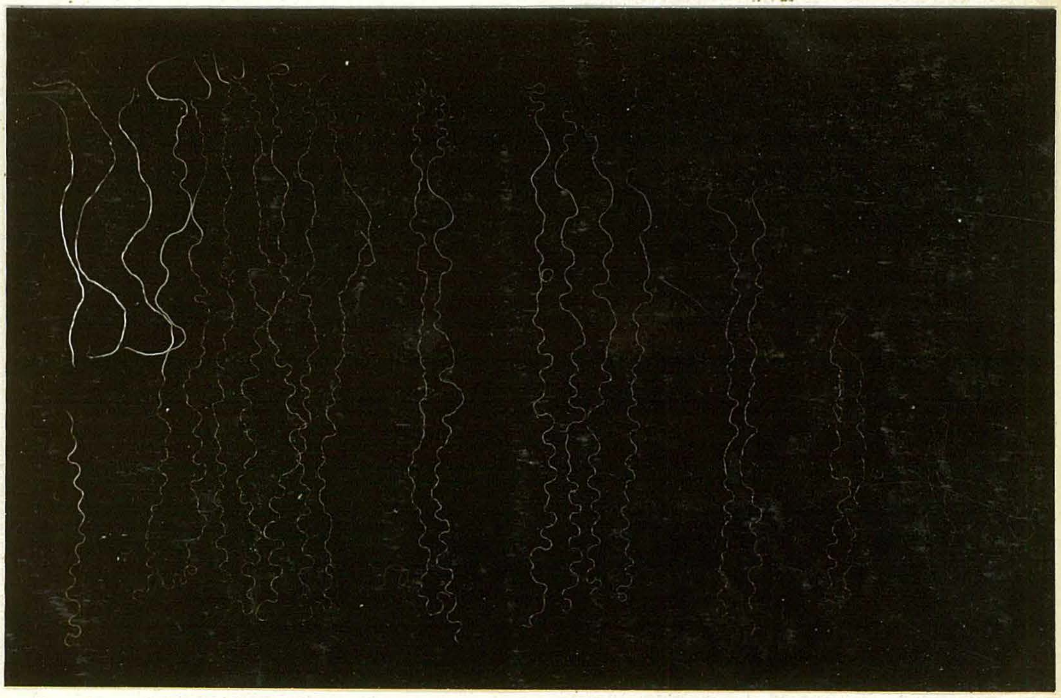


Typical PlateauArray with a close relationship between the Halo-hairs and the Curly-tip fibres. This array actually has more intermediate fibres than some of the very "tough" Plateau Arrays.

FIGURE. II.

Grade III lamb.

This photo shows apparent lack of association between the Halo-hairs and the Curly-tip fibres.

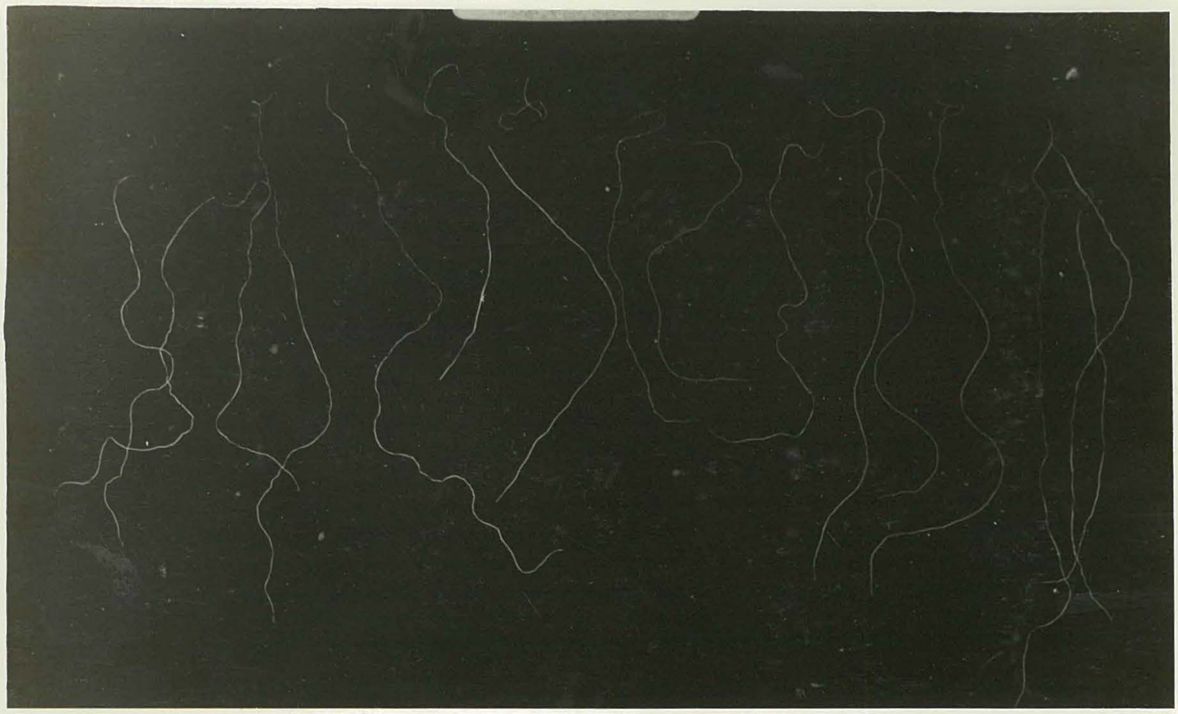


Array of sheep 1063 III Valley.

This array shows a lack of relationship between the Halo-hairs and the Curly tip fibres with consequent breakage of the Halo-hairs.

A cut G.2. fibre is shown below the Halo-hairs.

FIGURE. III.



1. 2. 3. 4. 5. 6. 7. 8.9. 10. 11.12.13.14.15.16.

Halo-hairs.

Halo-ahirs from different arrays varying within arrays in respect to Grade and Medullation of the Curly-tip fibres.

Fibres from left to right:

Number of fibres.	Array.	H.H.Grade.	Medullation.
1&2	Valley.	III	coarse.
3	Valley-Plain.	III	fine.
4&5	Valley.	III	fine.
6	Ravine.	III	fine
7	Saddle.	IV	coarse.
8&9	Valley.	V	coarse.
10	Valley.	V	fine.
11&12	Valley.	VI	coarse.
13	Plateau mild.	VIOrd.	fine.
14	Ravine.	VIOrd,	coarse.
15&16.	Plateau.	VI!.	coarse.

is evident when samples from the animals are analysed fibre by fibre. In grades other than VI! (Dry unpublished) the relation between the Halo-hairs and the Curly-tip fibres is through considerable numbers of intermediates, (Figure II), with the result that the Halo-hairs are much coarser than any of the Curly-tip fibres. In Grade VI! the relationship between Halo-hairs and Curly-tip fibres is much more direct (Figure I) with the result that there are many Curly-tip fibres of a coarseness and length not greatly dissimilar to the Halo-hairs.

Halo-hairs, although always long and chalky throughout, can vary considerably from array to array, from grade to grade, and within grades and arrays. This variation may be in length, type of curl, and coarseness, or in any combination of these features.

<u>Halo-hair Length.</u>

For the purposes of this study of the variation within the Halo-hair classification a collection of Halo-hairs was made from arrays of different types varying also in Halo-hair grading, and medullation of the Curly-tip fibres in regard to distance along the array together with the distance down the staple to which medullation extends (Figure III). All possible variations of the above are not figured but there are sufficient types to show any variations that may exist within the Halo-hair classification. The actual types are described beneath the figure and will not be described here, although to simplify the description of the fibres and the discussion arising therefrom the "grading" of the individual fibres will be given, fibres being referred to by their numbers from left to right.

Considering the lack of uniformity of the arrays in which the fibres illustrated in Figure III were found there is a remarkable similarity in the fibres, and yet this series of fibres contains the extremes within the Halo-hair classification.

Variation in length of Halo-hairs can only be observed in the completed fibre, that is, in the shed fibre. In a few arrays persistent fibres have been found that must, due to their total macroscopic appearance be called Halo-hairs. These fibres are best regarded as the extreme case of long Halo-hairs and are dealt with more fully later under "Shedding of Halo-hairs"

The extremes in length in the back position are represented by No.9, a Halo-hair from a coarse Grade V. Valley array and Nos. 4 and 5 which are fibres from a fine Grade III Valley array. These fibres show a very wide variation but are nevertheless of the same Array type and are not even of the extremes of Halo-hair grading. Further, the long Halo-hairs are found in the array with the fine Curly-tips, the short fibres in the array with the coarse Curly-tip fibres. Thus it appears that length at the back position is not correlated with Halo-hair grading, Curly-tip; coarseness or array.

A comparison of the Halo-hairs found in the various types of Plateau (Figure IV) and non-Plateau arrays (Figure III) (except for the last three fibres) throws some light on the relationship between Halo-hair length and array. These two figures are both almost life size and are thus directly comparable. Figure III is on the scale of 1 cm.-.96 cms. life size and Figure IV 1 cm. - .95 cms. life size. Also fibres 15 and 16 in Figure III and 6 and 7 in Figure IV are from the same animal. From such a comparison it is clear that the variability within the Plateau Halo-hairs is less than within the non-Plateau Halo-hairs. This lack of variability is due to the absence of short Halo-hairs in the Plateau series. It thus appears from the figures that long Halo-hair fibres are found in the Plateau Array animals far more frequently than in the other arrays which have a lower limit in length to their Halo-hair series.

The degree of medullation along the array appears to be unrelated to Halo-hair length within the Plateau Array. Fibres 18, 19 and 20 from sheep 904, an extremely coarse Plateau animal, are no shorter than Nos. 1 and 2 from sheep 905 which is an example of a Plateau array Grade VI with a lack of association between the Halo-hair and the Curly-tip (see Figure I) together with a precipice with consequent fining of the Curly-tip fibres early in the Curly-tip series of the array.

From the above it appears that although there is no correlation between length of Halo-hairs and the grading, Curly -tip coarseness, or array, it is impossible to get a Plateau Array with Halo-hairs as short as are found in some of the non-Plateau Arrays. In this respect, however, the classification of Halo-hair in relation to Super-sickle A. fibres is important.

The distinction between Halo-hairs and Super-sickle A. fibres is rather arbitrary and depends largely on length. In the Plateau Array where all the Pre-Curly tip fibres and many, at least, of the Curly -tip fibres are coarse the Halo-hair classification tends to become more and more scrupulous and any fibre that resembles a Halo-hair but is not of outstanding coarseness and length will be classified as a Super-sickle A. fibre. Such a fibre may, in some cases, be indistinguishable from those fibres termed Halo-hairs in the finer non-Plateau arrays. Figure V throws some light on the above in that it illustrates Super-sickle A. and Halo-hair fibres from arrays that are considered to be typical of their type. These consist of the following:- (from left to right) (a) tough Plateau Grade VI, (b) a weak Plateau Grade VI, (c) a coarse Saddle Grade VI, (d) a coarse Valley Grade V, (e) a fine Valley Grade III, From a comparison of these it is plain that the Super-sickle A fibres in the weak Plateau are comparable with the Halo-hairs of the fine Valley Array. There appears to be a sharp distinction between Super-sickle A. and the Halo-hairs within all the arrays with the possible exception of fibre No.7 in the fine Plateau Array. In the 'tough' Plateau Arrays this distinction is due to a break in the continuity of the coarseness and the shape of the tip. In the fine arrays length and tip shape are still important although length appears to be dominant giving a clear cut distinction within the array. Thus it is apparent that the classification of the Halo-hairs and the Super-sickle A. fibres is a classification often dependent on the macroscopic appearance of fibres <u>within</u> rather than between arrays.

Such a state of affairs throws some light on the comparison of Halo-hairs of different arrays in that it appears to invalidate such a comparison. However, as has been pointed out above, the Halo-hair series is either discontinuous or linked by only a few intermediates to the Super sickle A. series and thus although between arrays a Halo-hair and a Super sickle A. may appear identical in relation to the rest of the fibres in the sample they form two distinct groups comparable between arrays by virtue of their position and their essential discontinuity in the array series.

Variation in Halo-hair Length in Different Parts of the Body.

The above discussion on the length of Halo-hairs is confined to Halo-hairs from the standard back position of different animals. A study of Halo-hair length in the same animal but at different positions has been made with special reference to animals that have a Plateau Array at the "standard back position". These animals have a Grade VI. at this position. The positions studied were the Side and Withers and to a lesser extent the Britch. The exact location of these sampling positions is given in the Chapter on 'Methods'.

A more complete study of the britch position was not undertaken because of the lack of reliable britch samples. The britch with the present method of covering is not well protected from both weathering of the tips and loss of shed fibres. Thus it has come about that the britch sample has been largely neglected but the few samples that have been done have shown the britch Halo-hairs to be exceptionally long when compared with the back Halo-hairs. This observation with reference to sheep with the Plateau on the back agrees with Dry's (19) generalisation that 'the Halo-hairs of the britch are larger than the Halo-hairs of the back.

The Side and Withers Samples:-

Wide variations were found in Halo-hair length at these positions and shed fibres varied in the same animal by as much as half the length of the back Halo-hairs. The variation between samples was always in the same direction, that is when variation did occur at all. Where a difference between the Halo-hair was found the back fibres were always the shortest when compared with the side and withers Halo-hairs. The variation may be slight or in some cases completely absent, or at least impossible to detect by eye estimation, or it may be very marked, the side and withers being almost half as long again as the Halo-hairs found on the back position.

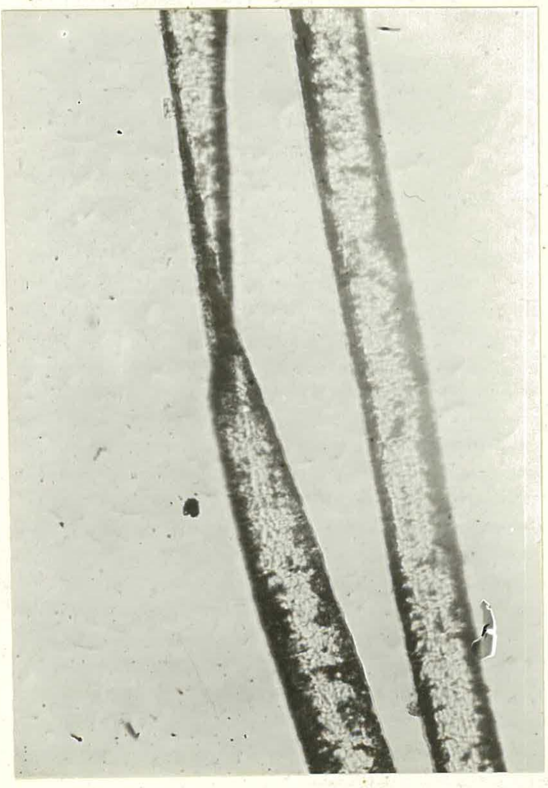
The distinction between the side and withers is by no means marked as regards Halo-hair length. Even when there are considerable differences in length between these positions and the back, the Halo-hairs of these two positions are mutually indistinguishable as regards length. The wither fibres appear to be more variable than the back Halo-hairs or those of the side. If there is a variation in the length of the withers and side Halo-hairs then the withers have been found to be the smaller. In such cases, however, the variation is small and is in no way comparable with the variation between these positions and the back position.

The variation in Halo-hair length between different positions on animals practically identical in the array of the back has been further explored. The animals studied were those with a tough Plateau on the back position. The Arrays for each position were done and although the number of samples analysed was very small it appears that where the Plateau Array is found on the withers sample as well as on the back, then the Halo-hairs of the withers are likely to be of similar length to the Halo-hair of the side and the back, but where there is a substantial alteration of the array between back and side, and withers, then the Halo-hairs will be of varying lengths. The situation is masked somewhat by the fact that a Valley Array at the withers on a Grade VI. is prone to have nothing but broken Halo-hairs.

Although it is tempting to speculate on the variations in time of shedding at different parts of the body and its relation to Halo-hair length, it is considered that it would be unprofitable with our present rather meagre knowledge of the

FIGURE VI.

Halo-hair in benzol, medullation normal.

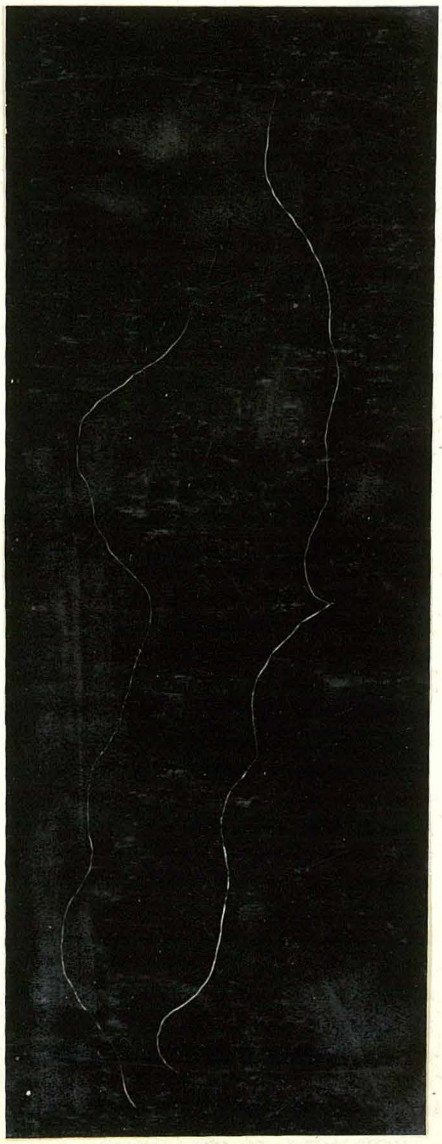


Halo-hair in benzol showing collapse.

FIGURE VII

The Fibre on the left is regarded as a S.S.A. due to its lengthy non-medullated tip.

The Fibre to the right is a normal Halo-hair.



detailed facts of shedding. It is therefore sufficient to point out that with the accumulation of further facts this feature of variations in Halo-hair length may assume importance in elucidating the forces at work in the fleece and their relationships between different regions of the body.

Halo-hair Coarseness.

If a fibre is not chalky throughout it is not a Halo-hair. Care must be taken, however, that lack of medulla is a real lack and not an artifact due to the collapse of the medulla giving a macroscopic non-chalky appearance. This is possible with Halo-hairs due to their relatively thin cortical walls. That this is actually due to external pressure and not directly to type of growth can easily be seen when a fibre is examined under a microscope and then squeezed with a pair of forceps and examined again. The possibility that other factors enter into this "infilling or collapse" as Elphick (23) described this condition should not be overlooked because it is a feature that infilling is more prevalent in some parts of Halo-hairs than in others and further it appears to be more common in some sheep than in others. In this respect it is interesting that Dry (unpub.) states that this squeezed condition has been found in the Halo-hairs of an unborn lamb. A possible reason may be variations in relative thickness between the cortex and the medulla in different parts of the same fibre and between different fibres.

It is, however, with practice soon possible to distinguish macroscopically between the real lack of medulla and damaged medullated fibre. The characteristics to be looked for are in the main two:

(1) A flattening of the fibre often giving the appearance of two ridges with a thinner section or portion in the centre.

(2) A ragged appearance of the medulla on each side of the non-medullated portion. When fibres are compressed the air in the medulla is expelled due to

the breaking down of the medulla structure and thus it is not surprising that the broken appearance persists. In true loss of medulla the reappearance of medullation has a certain regularity, either it is of a sparkling type, gradually increasing in intensity to full chalkiness, or it is a sudden burst of medullation. This latter type is common in Super-sickle A (page 40), Super-sickle B (page 65) and also in some Curly-tip fibres chalky after birth.

Halohairs may vary in the degree of chalkiness but they must never reach the stage where medullation becomes so weak that it is necessary to resort to other than eye methods of determination, that is, chalkiness ceases. Variation within the term "chalkiness" is almost universal for Halo-hairs, and has been mentioned by Dry (19) when he writes "The Halo-hairs of the back have commonly, perhaps always, a thin sub-apical pre-natal region of area of cross section small compared with a stouter more apical part and with the coarser post-natal region". In the coarsest type of Plateau Array this thinning does not occur although the coarseness of the fibre may lead to mechanical damage giving the thinned appearance previously described.

The macroscopic examination of the Halo-hairs leads one to the belief that perhaps their coarseness is due not so much to the production of more fibre stuff but to the production of more medulla, that is, that the cortex may not increase in width and may even decrease with increase in diameter. This does not involve the supposition that the Halo-hair is a relatively fine fibre puffed out as it were but it does involve the possibility that the particularly coarse Halo-hair is perhaps merely a coarse Halo-hair puffed out and weakened and thus more liable to mechanical injury.

Shedding of Halo-hairs.

Dry (16), adopting names suggested by Garstang, divided the developmental history of the fibres of the mouse into three phases as follows:-

(1) The Anagen Phase: The longest part of the growing period, lasting from the inition of growth up to the Catagen phase.

(2) The Catagen Phase: During which the root decreases in size.

(3) The Telogen Phase: When the fibre has ceased to grow, the medulla free base then terminates in a little club which is characteristic of every diciduous fibre.

These three stages occur in the birthcoat kemps of the Romney. There is, however, some variation in the expression of both the Catagen and the Telogen phases. In Halo-hairs and the coarser kemps, the Catagen phase results in a complete cessation of medulla production with the result that this phase of fibre development is readily seen with the naked eye. The Telogen phase of this type of shedding, which has been termed "normal", has been illustrated by Dry (19) and also in Figure From these illustrations it is apparent that the proximal extremity of these shed fibres is of two types, both of which appear to be the result of an ordered process. On the other hand there is that type of shedding which, because of the appearance of smokiness, Elphick (23) and Dry (unpub. paper) in the near-distal region is called "smokily" shed. This type is regarded as the result of some accident, which may be of either internal or external origin. The reason for believing this is that the shed end, as is clear from the illustration (Figure X), does not have the neat regularity encountered in the normally shed fibres. Rather is the shed end terminated abruptly in a hollow cavity. This latter is clear as it is possible when the fibre is examined in a benzol mount under the microscope to obtain a bubble of air in this cavity. It is possible to move this bubble and even to extrude the air by carefully pressing the fibre with a needle.

The fact also that smokiness, apparently identical with that found in these shed fibres is also obtained in the sub-apical region after tugging the wool (Rudall 25), combined with the further fact that this type of shedding is always confined to fine fibres rather suggests that this type of shedding is peculiar to fortuitously shed fibres and is, therefore, the result of a different set of circumstances to those responsible for normal shedding.

Thus there is sufficient evidence to conclude, if shedding is to be regarded as the result of vigour, that normal shedding would be found typically in the Halo-hairs. This has invariably proved to be the case and the fact that it is possible with practice to recognise differences between the two types macroscopically (this judgment has been checked by many microscopic observations) it is improbable that smoky shedding occurs in the Halo-hair fibres.

Dry (19) has described and illustrated persistent Halo-hairs. These fibres have been studied and it was found that the majority would, under the present classification of pre-curly tip fibres be called Super-sickle A. fibres. One array, however, was found that contained persistent Halo-hairs and a study of this array was made in an endeavour to discover the possible causal effects.

Analysis of Sheep 286. Grade VI. Saddle.

	H.H.	S.S.A.	S.S.A-.	S.S.B.	Sickles. Lge.ended.	Sickles. Med. & sm.ended
shed.	14	6	0	0	0	0
pers.	2	9	2	8	8	16

Curly-tip fibres:- 21 - fine - closely associated with Sickles
228 - includes peak Curly-tip fibres which are indistinguishable from the remainder of the fibres.
Medullation is distinct and although not heavily chalky is continued to the Histerotrichs.
Histerotrichs - 120.

The features of the above array, other than the persistent Halo-hairs, are the absence of Super-sickle A- and the persistency of the Super-sickle A fibres. On inspection of these latter it is apparent that there are two different types, one that is closely related to the Halo-hairs, the other, of which only three were found in the above array, is closely associated with the Super-sickle A- and the Super-sickle B fibres. Also the Halo-hairs themselves have definite neck thinning and are a distinctly debilitated type. Despite this fact they are numerous and the array has medullation continued to the Histerotrich fibres. To antiaipate a future postulation (pg. 166) for the support of which varying evidence is presented, it appears that the potentialities of this animal may be considered to be of sufficient calibre to give a considerable number of Halo-hairs, but that there has been an early and sufficiently intense pre-natal check, to not only prevent the fixation of any Super-sickle A-, by reducing these fibres to conform with the Super-sickle B classification, but has been sufficiently prolonged to cause the first 10% of the Curly-tip fibres to be finer than any subsequent Curly-tip fibres.

Thus if the above assumptions are assumed to be correct it is apparent that the presence of this check may be regarded as the reason for the persistent Halo-hairs in this array. Thus the persistency of these Halo-hairs is considered to be a persistency of weakness.

In the light of the above a further search was made of high grade animals with weak succession and a further array containing persistent Halo-hairs was found. This array was a Saddle with the typical Saddle check and with medullation extending not past the Curly-tip series. It thus appeared to have no unusual features as regards the pre-natal check or its potentialities. Other arrays that appeared to be identical with this array as regards the above mentioned assumed criteria for these features were found in which shedding was free. Thus it appears that although the above may be a partial explanation it is unlikely that it is a complete explanation.

Dry suggests that Halo-hairs may persist on occasion owing to the fact that the follicle is more vigorous than usual and although vigorous enough to produce a Halo-hair it has sufficient additional vigour to retain its fibre past the 'crisis period' when shedding normally takes place. This is exactly the converse of the above and has been explored by examining samples from regions other than the back in sheep with a particularly coarse Plateau Array at the back position.

The results of this exploration have been touched on previously under the heading of "Halo-hair Length", where it was pointed out that wide differences occurred in different positions of the body of the sheep. In regard to shedding, persistent Halo-hairs were found but in samples that did not fit either theory.

Summarised in the light of the distribution of arrays the positions in which persistent Halo-hairs were found are :-

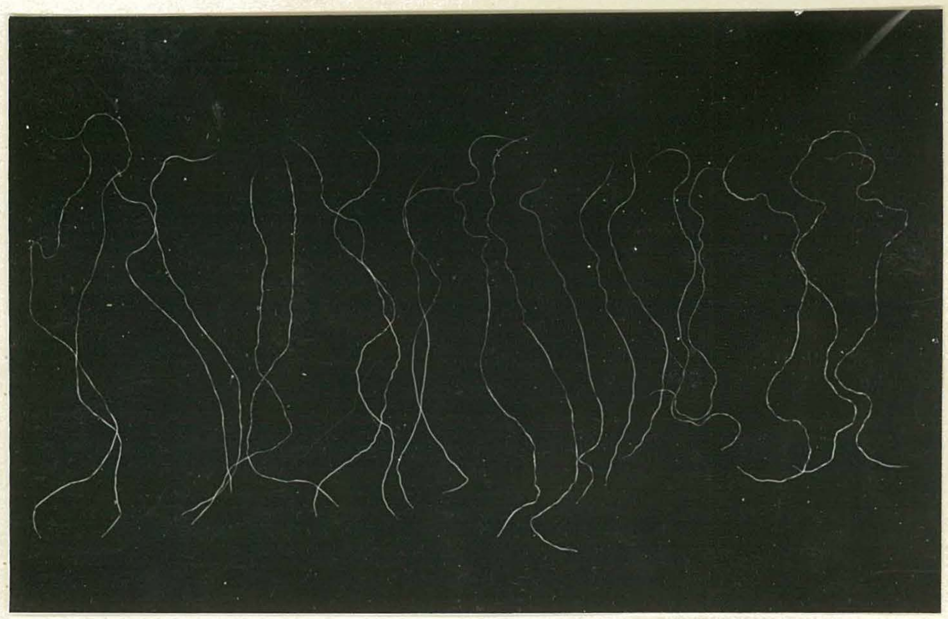
Sheep	Back	Side	Withers.
77.5	Plateau.	Saddle.	Saddle.
78.5	Plateau.	Plateau	Saddle.
1327	Plateau.	Plateau.	Plateau.

Where persistent Halo-hairs were found the array is underlined.

A point of note in regard to the persistent Halo-hairs from the above arrays is that there appears to be a certain regularity between the type of Halo-hair and persistency. Persistent Halo-hairs have always a deeply crimped neck region which is definitely thinner than the distal extremity and that portion grown post-nataly. These characters are regarded as indications of weakness.

From the above arrays it is apparent that the situation is not likely to be a simple one and therefore in the light of the inadequacy of the material studied, which involved a fairly extensive search, and also noting that no pretence has been made at making a complete study of the lambs examined in

FIGURE. IV.



1. 2. 3.4. 5.6. 7.8. 9.10.11.12.13.14.15.16.17.18.19.20.

Halo-hairs of different Plateau Arrays.

A selection of Halo-hairs from different types of Plateau Array. From left to right the series is fromthe extreme coarse type to the relatively fine near Saddle Array. The sheep andthe fibres which they supplied are listed below:-

Sheep No.	Numbers of fibres.
905	1&2
1327	3&4
1238	5&6
1068	7&8
1239	9&10
678	11,12&13.
11308	14&15.
1329.	16&17
904.	18,19&20.

regard to the different positions of the body, little can be attempted by way of a generalisation. It does, however, appear in the light of unpublished work by Dry, who found shedding of the Super-sickle fibres on the withers to be poorer than at the back position, and also not neglecting the work of Galpin (21), who demonstrated in the non N-type animals that the check was more severe on the withers than elsewhere, that the persistency of the Halo-hairs in these withers samples may be regarded as a persistency of weakness.

Finally it seems likely that our present meagre understanding will be improved on when further studies of the side and withers positions have been completed and when further material becomes available that contains persistent Halo-hairs.

Halo-hair Shape.

Halo-hair shape as distinct from other features of Halo-hair fibres, that is, medullation, coarseness and length, is of considerable importance in distinguishing Halo-hairs from the other fibre types. It also appears to be of importance in distinguishing Halo-hairs of different parts of the body.

As with other features, there is considerable variation within the Halo-hair classification and there are consequently wide differences between extremes within those fibres classified as Halo-hairs.

The typical shape of the back Halo-hairs of a Plateau Array is that of fibre 18 in Figure IV. It will be seen also with reference to Halo-hairs figured in Figure III that the fibre with the long sweeping tip with an almost complete lack of crimping in the neck region is by no means confined to the Plateau array and is found in Valley Arrays of the back region which are both fine and coarse as regards non kemp hairiness.

Crimping, as has been pointed out above, is almost entirely absent in the neck of many Halo-hairs and it is notable that it is seldom found in other portions of the fibre. This refers to crimping as it is generally understood and has been described and figured by various workers on wool. Long undulating curves are common in the robust Halo-hairs and extend from tip to butt. This curving at the tip of the fibre causes the tip to have a wide Sickle shape. In some Halo-hairs that must be regarded as the extreme of coarseness this waviness is not found and the fibre has a straight and rigid appearance. An example of such a fibre is fibre 16 in Figure III

The above is not the only type of crimp that is found in Halo-hairs. It is common to find a relatively fine, angular, uniplanar crimp superimposed on the long frequency crimps. This type of crimp is found most commonly on the exceedingly tough Halo-hairs but is by no means limited to these, being found mostly post-natally on many of the weaker types of Halo-hairs.

In many of the Halo-hairs that are regarded as weak that is, fibres with a thinned neck region, there is a quite definite crimping in the neck. This crimping is usually irregular and is apparently found in that type of Halo-hair that has a 'Curled' tip. These Halo-hairs often resemble the coarsest type of Hairy-tip-Curly-tip fibre found in other arrays but due to the fact that the arrays in which these fibres are found usually have the Halo-hairs separated from the Curly-tip fibres by considerable numbers of intermediates there is little likelihood of confusing the classification. On occasion, however, these fibres are difficult to distinguish from Super-sickle A fibres. In one array at least there was considerable difficulty experienced in distinguishing these Halo-hairs from the Hairy-tip Curly-tip fibres. In this animal there were virtually no curls in the whole sample and it was due more to the lack of curl in the Curly-tip fibres than to the presence of curls in the Halo-hairs that made classification difficult.

Halo-hair shape in different parts of the body also varies considerably. Those of the back are usually not crimped and also have the wide sweeping tip shape, while those of the side and withers have the crimped type and the more closely curling tip. This is in the case linked closely with a finer type of Array. On the britch the Halo-hairs are usually heavily uniplanar crimped, crimping extending practically throughout their entire length. The fibre thus appears as a spiny fibre with no long frequency crimp at all, the fibre being hard, erect and spinous. This is the most extreme type of Halo-hair yet found.

SUMMARY.

From the foregoing, the following points are considered to be important :-

1. Halo-hair length is not correlated with Halo-hair grading, coarseness of Curly-tip fibres, or type of array.

2. Material was presented which led to the conclusion that despite considerable overlap between the Plateau and other arrays, Halo-hairs are never as short in Plateau as they may be in samples showing a more intense pre-natal check.

3. The study of the inter-relationships of these two fibres types leads to the conclusions that the distinction between them is dependent on macroscopic appearance within, rather than between arrays.

4. The Halo-hairs of the britch appeared to be longer than those of the back.

5. The Halo-hairs of the sides and withers can be half as long again as the Halo-hairs of the back.

6. The Halo-hairs of the side and withers position appear to be of identical length, even when there is a considerable difference in array type.

7. Infilling is described in Halo-hairs and a discussion of its appearance and causes leads to the suggestion that coarse Halo-hairs may owe their unusual coarseness, not to the production of more cortical material but to more medulla.

8. The shedding of fibres in the Romney fleece is briefly surveyed and the mode of shedding typical of the Halo-hairs is described. It is concluded that this type is an indication of follicular vigour.

9. Persistent Halo-hairs appear to be of a particular macroscopic type. The cause of their failure to shed is not clear and it appears that excessive follicular vigour

or weakness do not provide a satisfactory explanation.

10. The type of crimping of the Halo-hairs is discussed and illustrated.

11. The association between Halo-hairs and Hairy-tip-Curly-tip fibres is considered. Fibres of these two types are frequently very similar and definite classification is occasionally difficult.

12. Considerable variation in Halo-hair shape has been noted. This is probably associated with the type of array.

SUPER-SICKLE FIBRES.

These fibres are described by Dry (19) as intermediates between the Halo-hairs and the Sickle fibres in that they have a medullated pre-natal region. Further, he points out that when a strict distinction between these Super-sickle fibres and the Sickle fibres is needed the presence of chalky medullation is used as a criterion. In a later unpublished work Dry classifies Super-sickle fibres into:-

Type A. - Chalky throughout the neck, chalkiness being continuous from the tip to the post natal region.

Type A-. - Chalky throughout the neck except for a short region grown about the time of birth.

Type B. - Chalky in part of the neck but not chalky in some portion other than or in addition to that of Type A-.

Thus it is apparent that the Super-sickle fibres, the intermediates between the Halo-hairs and the Sickle fibres, are graded in order of the intensity of pre-natal check. The Super-sickle A has not suffered sufficient check to cause it to loose its chalky medullation but merely to thin; the Super-sickle A-, just sufficient to cause it to loose medullation at what appears to be a particularly vulnerable part of its career - the birth point; and the Super-sickle B, though suffering often from a severe check has succeeded in reaching chalkiness in a portion of its neck region and thus becoming differentiated from the chalky Sickles.

This type of classification has, therefore, great importance in regard to the Plateau Array. Where there are few Super-sickle A- and Super-sickle B fibres it is obvious that the check has been of a minor kind or that the individuality of the animal was such that the effectiveness of the check was reduced by a strong urge to coarseness. In either case there will tend to be a close relationship between the Halo-hairs and the Curly-tip fibres. Conversely when there is an abundance of Super-sickle B fibres there has obviously been a marked checking effect and the array comes to approach the Saddle Array. Thus it is apparent that a close study of the Super-sickle fibres is an important section of the complete description of the Plateau Array.

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SUPER-SICKLE A.

These fibres have been defined above as "chalky throughout the neck region, chalkiness extending into the post-natal region". Amongst fibres to which this description applies wide variation is found and this is not surprising when it is realised that these fibres form a connecting link between the extreme of the Halo-hair and the Super-sickle A-. fibre type, with its total lack of medullation in the lower neck region. It is thus clear that some Super-sickle A fibres must closely resemble the Halo-hairs while others must be difficult to distinguish from the Super-sickle A-. fibres and that between these two extremes all grades of intermediates must occur.

In relation to their association with Halo-hairs it has already been noted in the section on Halo-hair length that there is an essential discontinuity between the Halo-hairs and the Super-sickle A fibres in any or all of the main macroscopic features, namely: length, coarseness, and tip shape. It is also remarked that the classification of the Halo-hairs and Super-sickle A fibres is a classification often dependent on the macroscopic appearance of the fibres within rather than between arrays.

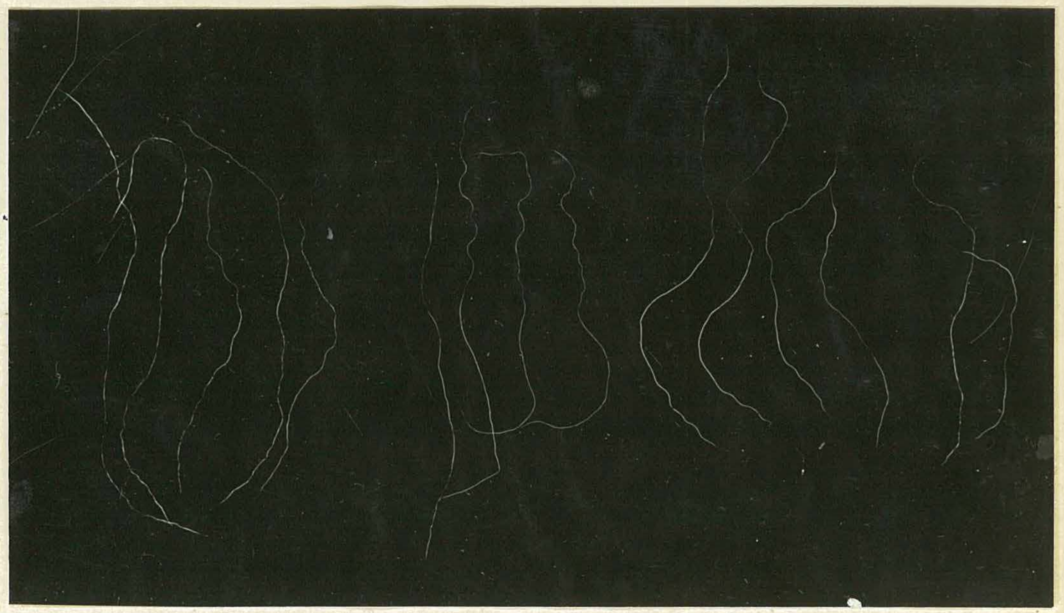
It is thus apparent that the Super-sickle A classification, although forming a link between the Halo-hairs and the Super-sickle A-. fibres is a real classification. Intermediates do occur but these are scarce and do not detract from the importance of this fibre type as an indicator of the intensity of the pre-natal check. Similarly with the relationship between the Super-sickle A. and the Super-sickle A-. fibres, where, when intermediates have occurred, it has occasionally been necessary to use benzol to determine the extent of medullation.

"Short" Super-sickle A Fibres.

From the above it is clear that the Super-sickle A. classification contains many fibres that are widely different from other fibres classed as Super-sickle A. This variation within the Super-sickle classification is, however, much wider than can easily be accounted for on the supposition that these fibres are due to the usual check, regarded as responsible for the fibre types in the Romney. (Dry 12, Galpin 22). These differences are often remarkably discontinuous within an array and the 'off type' fibres hereinafter termed "short" appear to have no relation to the Halo-hairs or the Super-sickle A-. series in either length, coarseness, or general macroscopic shape. Neither is this difference confined to macroscopic features for these fibres never exhibit the infilling so common in the Halo-hairs. This latter is not due to a lack of medullation, for these fibres are invariably exceedingly chalky. In this respect, therefore, these fibres may offer some valuable material for the study of the types of medullation that occur in the Romney in that they show an extreme type of medullation with apparently sufficient strength in the cortical walls to prevent infilling.

In relation to fibre types, however, it is apparent that short Super-sickle A fibres appear to be something different from the other fibres found in the Romney lamb and thus one is forced, for their explanation, to conclude that factors other than those that are generally recognised as giving rise to fibre types may be of importance. This makes the Super-sickle A fibres especially interesting in the study of the architecture of the fleece of the sheep, but such a study is hampered by the small numbers of Super-sickle A fibres found in many Arrays

FIGURE V.



A comparison between Super sickle A fibres
and Halo-hairs in different arrays.

From left to right:-

A tough Plateau Grade VI. 2 Halo-hairs, 3, S.S.A.

A weak Plateau Grade VI 2 Halo-hairs, 2 S.S.A.

A coarse Saddle. Grade VI. 2 Halo-hairs, 2 S.S.A.

A fine Valley Grade III. 1 Halo-hair, 1 S.S.A.

Fibres 4,12,13, and 15 are "Short" Super-sickle A fibres.

and the still smaller number of Short Super-sickle A fibres present. The array in which these were most numerous was a 'weak' Plateau Array from a Grade VI! (D). where 2 Short Super-sickle A fibres per 100 Curly tip fibres were found. One of these fibres is illustrated in Figure V , fibre 4. Others have been found in tough Plateau Arrays, for example, sheep 1279 contained about one short Super-sickle A fibre per 100 Curly-tip fibres. This animal Graded VI! (D) with an array on the back position in which only two Super-sickle A- fibres and one Super-sickle B fibre was found, and in which the relationship between the Halo-hairs and the Hairy-tip-Curly-tip fibres was very close. It thus appears that the Short Super-sickle A fibre type is not a peculiarity of the weak Plateau Array. Neither is it a peculiarity of the Plateau Array as such, for short fibres have been found in Saddle Arrays. They have not been found in Ravine or Valley Arrays although admittedly the material available was meagre. This was particularly so for the Ravine Arrays, only three high grade Ravine Arrays being available. With the Valley Arrays the situation was also unsatisfactory as only six Grade V and VI Valley Arrays were found.

In the Arrays in which these fibres have been found shedding of the birthcoat kemps has been particularly free. However, the presence of these fibres is by no means regarded as an index of the freedom of shedding, as very free shedding has been observed in arrays where no Short Super-sickle A fibres were found. It is, however, unusual to find these fibres in arrays where shedding is not free. Such an array is that of the back sample of sheep 541, a Plateau Array dealt with in detail in the section on Toughness (see page 129)

It thus appears that there may be some connection between shedding and the presence of Short Super-sickle A fibres. In this connection a search of arrays was made in which there was poor shedding of the big ended Sickle fibres and therefore lack of medullated successors of the Halo-hairs (Dry unpublished report) and no Short Super-sickle A fibres were found.

From the above it appears that the Short type of Super-sickle A may be associated with the presence of free shedding. It is postulated, therefore, that these fibres may actually be successors of fibres shed prior to birth. In support of this theory it is notable that these fibres closely resemble the successors of shed birthcoat kemps. Further evidence on this point will perhaps be obtained by pre-natal studies if fibres are found growing in follicles that are too big for them. (Rudall unpublished).

An obvious possible explanation of the shortness of these fibres is that they shed early in the life of the lamb - definitely earlier than the rest of the fibres, and thus will be shorter, due to the shortening of the growing period. A search was therefore made for samples taken at the time when shedding was taking place. Such a sample would be recognised by the presence in the analysed array of both shed and persistent fibres of the same fibre type. Only one such sample was found that contained the necessary types of Super-sickle A fibres. The array was a weak Plateau Array which on analysis gave the following :-

Super-sickle A:

Long near Halo-hairs - shed normally	1
Long near Halo-hairs - persistent	4
Short type - persistent	2
Short type - shed normally	7
Total Super-sickle A fibres	14

It thus appears that in this sample the loss of both types of Super-sickle fibres takes place at a similar period. One sample is, however, insufficient evidence on which to base any conclusions, and for more complete elucidation it would be necessary to take samples at relatively short intervals, about the time when shedding usually takes place.

In taking such samples fibres could well be pulled in an endeavour to distinguish between those fibres actually shed and still standing in the skin and those not shed. In this respect it appears from work by Dry (36) that fibres actually fall out of the follicles and are not pushed out by the successional fibres. If this is so the reason for a fibre becoming actually free from the follicle appears to be mechanical and therefore it would seem probable that the larger Halo-hairs being little protected by the general fleece would be retained for a shorter period than the Super-sickle A fibres which are lower in the fleece and thus more efficiently protected. However, this relative protection may not be very effective in the lambs fleece previous to covering. Further, where shedding of the Halo-hairs has commenced by this time the situation will be in favour of the idea that Super-sickle A fibres shed earlier than Halo-hairs. This is due to the partial loss of the Halo-hairs that have shed and the complete retention of those that persist, together with the retention by the fleece of all the Shed Short Super-sickle A fibres. This will make it appear that the Super-sickle A fibres shed earlier than the Halo-hairs.

In respect to the above Dry notes (unpublished paper) that short Super-sickle fibres, hairy after birth, are known to be at least amongst the first of the Halo-sickle group to finish growing.

If these shed Super-sickle A fibres are really identical with the normal Super-sickle A type but have shed earlier, then they would be less plentiful in those samples that have been taken late, than in those taken early. However, the animals in which they have been found most plentifully are animals that have been early lambs and have, therefore, been sampled particularly late.

A further possibility is that the checking force which is responsible for the deterioration of fibre robustness may, as regards dimensions, effect different fibres in a different manner. That is, that the same force which may cause one fibre to become thin and even to loose medullation completely, may cause another to become shorter without loss of medullation. Evidence for this rather fantastic idea is found in a study of the lengths of the Super-sickle A fibres other than Short and also in some of the Super-sickle A- fibres. These fibres are dealt with more fully later but here it is sufficient to note that it is not uncommon for many of these fibres to be definitely shorter than the shed Curly tip fibres and the shed Super-sickle B fibres. This state of affairs could be best explained by differential shedding, but, as mentioned above, there is no evidence in the Plateau Arrays that I have studied to suggest that this is the case.

Macropscopic Features of the Super-sickle A Fibres, Other than "Short".

The features of the Super-sickle A fibres that distinguish them from Halo-hairs are: weakness in either or all of features of length, fibre shape, diameter over the whole or portion of the fibre, and medullation. The last two features are closely associated in that weak chalky medullation appears to be accompanied by a loss of fibre diameter with consequent crimping, together with a general weak appearance of the fibre. No measurements have been made, the above being judged on macroscopic appearance alone.

Variation in length of the Super-sickle A fibres appears, with some exceptions, to be associated with variation in both diameter and medullation. Thus when the Super-sickle A fibres are reduced in length they are also reduced in these other two features and thus generally exhibit a distinctly weak neck region. This neck region corresponds with the neck region found in the weaker Halo-hairs in respect to period of fibre development and it is also of a similar structure.

Super-sickle A fibres are almost invariably shorter than the Halo-hairs and are usually distinctly so. It is also not uncommon for these fibres to be somewhat shorter than some fibres which must be regarded as coming late in the array, namely, Super-sickle B and even Hairy-tip-Curly-tip fibres. This type of fibre cannot be confused with that described above, as Short Super-sickle A, as it resembles closely large ended Chalky Sickle fibres but with a chalky neck region. These fibres are generally closely associated with the Super-sickle A-. fibres, from which they can only be distinguished in extreme cases by the use of the microscope.

On the other hand there is that type of Super-sickle A fibre which is exceedingly long - little shorter if at all than the Halo-hairs and definitely longer than the other shed Super-sickle fibres (shed Hairy-tip-Curly-tip fibres). These fibres are of two distinct types and they apparently do not occur in the same array. One type is very robust and is distinguished from the Halo-hairs by its general macroscopic shape in that it fails to show the wide Sickle shape tip, and the other is the type that is weakly medullated throughout and may, or may not, have coarse Sickle shaped tips. In the latter, however, the Sickle tip is unusual. The former is typical of the coarsest type of Plateau Array.

From the foregoing it is apparent that in the classification of the Super-sickle A fibres, tip shape, length and medullation all play an important part, the fibre being in general classified on the feature that is weakest when compared with the Halo-hairs. In this respect a Super-sickle A fibre found in the britch sample of sheep 71.5 is of interest. This fibre is figured in Figure VII, from which it is apparent that although of general Halo-hair shape and length it took some time to reach the stage where medullation was of such a density that it could be termed chalky. This weakness has been considered sufficient for this fibre to be classified as a Super-sickle A fibre and not as a Halo-hair.

Shedding of the Super-sickle A fibres.

The types of shedding together with their implications have already been briefly dealt with in the section on Halo-hairs (page 30). Shedding in the Super-sickle A fibres has been

touched on previously under the heading of 'Short Super-
sickle A fibres", where it was evident that the situation could be masked in early samples due to the loss of the shed fibres. It was further pointed out that this is particularly the case with the britch position which is at present not adequately covered.

Dry, writing of Super-sickle fibres in his unpublished paper, summarises the shedding situation when he writes : "On the whole, the proportion of Super-sickles shed is greater than that of chalky Sickles, and within the Super-sickle Series more fibres of type A shed than the other types. Often all the chalky Super-sickles are shed. When no Super-sickles are shed as has happened very occasionally it is in lambs that have done badly........., if the Super-sickles largely persist then the Sickles whether early or late in the series also persist".

This generalisation can perhaps be extended, in that, if the Halo-hairs persist, or if any persistent Halo-hairs are found, then Super-sickle A, as a fibre type, will be found to persist also. The data for this generalisation are, however, too sketchy for it to be accepted as fact. This is due to the scarcity of persistent Halo-hairs, together with the fact that the only animals searched are those with the Plateau Array on the back position. (Halo-hairs page 22.).

The actual arrays are :-

	Sheep 77.5 Withers Saddle Array.	Sheep 78.5 Withers Saddle Array.	Sheep 1327 Side Plateau Array
Halo-hairs		1	
normal shed	6	12	52
persistent	3	8	- 4
Super-sickle A.			
normal shed	1	0	9 3-short
persistent	1	25	48
Super-sickle A-.			
persistent	1	3	8
Super-sickle B. (all persist.)	11	5	3
Sickles (all persist.)	8	12	0
Curly tips (all pers.)	316	364	403

77.5 No hairy G_2 fibres found.

78.5 No hairy G_2 fibres found.

1327 Grossly hairy to butt with slight diminution during the winter period. Successors were considered to be persistent and shed successors were not found after an extensive search.

Thus these arrays in which persistent Halo-hairs have been found appear to have no G_2 kemp.

The uniqueness of the above arrays is evident from Dry's unpublished Kemp report (page 12) where he states : "As in other arrays a relation exists between the shedding of G_1 and the shedding of G_2 fibres. When the shedding of big birthcoat fibres in addition to Halo-hairs, namely Super-sickles and large Curly-tip fibres, is free, the rule is much G_2 kemps (16 lambs). When the shedding of the birthcoat fibres in question is not free, the rule is little G_2 kemp (5 lambs)".

"On the animals studied having much G_2 kemp, it has nearly always happened that Hairy-tipped-Curly-tip fibres were shed freely. Data from a small number of animals show that there may be only a little G_2 kemp when Super-sickle A fibres shed freely, and fibres later in the array poorly, and the records suggest that the presence of abundant G_2 kemp may be correlated with free shedding of the Super-sickle A-, even although fibres later in the array (Super-sickle B, odd Sickles, and large Curly-tip fibres) may shed poorly".

Thus it is that the discovery of persistent Halo-hairs offered a welcome opportunity to contribute something to our knowledge of succession in the follicles of birthcoat kemps. Earlier work, published and unpublished, has shown that a correlation exists between the freedom of shedding of birthcoat fibres and the extent to which the successors of Halo-hairs (and sometimes other large birthcoat fibres) shed, and so become kemps. In my material when even a few Halo-hairs persist, shedding of the other large birthcoat fibres has proved to be unusually poor. When this occurs it has been shown that in the material available the G_2 fibres persist. It may be suggested that if it should ever be desired to breed against kemp in Mountain breeds in which persistent hairy fibres are acceptable then it should be considered whether selection for persistent Halo-hairs would be worth while.

Super-sickle A Fibres at Different Parts of the Body.

The same samples were used that were used for the observations on the Halo-hairs, together with certain other samples that were not necessarily Plateau at the back position. Three of these samples were from the britch position of Grade II animals and were November samples. In these samples it is clear that there could be only an incomplete comparison between the Super-sickle A fibres of the britch and of the back due to the lack of Super-sickle A fibres on the back. However, in a comparison between these fibres and Super-sickle A fibres, from other arrays that were not Plateau, there appeared to be no difference in type. In the comparison between back, side and withers on those animals with Plateau at the back position there was apparently no difference between different body regions in the Super-sickle A fibres and definitely no differences that in any way parallel the differences found between the Halo-hairs.

The numbers of Super-sickle A fibres in different portions of the body are also variable but this variability appears to be due to the expression of the different arrays. To test this, Saddle Arrays on the withers have been compared with Saddle Arrays on the back position. The Saddle Array was chosen for the following reasons :-

(a) It is an array that has an appreciable number of Halo-hairs and Super-sickle fibres.

(b) It is an array that in the high grades for Halo-hairs at least appears to have comparatively narrow limits.

(c) It depends for its classification on the presence of chalky Sickles and thus its classification is free from any bias towards the Halo-hair end of the pre-Curly tip fibre type series.

(d) It is a common array on the withers position for those animals with Plateau Grade VI! at the back position.

The arrays for comparison were not selected Saddle Arrays, except that they were Arrays that contained either Super-sickle A fibres or Halo-hairs, or both.

The results of the comparison were :

Withers - Saddle Arrays		Back - Saddle Arrays.	
Halo-hairs.	Super-sickle A.	Halo-hairs.	Super-sickle A.
0	4	4	1
7	1	10	8
12	10	1	2
12	10	6	7
0	2	6	2
		9	6
31	27	36	26

Expressed as percentages of the Halo-hairs plus Super-sickle A fibres the following comparison between the two groups as to frequencies of Super-sickle.A fibres is obtained.

Withers. Super-sickle A 47% Back Super-sickle A 42%

From the above short table it is apparent that there is no real difference between these percentages and thus, although the data is definitely extremely meagre, it appears improbable that there is any difference between the abudnance of Super-sickle A fibres in different parts of the body other than that due to a pre-natal check and expressed as an array.

That there are differences between the arrays is shown by the following figures which compare Saddle and Plateau Arrays. These figures have been obtained by adding the above figres for Saddle Arrays. This is not strictly correct, as it brings in the complication of different positions of the body, but the error is small, as from the above, it is improbable that there is any innate difference between body regions except that expressed in array type. Also, the deviation between the two is in favour of the withers position, which has the highest percentage of Super-sickle A. fibres, and thus its inclusion will tend to mask the difference due to the apparent higher percentage in the Plateau Array.

The Plateau Arrays are arrays that have been taken at random from analyses of the back position samples of the progeny of sire 1084.

Saddle Arrays.		Plateau Arrays.	
Halo-hairs.	Super-sickle A.	Halo-Hairs.	Super-sickle A
0	4	24	19
7	1	21	6
12	10	8	7
12	10	27	6
0	2	25	2
4	1	27	13
10	8	15	18
1	2	39	12
6	7	27	2
6	2	11	21
9	6	36	3
67	53	260	109

Super-sickle A 43% of Super-sickle A and Halo-hairs.

Super-sickle A 29% of Super-sickle A and Halo-hairs.

It thus appears that Super-sickle A abundance is related to the array in that the less checked the array the fewer the Super-sickle A fibres and the more numerous the Halo-hairs. This generalisation only applies to those arrays that are of high grade for Halo-hairs, as it is essential that there be a large number of Halo-hairs and Super-sickle A fibres present.

In relation to the importance of the Super-sickle A fibres on the judgement of the arrays other than Plateau the arrays of sheep 68.5 and 51.5 which are figured below are interesting. These two animals are both Valley but are of definitely different types.

Sheep 68.5 is a Grade II Valley approaching Saddle with few fine Sickle fibres and Checked Curly tips. The medullation of this array is of a very chalky type and the peak Curly tip fibres are particularly robust. Sheep 55.1 on the other hand, is a Valley Array approaching Plain and the majority of the Sickle fibres are fine. Further, the medullation of the Peak Curly tips, although definite, is weak. It is notable that there are considerably more Sickle fibres in the array of Sheep 51.5 than in that of Sheep 68.5, despite the fact that there are comparable numbers of pre-Curly tip fibres.

Thus in the light of the above it is concluded that the effectiveness of the pre-natal check is greater in Sheep 51.5 than in Sheep 68/5.

ANALYSES.

	S.S.A.	S.S.A-.	S.S.B.	Ch.S.	Fine S.	Ch.C.T.	Peak C.T.	Total C.T.
Sheep 68.5 II	4	2	16	67	12	62	69	528
Sheep 51.5 I	0	0	2	3	71	54	153	318

It is clear from these analyses that there is a considerable difference between the Super-sickle fibre populations of these arrays. Thus in Sheep 68/5, concluded from the above to be less severely checked than in the array of Sheep 51.5, there is, despite the fact that Halo-hairs are not present in either sample, an abundance of Super-sickle A fibres in particular. Thus it may well be argued that in such a low Grade animal as Sheep 68.5 the presence of Super-sickle A fibres may well be regarded as a criterion of a weak pre-natal check. This is clearly the converse of the generalisation for the Plateau Array (see page 52), that "the less checked the array the fewer the Super-sickle A fibres".

SUMMARY.

1. The features of the Super-sickle fibres are briefly surveyed and the importance of this fibre type as indicators of the intensity of the pre-natal check in the Plateau Array is noted.

2. The Super-sickle A fibre type is defined and its classification is considered to be based on that macroscopic feature which is regarded as exhibiting the maximum effect of the pre-natal check.

3. Intermediates between the Super-sickle A and the Super-sickle A- fibres have been distinguished by the use of benzol.

4. A type of Super-sickle A fibre is illustrated and described which appears to be virtually unrelated to those Super-sickle A fibres which are associated through a series of intermediates with the other fibre types. This "off type" is termed "short".

5. The medullation of the Short Super-sickle A fibres is described and it is suggested that these fibres would provide valuable material for the study of medulla.

6. Material is presented to show that these fibres are not limited to the Plateau Array.

7. In the high grade Ravine and Valley Arrays no Short Super-sickle A fibres were found.

8. Short Super-sickle A fibres were not found where shedding of the birthcoat fibres was not free.

9. The possibility of these fibres being successors of fibres shed pre-nataly is discussed and material is presented for the support of this view.

10. Evidence is presented which leads to the conclusion that shedding in both types of Super-sickle A fibres probably

takes place at the same time. Possible methods of checking this conclusion are discussed.

11. The possibility of the pre-natal check having a different effect on fibre length and coarseness is discussed and evidence is presented.

12. Normal type Super-sickle A fibres are described.

13. A distinction is made within the normal type Super-sickle A fibres and normal Super-sickle A fibres are described which are distinctly shorter than later birthcoat fibres.

14. The long type Super-sickle A fibres which resemble the Halo-hairs were found to be typical of those Plateau Arrays which give the least evidence of the pre-natal check.

15. The occurrence of Super-sickle A fibres at different body regions is briefly explored.

16. Evidence is presented which permits the conclusion that variations in different body regions are probably due to variations in array.

17. A comparison between high grade Saddle and Plateau Arrays leads to the conclusion that the less checked the array, the fewer the Super-sickle A fibres and the more numerous the Halo-hairs.

18. It is tentatively concluded from a discussion of the analysis of two selected animals that the presence of Super-sickle A fibres may be regarded as a criterion of a weak pre-natal check in low grade animals and it is pointed out that this is the converse of the situation in high grade animals.

SUPER-SICKLE A-. FIBRES.

As defined previously, the Super-sickle A- fibres are fibres which have a very definite check - a check sufficient to stop entirely the production of medulla in an otherwise chalky fibre. It is remarkable that it is possible to distinguish clearly by such a minute detail of structure an often considerable group of fibres related only by few intermediates to the fibre types above and below.

It is notable that there are very few fibres that are chalky throughout except for a short section of non-medullation, that have a loss of medulla in a portion of the fibre other than that typical for the Super-sickle A- fibres. It is thus perhaps not without profit to speculate that this thinning represents a period in the life of fibres that is particularly vulnerable, a period when either the check is at maximum intensity or the fibre is particularly susceptible (see Super-sickle B fibres, page 67.). From the above alternatives it is probable that although the former may be of importance in the Super-sickle A- fibres the latter is of more general application. This statement is based on observations on the Super-sickle B fibres and Hairy-tip-Curly-tip fibres, where, as mentioned above, the loss of medullation is seldom limited to a portion of the fibre other than that typically lost in the Super-sickle A- fibres. Even in the Super-sickle A fibres there is often a distinct thinning in this region although, of course, chalkiness is never entirely lost. The implications of this thinning as regards fibre type classification are dealt with in the next paragraph.

The Super-sickle A- classification then appears to be distinct from other types. Intermediates do, however, exist and are of three types; intermediates between (a) Super-sickle A, (b) Super-sickle B and (c) Hairy-tip-Curly-tip fibres. The last type is the least common and is limited to some Plateau Arrays which have heavily medullated Hairy-tip-Curly-tip fibres with tips that have the type of curl that closely resembles the curved tip of the coarser pre-curly tip fibres. The difficulties in classifying the first two are due to the fact that it is on occasions not easy to determine whether chalkiness has ceased or not. It has thus been found necessary with such intermediate fibres to check the classification with the aid of benzol and the microscope. Such an observation must, however, be interpreted with care as loss of chalkiness, a strict eye determination of medullation, and not a loss of medullation as determined with the aid of the microscope is the criterion of judgement. Actually, due to occasional staining of the fibre the degree of medullation was somewhat masked and an arbitrary complete break of medullation the width of the field at X60 magnification was required for a fibre to be deemed to have lost medullation. sufficiently to be termed a Super-sickle A- and not a Super-sickle A. This was not completely arbitrary as it was found with trials with uncoloured clean fibres that a break in medullation of the above magnitude was sufficient for the fibre to be classified, on eye determination alone, as a Super-sickle A- and not as a Super-sickle A fibre.

A further complication bearing on this problem of classification between the Super-sickle A and the Super-sickle A- fibres is that there is seldom a sudden break in chalkiness in an otherwise completely chalky neck. The loss of medullation is usually relatively gradual, thinning taking place more or less evenly from extreme chalkiness through fine medullation to complete loss. With practice one comes to set eye standards that have been found to be quite accurate when checked with the microscope as described above.

At what may be termed the late end of the Super-sickle A- fibres, that is, those fibres in the series that most nearly resemble the Super-sickle B and other fibres regarded as developing late in the life of the animal, there is on occasion a close association with Super-sickle B fibres. This is generally due to a weakly chalky neck throughout - a type of medullation about which it is impossible to be dogmatic as to whether medullation exists as a chalky type or not. These fibres in my experience must be checked under benzol and it has been found by this check that occasionally they have been wrongly classed as Super-sickle A- fibres when actually they are Super-sickle B fibres.

These intermediates between the Super-sickle A- and other fibre types are of considerable importance, as will be evident in a future section (page 125), because they serve as pointers to the type of fibre-type associations. Thus if fibres are found about which there is some doubt as to whether they are Super-sickle A- or Hairy-tip-Curly-tip fibres, it is apparent that either (a) the pre-natal check has not been of sufficient intensity to thin the necks of the fibres completely, that is the array is a tough Plateau Array with a lack of Super-sickle B fibres, or (b) the potentialities of the animal are such that despite a check sufficient to cause Super-sickle B,- assuming that Super-sickle B fibres are found - the Hairy-tip-Curly-tip fibres closely resemble the Super-sickle A- fibres in that they have medullated, imperfect (see above) tips, a completely medullated pre-natal length except for a short length of no medullation followed by heavy post-natal chalkiness. In this latter case the "toughness" (see later) of the array is dependent on the concentration of the Super-sickle B fibres.

<u>Super-sickle A- Length.</u>

As a fibre type the Super-sickle A- fibres are, as contrasted with the Super-sickle A fibres, surprisingly uniform. There are no Super-sickle A- fibres that are comparable with the Short Super-sickle A, previously described, and it is notable that this is a further testimony to the vigour of these latter.

In comparing fibre length there are several factors that must be considered. These, if not given some consideration may easily upset the comparisons and lead to totally erroneous conclusions. It has been pointed out previously, in the Halo-hair section, that when comparing lengths of shed fibres caution must be exercised in view of possible differential shedding. It must be remembered also that the birthcoat fibre grows in two distinct, although of course continuous, periods. These are the pre-natal and post-natal growth periods.

Although it is clear that the factors influencing fibre growth in these two periods are basically similar, it is not improbable that environment is vastly different and, therefore, since environment is known to have some effect on length growth, Fraser (25), Nichols (26), care must be exercised in comparing fibre lengths. Also, since, as both Dry, Galpin and others have made abundantly clear, pre-natal happenings can have a marked influence on post-natal occurrences, it is dangerous to compare post-natal portions of fibres showing obvious pre-natal differences.

Thus length comparisons between fibre types must not involve the post-natal portions of the fibre, and since this is included in total fibre length measurements and assumes particular importance in samples that have not been taken very early it is apparent that to be beyond criticism length measurements must be confined to the pre-natal portions of the fibre.

Despite the above, however, it is worthy of mention that cases have been found where the total lengths of some fibres which have been heavily checked pre-natally is distinctly less than that of fibres which although developing later have received a less intence check. Thus, for example, checked Curly tips and fine persistent Super-sickle and Sickle fibres have been found that are distinctly shorter than Peak Curly-tips from the same sample.

In relation to the pre-natal length it is possible to make comparisons between fibre types. Further, it is considered that differences which occur can be attributed to the position of the individual in the fibre series and to the pre-natal check. It is also considered legitimate to assume, if the check is neglected, that fibres which, from macroscopic appearance develop late, will be shorter in pre-natal length than those that for the same reasons are regarded as early developing. Thus, in the light of the above, it is apparent that any deviation from regularity in pre-natal length down the series must be explained as due to the pre-natal check. Actually, of course, the two will usually run parallel in that those fibres coming late, for example the Super-sickle B, are assumed to suffer from a more intense pre-natal check.

It is obvious that any measurements of pre-natal length must involve an accurate determination of the period of birth from the fibre. It has long been considered that the end of the pre-natal check section of a post-natally chalky fibre is that portion of the fibre that was being produced when the animal was born. (It is notable that the very terminology assumes this). This portion of the fibre is capable of more sudden changes than any other portion and the increase in medullation from completely fine to chalky is often so sudden that the chakiiness appears to form a collar on the fibre. The exact position of this portion at birth is unknown but in the light of its abruptness it is clear that it must result from some phenomenal change in the life of the lamb.

Further, this abrupt increase in medullation takes place in all fibre types except the histerotrichs, and at approximately the same time, that is, it is very near the tip in some Curly-tip fibres and a considerable distance from the tip in Halo-hairs and early developing Curly-tip fibres. Thus it gives a more or less continuous length series between fibre types, and also, since it is not found in fibres pulled or cut from lambs at birth, and further, since it is a phenomenon that is present with more or less clarity in all lambs, it is apparent that the assumption that this portion of the fibre represents the birth point is at least a plausible one.

Further evidence of this was obtained by pulling daily samples from the back position of lambs from birth to 6 days old. In this series it was found that the earliest sample showed a loss of medullation that had presumably started pre-natally, while in the 6-day samples medulla had revived. Actually the revival of medulla was found to take place some time before the 6th. day. It is therefore concluded that this sudden thickening of medullation, although it does not represent the exact birth point, represents a similar period in the life of all lambs and thus serves as a legitimate position of comparison between lambs.

A further fibre variation that defines this position beyond dispute is the almost universal thinning that takes place just previous to this sudden thickening. This thinning may be complete, as in Super-sickle A-, or it may be a slight lessening of the degree of chalkiness, as in many Super-sickle A fibres and Halo-hairs. It is considered that in a study of the causes of this thinning the possibility of an environmental vector should not be overlooked. This is thought to be a possible cause, since where extensive weight measurements have been made it appears that the change in environment in the larger mammals, involved in birth may be such as to cause a short check in the rate of fibre growth. If this is so it may well be that the sudden increase is due to the new born animal becoming physiologically in harmony with its environment and thus able to resume with apparent increased vigour the growth of its coat which has been interrupted by the vicissitudes of being born.

In view of the above, pre-natal length measurements were made of Super-sickle A- and other fibres. From these it appeared unlikely that Super-sickle A- fibres are ever comparable with Halo-hairs. This is relatively clear even from the total length measurements of early cut samples. When compared with the Curly-tip fibres it was found that although they (the Super-sickle A-) were usually shorter, it was possible to get Super-sickle A- fibres a little shorter than the Curly-tip fibres. This latter can be explained on the supposition previously advanced and discussed under Super-sickle A fibres, that the pre-natal check acts on the rate of fibre growth as well as on fibre thickness. In this respect it is noteworthy that the post-natal portion of the Super-sickle A fibres are not dissimilar from the post-natal portion of the somewhat longer shed

Curly-tips. Thus it appears that the check has a greater effect on the pre-natal portion of the fibre than on the post-natal portion.

Tip Form:

Before discussing tip shape it is considered necessary to note that in the discussion to follow typical tips are perfectly sickle shaped - tips that are not sickle shaped are termed poor or imperfect.

The tip form of the Super-sickle A- fibres is usually somewhat more typical of a sickle shape than that found in the Super-sickle A and Halo-hair fibres. This is especially marked when the Super-sickle A fibres are of the excessively medullated type - a type that appears to be associated with poor tip shape. It is, however, not a feature of the Super-sickle A- fibres to have perfect sickle shape tips but merely to have better tips than are commonly found in the Super-sickle A fibres. Actually the Super-sickle A- fibre tips are seldom as perfect as those found in the Super-sickle B and never as perfect as those of the large ended Sickle fibres. Where the Super-sickle A- fibres resemble the Super-sickle B in general macroscopic appearance there is a very distinct neck thinning. In this case the tip is somewhat better than that found in those Super-sickle A- fibres that closely resemble the Super-sickle A fibres, that is, those with medullated necks.

On occasion Super-sickle A- fibres are closely associated with the Curly-tip fibres and not the Super-sickle B fibres. On these occasions the tip is less perfect than when Super-sickle B and Sickle fibres are present in the Array. Thus tip shape has come to be associated with lack of check in the array. The greater the checking force the more distinctive the sickle shaped tip.

SUMMARY.

1. The Super-sickle A- fibre type is described.

2. It is suggested that the position of loss of medulla which is typical of the Super-sickle A- fibres represents a period in the life of fibres that is particularly vulnerable. This suggestion is discussed.

3. Relationships between Super-sickle A- and other fibre types are discussed.

4. The importance of intermediate fibres as criteria of array appraisal is discussed.

5. Discussion of the factors affecting fibre growth leads to the conclusion that length determinations must be confined to the pre-natal portions of the fibre.

6. It is considered that differences which occur in pre-natal length can be attributed to the position of the individual in the fibre series and to the pre-natal check.

7. What is termed the "birth point" is described and evidence is presented to show that the renewal of medullation takes place within six days of birth and therefore represents a comparable period between animals in fibre length.

8. Possible causes of this thinning are briefly discussed and it is considered that the change in the lambs environment at birth may be important.

9. Pre-natal length comparisons between Super-sickle A- and Halo-hairs leads to the conclusion that it is unlikely that Super-sickle A- fibres are ever comparable with Halo-hairs.

10. Similar comparisons with the Curly-tip fibres makes it appear that although the Super-sickle A- fibres are usually longer it is possible for them to be a littler shorter than the Curly-tips.

11. Comparisons between pre- and post-natal fibre length in different fibre types leads to the conclusion that the check has a greater effect on pre-natal fibre length than on the post-natal length.

12. Perfection of tip form is discussed.

13. The study of Super-sickle A- tip form and its comparison with the tip form of other types leads to the association of a perfect sickle shaped tip form with pre-natal check.

SUPER-SICKLE B. FIBRES.

These, as stated previously, have been defined by Dry as fibres, chalky in part of the neck, but not chalky in some portion other than, or in addition to, the non-chalky region of the Super-sickle A- fibres. The Super-sickle B fibres, therefore, appear to fill a wide niche in the fibre type series and therefore large variations within the classification will be expected. This is exactly what happens and the Super-sickle B types can be classified into the following :

(a) Loss of medullation confined to region immediately proximal to the tip.

(b) Loss of medullation as above in addition to loss at the birth point or position similar to the Super-sickle A- fibre. Medullation in the neck region is heavily chalky except for these sections of the fibre.

(c) Loss of medullation similar to that occurring in the Super-sickle A- fibres but more extensive with chalky medullation throughout the remainder of the fibre.

(d) The above types of losses of medullation with the medullation existing being of a weak rather than of a chalky type.

The importance of these is due to the fact that they give an indication of the relationships which exist between fibre types. These relationships, as is evident from a later section, are an indication of "array toughness" in the Plateau Array. Thus type (d) is characteristic of those arrays which provide evidence of a heavy checking effect and are therefore regarded as "weak" Plateau Arrays, or arrays that closely resemble the Saddle Array. On the other hand type (a), and to a lesser extent type (b) are examples of a more direct association between the Halo-hairs and the Curly-tip fibres, and thus these fibres provide evidence for judging an array as due to a weak checking effect. Type (c) is also characteristic of a marked checking effect.

It must not be assumed from the above that this classification of Super-sickle B fibres is an infallible guide to the effectiveness of the checking force. Variations and intermediates of all kinds occur, both within and between different types of Plateau Array, and some Super-sickle B fibres must be regarded as strictly "in parallel", Dry (19 and unpublished). Thus it is occasionally found that type (a), that is those Super-sickle B fibres with the loss of medullation confined to that portion just below the sickle end must be so regarded when odd fibres occur in an array where Super-sickle B fibres are found that closely resemble the Sickle fibres and Super-sickle A-fibres.

The real reasons for the formation of this type of fibre are unknown, and the idea of regarding these fibres as a completely different type has been considered. This has not been established, however, due both to their scarcity and due to the fact that they have more perfect tips than is usual with Super-sickle A fibres to which they otherwise appear closely related. This question of tip form is dealt with later under its appropriate heading and it is thus sufficient to briefly observe that perfection of sickle tip form may be an indication of the relationship between these fibres and the other Super-sickle B fibres or it may be a secondary effect - merely the result of the thinned neck region.

In relation to the discontinuity of type (a) Super-sickle B fibres, the fact must not be lost sight of, that type (b) is often closely related. Thus a series can be found between type (a) and type (b) in relation to degree of medullation at what is termed the birth point. An explanation is that the prenatal check acts on a strong base (see later), and causes the fibre to lose medullation completely, but due to the fortunate situation of this fibre, medullation is immediately recovered. At birth, however, the position of the fibre in the series, as the result of further fibre development, is less satisfactory, with the result that the fibre never completely recovered from its initial check, suffers a further check (see Super-sickle A-section, page 56), sufficient to cause complete loss of medullation. There are several disadvantages in this speculation and not the least of these is the assumption of two distinct checks. That two checks do exist has been demonstrated by Galpin (22) who writes, "it seems as if we may regard the pre-natal check as a trio depression and the reduction of inherent coarseness as a nine depression". The former can be regarded as responsible for the initial thinning, but as the reason for the thinning immediately prior to birth it is rather contrary to the spirit of Galpin's findings and thus the above must be regarded as an explanation,- the shortest theory that fits all the facts.

A further possible reason for this lack of medulla at the birth point is that dealt with in relation to the Super-sickle A- fibres, where it was suggested that the check in these fibres may be the result of the change in environment as the result of birth.

In this explanation it is to be noted that the environment is regarded as the checking vector. A search of the literature for pertinent facts was made, and although the results are largely inconclusive, it is felt that some evidence does exist in support of this postulation. Weighing lambs at birth and shortly after is difficult and consequently few such weighings have been made. These are, however, interesting in that they show that such data suffers from the difficulty of distinguishing between the loss in weight of the lamb due to drying and the gain in weight due to the early intake of milk. These variations may well be the reason for the lack of agreement in weighings of different workers. Thus Hammond (38) quotes Richter and Brauer as showing that lambs at first lost weight at maximum of 4.1% of body weight and that this is then regained at the average in 1.7 days when the animal weighs approximately the same as at birth. These results are similar to those obtained by Sidey (39) and later by Donald and McLean (4) at Lincoln College, who found a loss in weight which was followed by an increase of anything up to one pound within 24 hours. These workers attribute the loss to the drying of the lamb and suggest that the subsequent rapid gain is due to the milk intake of the lamb.

That this may not be the whole story is evidenced by Hammond (39) who quotes Feldman as finding a loss of 9.2% of the body weight in the human. Certainly he attributed this to drying but in that this loss in the naked human is greater than that in the lamb it may well be that the difference between the loss of weight by drying and the gain in weight by milk intake may not be the whole story and that the act of being born may entail some physiological check, particularly marked in the faetalised human but also of importance in the lamb.

The weight data, however, is on the whole unsatisfactory and it may well be that dimensional measurements similar to those used by Cassen and his co-workers in their studies of the Sex Physiology of the South African Merino (37) may be needed to throw definite light on the correctness of this postulation.

In the above it is not suggested that this supposed environmental check is the only cause of this loss of medullation at birth, as it is recognised that the "9 stage" check of Dr. Galpin (unpub.) probably plays a part in bringing about the thinning of type (c) Super-sickle B fibres. This is thought to be the case as the type of medullation loss is essentially gradual (see Super-sickle A-, page 57) which is in direct contradistinction to the type of medullation renewal. Further, this sudden regain of medullation after birth is considered to provide evidence that variations in follicular concentration, is not the major force, as it is considered unlikely that such a check could cease with sufficient suddenness.

On the other hand, in the light of the above mentioned papers it is likely that the environmental check could be expected to rapidly terminate as the young lamb becomes accustomed to its new mode of living. A still further consideration is that this sudden renewal of medullation does not appear to be associated with other array features, as it occurs in all types of arrays in which post-natal medullation is definitely chalky. In this respect it is notable that this sudden increase in medullation is found in some heavily medullated fibres such as Halo-hairs, although the loss of medullation may not be complete.

In relation to the other Super-sickle B types it is apparent from their very structure that they merely represent intermediates between the Super-sickle A- and the Sickle fibres. Variations between (c) and (d) must not be lost sight of as they may throw light on the separation of base and check (see later). Thus it could be plausibly argued that type (c), with chalkiness absent except for an intensely non-medullated period somewhat longer than that found in the typical Super-sickle A-, can be regarded as a fibre type with heavy potentialities - potentialities sufficient to cause extensive chalkiness, but potentialities which have failed to come to expression throughout the major portion of the neck region due to a heavy superimposed check. On the other hand type (d) with only weak chalky medullation in the neck region could be regarded as a fibre with low potentialities acted on by an intensive and prolonged check. The separation of these must, in part, depend on other features which are discussed later, but it is possible that in the ultimate elucidation of the judgments of the base and the check (see later) Super-sickle B of type (c) and (d) should not be neglected.

<u>Tip Length.</u>

The following observations are in the light of the remarks appended to the section on length of Super-sickle fibres and thus have particular reference to the pre-natal portion of the fibres.

Super-sickle B fibres vary considerably in length. They may be distinctly shorter than some Hairy-tip-Curly-tip fibres and are always definitely shorter than the Halo-hairs. It is clear that in the above only shed fibres are compared, (see page 23 of the Halo-hair section). Super-sickle B fibres that are of type (d) which have tips that on measurement were found to be longer than some more heavily chalky Super-sickle B and even Super-sickle A- fibres. Few of these fibres exist, but their existence is worthy of record as it indicates that medullation and length are not always affected in a parallel manner in the pre-natal length. In any complete study of the fibre types the reasons for this should be explored as it appears to be a contradiction to the work by Elphick and Waters (unpub.) who, by using a dyeing technique, obtained results which led them to conclude that medullated fibre grew faster than fine non-medullated fibre.

Tip Form.

The perfection of tip shape (see Super-sickle A- for discussion on tip shape perfection page 62) in the Super-sickle B fibres appears to follow in an inverse manner the degree of neck medullation. Thus in fibres where the neck region is heavily medullated as in type (b), (see above), tip shape does not closely resemble the typical sickle shape. Where neck medullation is weak or absent as in type (d) in particular, and to a lesser extent in type (c), the tips become more typically sickle shaped. It is notable that type (a), that is, fibres with a loss of medullation immediately proximal to the tip, have tips that are not imperfect, usually being distinctly sickle shaped.

Thus it appears that neck medullation and perfect sickle shaped tips tend to be antagonistic and further that loss of medullation in that portion of the fibre immediately proximal to the tip tends to be associated with a more perfect tip form than when this portion of the fibre is heavily medullated. This appears to be the case, despite the type of medullation in the remainder of the pre-natal region. Further, it is considered that this delicacy of carving bears testimony to the post tipal inhibition of medulla being due to an ordered cause as distinct from an accident of development. This frankly, is a fine point, but in this whole method of exploration of form and its significance the search is for the meaning of that which is seen and the endeavour is to charge no more than is unavoidable to "chance".

Post-natal Medullation of Super-sickle B Fibres.

Super-sickle B fibres in the Plateau Array usually have heavy chalky medullation in their post-natal region, but in some Plateau Arrays which are regarded as weak, Super-sickle B fibres with weak chalkiness have been found. Such an array is that of sheep 1402 VI! (D).

Sheep 1402 VI! (D)

H.H.	S.S.A.	S.S.A-	S.S.B. (ch)	S.S.B. (fine)	S.Fine	H.T.C.T.	C.T.
24	19	22	4	2	2	46	319

It is notable that this array as is the case with all Plateau Arrays where fine or almost fine Super-sickle B fibres are found, has Hairy-tip-Curly-tip fibres that are definitely more robust than the Super-sickle B fibres. The implications of this are dealt with later in the section on the forces at work in the architecture of the fleece.

Super-sickle B Numbers in the Plateau Array.

The fact that the Super-sickle B fibres are those fibres in the Plateau Array that show the greatest effect of the pre-natal check makes a study of their numbers of importance. This is further evidenced by the fact that the more numerous the Super-sickle B fibres, the more extensive have the effects of the check been. It is notable that where large numbers of the Super-sickle B fibres are found there also will be found Sickle fibres which are for the purposes of the Plateau Array regarded as "in parallel" (Dry 19). This type of in parallelism has an obvious explanation in that it is due to the extension of the check responsible for the Super-sickle B fibres, an extension that is both an extension of intensity and period of action.

It is important to distinguish this type of "in parallelism" from the type where a few Sickle fibres occur apparently unrelated to other fibre types.

TABLE I.

Sheep.	H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	S.S.B.+ Sickles.	C.T.	Hist.	C.T.+ Hist.	S.S.B. as % C. T.	S.S.B. as % C.T.+ Hist.
1327	27	5	0	0	0	0	250	245	495	0	0
1238	41	6	10	1	0	1	274	380	654	.4	.2
59.5	27	2	0	0	0	0	200	190	390	.5	.2
18.5	31	8	0	2	1	3	280	445	725	.7	.4
78.5	87	99	12	6	0	6	534	622	1156	1.1	.5
77.5	21	18	4	2	1	3	327	374	701	.6	.4
1279	25	2	2	5	1	6	156	186	342	3.2	1.5
58.5	39	12	4	16	0	16	404	348	752	4.0	2.2
62.5	17	16	7	6	0	6	162	250	412	3.7	1.5
29.5	15	7	5	7	4	11	266	224	490	2.6	2.2
1402	45	25	29	11	4	15	522	577	1110	2.1	1.4
76.5	56	26	16	16	4	20	291	349	640	5.5	3.1
88.5	19	26	6	23	0	23	218	354	572	10.6	4.0
71.5	11	21	1	12	0	12	320	186	506	3.8	2.4

Table I, which tabulates data for Super-sickle B has the arrays as judged by fibre type association and fibre type numbers, in order of "toughness" (see page 123) from 1327 and 1238 regarded as the toughest array to 71.5 and 88.5, regarded as those arrays showing the most effects of the check. In such a series it is important to note that the classification due to the very nature of the criteria of "toughness" is not a fixed classification between adjacent arrays but represents a definite gradation from that array showing the least to that showing the greatest effect of the pre-natal check. Thus from the nature of the Table individual variations down the series will be found, and, therefore, its importance lies in revealing trends.

The trend in the population of the Super-sickle B fibres has already been discussed (page 71) and it is notable that although the population of the Sickle fibres varies considerably, it is apparent that those arrays with numbers of Super-sickle B fibres tend also to have Sickle fibres present.

It is to be observed that in one column the Super-sickle B and the Sickle fibres, deemed in parallel, have been added together. Thus for these Plateau Arrays it is suggested that these Sickle fibres be regarded as "super checked Super-sickle B" fibres.

As is usual in such Tables the Curly-tip and Histerotrich fibres have been added and the Super-sickle B and Sickles calculated as percentage of these fibres. This type of calculation obviates any possibility of the results being invalidated by difficulty in classification between Histerotrichs and the Curly-tip fibres. These samples are relatively late samples and therefore it is considered improbable that there will be any further growth of Histerotrichs. Percentages calculated in this manner are more even and the gradation in Super-sickle B and Sickle fibres with toughness is very notable.

SUMMARY.

1. The Super-sickle B fibre type is defined.

2. Variations within this type defined in this way are described and these are classified into four major types linked by intermediates.

3. The importance of the Super-sickle B fibre type to the study of the pre-natal check is briefly discussed.

4. The reason for the loss of medullation immediately proximal to the tip and its relation to the loss of medulla at the birth point is speculated upon.

5. It is suggested that the lack of medulla at the birth point and the sudden increase in medulla immediately after may have a partly environmental basis.

6. Variations in Super-sickle B fibre length with particular reference to pre-natal length are briefly explored and a lack of correlation is found between pre-natal length and medullation.

7. A study of Super-sickle B tip shape leads to the conclusion that neck medullation as a whole and particularly that portion immediately proximal to the tip region is associated with Sickle tip form.

8. A Plateau Array is quoted as an example of those arrays in which Hairy-tip-Curly-tip fibres are found which are definitely more robust than the fine or almost fine Super-sickle B fibres.

9. Large numbers of Super-sickle B fibres in the Plateau Array are associated with the presence of Sickle fibres.

10. A Table of Plateau Array analyses from which it is apparent that the Super-sickle B fibre population decreases with the decrease in the effectiveness of pre-natal check as judged by fibre type association. is presented

SICKLE FIBRES.

These fibres in the Plateau Array are conspicuous by their absence and are thus only of importance in a study of this array in so far as they are related to the Super-sickle B fibres, and to the Hairy-tip-Curly-tip fibres. These relationships are dealt with under the heading of Super-sickle B and Curly-tip fibres respectively and it is sufficient to mention here that intermediates are of importance in the study of arrays because they define the relationships that exist between fibre types.

Sickle fibres have been described by Dry in various publications (12, 19, 29), it is therefore considered that a further description would serve no useful purpose and would be an unnecessary addition to the study of the Plateau Array.

The Occurrence of Sickle Fibres in the Plateau Array.

This has been dealt with under the heading of Super-sickle B fibres for which discussion Table I was appended. For the purposes of this table the relationships between Sickles and Super-sickle B fibres were discussed and the decision arrived at, that for the Plateau Array the Sickle fibres could be regarded as what was termed "super checked" Super-sickle B fibres. This, in the light of other arrays, which depend on the Sickle fibres for their classification, is rather an unusual point of view, but it is justified by the definition for the Plateau Array. Thus it is that the Sickle fibres in the Plateau Array can be merely regarded as evidence of a heavy checking effect, a checking effect sufficient to cause the Plateau Array to closely resemble a Saddle Array. Such arrays are :

Sheep	H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	Hist.
76.5	56	26	16	16	4	291	349
1402	45	25	29	11	4	522	577

There is a further type of Sickle fibre population in the Plateau Array and that is the type that appears not to be associated with any other fibre type except perhaps for a few Super-sickle B. These Sickle fibres are regarded strictly as "in parallel" a concept of Dry's (19) whereby such fibres are explained as due to localised high intensity of the pre-natal checks. Such fibres are not regarded as an indication of "weakness" (see later) of the array as a whole. An array that contains these "in parallel" Sickle fibres is :-

Sheep	H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	Hist.
18.5	31	8	0	2	1	280	445

This array has both Sickles and Super-sickle B fibres in parallel and these two fibre types, while very similar, appear to be quite unrelated to the Super-sickle A fibres that immediately precede them or the Hairy-tip-Curly-tip fibres which immediately follow them.

Similar in parallelism, but of the type in which the checking effect has not been sufficient to prevent the formation of some medullation in the neck region, giving Super-sickle B fibres, is found in the following array :

Sheep	H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	Hist.
59.5	27	2	0	1	0	200	190

Thus it is apparent that the occurrence of these discontinuous Sickle fibres must with our present state of knowledge and our present scarcity of suitable material remain virtually unexplained, to serve as reminders that fibres may on occasion have a certain individuality.

SUMMARY.

1. Reference is made to Dry's descriptions of this fibre type and too a discussion in a previous section of these fibres in relation to the Super-sickle B fibres in the Plateau Array.

2. The occurrence of Sickle fibres in the Plateau Array is briefly discussed.

3. It is concluded that the presence of Sickle fibres in the Plateau Array may be regarded as evidence of a considerable pre-natal check.

4. An example of what appears to be the fortuitous appearance of Sickle fibres in the Plateau Array is given and discussed.

CURLY-TIP FIBRES.

These fibres have been treated very fully by Dry (19) in both published and unpublished papers. He draws attention to their importance in connection with hairiness in the fleece of the sheep and notes the variations that can occur in the medullation of these fibres both before birth, and particularly, after birth.

Further, in regard to "non-plateau" he deals with the relationships between the Curly-tip and the pre-curly tip fibres of the array, noting that (19) "from the study of unborn lambs by Dr. N. Galpin, together with the examination of specimens taken at birth, it is concluded that, probably with some slight overlapping, the Halo-hairs and the Sickles begin to grow before the Curly tips and the more curls there are in the pre-natal part of a Curly-tip fibre the earlier it begins to grow". Observations on Curly-tip fibres in Plateau Arrays have, in the main, led to a recognition of the essential similarity of the Curly-tip fibres of the Plateau and other arrays. Although these Curly-tip fibres, on accasion, are of a more extreme type than those found in other more heavily checked arrays, it is not uncommon to find that Curly-tips of the two types are identical. Thus a study of the Curly-tips as they occur in the Plateau Array tends to be similar to descriptions of these fibres for other arrays. Their treatment has been limited, therefore, to a few observations of apparent differences between Curly-tip fibres of the Plateau and other arrays.

This limited description, however, does in no way deprecate their importance in the Plateau Array, and it is fully realised that these fibres from their sheer weight of numbers provide wide fields for study in the elucidation of the architecture of the fleece.

Tip Form.

It is clear from the very name of these fibres that tip form is an important feature in their classification. Dry

(19), in discussing tip form of the Curly-tip fibres in arrays other than Plateau, states, "where the curls are very big the tips of the largest tend to be coarse". This generalisation has been found to be applicable to the Curly-tip fibres of the Plateau Array, although in the light of previous remarks on both Super-Sickle A and A- (page 62) it is considered that tip form is relative to degree of medullation and not medullation relative to tip form. The degree of medullation is, therefore, considered to be primary. Thus where pre-natal medullation is considerable there will be a lack of fineness in the curl or pre-natal crimp. This is particularly noticeable in some arrays where the Curly-tip fibres are very closely related to the Halo-hairs and the Super-sickle A fibres. Such Curly-tip fibres have almost their entire pre-natal length heavily chalky and it is common to find pre-natal crimping limited to one half curl at the extreme distal tip. These fibres are only found in exceedingly "tough" Plateau Arrays (see later) where there is a lack of Super-sickle fibres. On occasion difficulty has been experienced in distinguishing these extreme Curly-tip fibres from the Halo-hairs and Super-sickle A fibres.

This lack of distinction between these fibre types is important in the light of work briefly discussed by Galpin in published work (22) but more completely discussed in an unpublished paper. In this latter, evidence is presented which leads to the conclusion that "in no part of the body can any follicles but trio stage follicles become pre-curly-tip fibres", and further, "in some areas very few trio follicles will be allowed to become pre-curly tips, many of the trio follicles growing coarse curly-tips". Thus it is easy to suppose that these Curly-tip fibres that resemble to a remarkable degree the coarser pre-curly tip fibres are the type <u>par excellence</u> that Galpin considered grew in the trio follicles.

This is interesting in the light of speculations on the causal factors for fibre tip form. It has been postulated that tip form, whatever may be the physics of the causes, is dependent on period of development. If the rate of founding of follicles is slow, then fibres which judged on tip shape would have been Super-sickles or perhaps even Halo-hairs tend to curl and thus become classed as Curly-tip fibres. In relation to this explanation it is notable that slow rate of follicular development would necessarily, with our present ideas of pre-natal check (Galpin 22), involve a very mild check which is exactly what a 'tough' Plateau expresses (see later).

Thus it is apparent that in a study of tip form in relation to fibre types these very coarse Curly-tip fibres will merit considerable attention and will be important in elucidating the real differences between fibres in this respect. Not all Plateau Arrays have these extremes of tip form. Many have tips that are identical with those described by Dry and even in those arrays where the extreme type is found, what may be termed, typical "curly-tipped" Curly-tip fibres, are common. Thus it is apparent that the range of variation in tip form within and between Plateau Arrays in particularly wide.

It is important in relation to the above to note that the tip form discussed is the shape of the extreme distal portion and does not necessarily involve the neck region. Thus the pre-natal portion of a typical Curly-tip fibre may be divided into two portions which are, of course, continuous. These portions are (a) the extreme distal tip, (b) the remainder of the neck region which has distinct crimping varying considerably in both amplitude and wave length. Whether or not there is any real difference between these is unknown. But despite this it is considered that the above classification serves a useful purpose in clarifying the description of the pre-natal portion of the Curly-tip fibres. Actually, in the light of the Wensleydale data discussed below, it is doubtful if there is any real difference between these two fibre regions.

The distal tip of the pre-natal region is distinguished in the Romney by the fact that the tips of many Curly-tip fibres are distinct from the remainder (pre-natal portion) of the fibre by reason of the occurrence of one complete or almost completely circular apical curl. The occurrence of these completely curled tips is a common feature in the Curly-tip fibres of many arrays but it is not necessarily present in any, other than almost completely non-medullated arrays. Thus there are many Plateau Arrays in which these complete tip curls are not found. A thorough study of their occurrence has not been made but it appears that :

(a) The early Curly-tip fibres are the most likely fibres to have complete tip curls - proneness to curling becoming less marked as the Curly-tip fibres approach the Histerotrichs.

(b) Fibres that are not absolutely non-medullated for the pre-natal portion at least, are unlikely to have completely curled tips. Thus their absence, although most common in Plateau is not confined to this array, and appears to depend on medullation of the Curly-tip fibres, rather than on array.

The occurrence of this feature was remarked in animals other than the experimental Romney sheep. Curly-tips from Stud Romneys, Wensleydales and Merinos were studied. In the first the curls were found in all Curly-tip fibres except for a few fibres which were approaching Histerotrichs in the fibre series. In the Merino samples the curl was very tight and appeared very common. It gave rise to a regular crimpiness which was continued throughout the fibre to the butt and thus, together with the complete lack of medullation and the extreme fineness of these late Curly-tip fibres resulted in the complete masking of the birth point. In the Wensleydales the tip region of the early Curly-tip fibres was usually completely curled and these complete curls were common in Curly-tip fibres that were found late in the Curly-tip series.

The explanation of these complete curls, particularly in the light of their prevalence in the Wensleydale, and also in the light of their occurrence sub-apically in these fibres is that the complete curl is a compression of a spiral tip. Thus the study of these curled tips in the birthcoat fleece may throw some light on the theory of Duerden (27) that, "all wool fibres are fundamentally spiral as they emerge from the follicle and that where the fleece is sufficiently loose and open they form separate spiral ringlets". That the real facts are as simple as would appear from this is doubtful when the tips of the Merino and the Romney are compared. At first sight the fact that the Merino, the type example of a uniplanar crimp, (Barker and Norris 28), should have a complete curl appears to support Duerden's theory, in that it may be argued that these fibres which show this feature most come early in the fibre series and thus cannot be affected by the weight of the fleece. However, when this is considered in relation to the Plateau Array, where the early prenatal density is very probably less, it would appear that a further factor may have an appreciable effect.

Observations of different types of arrays in regard to Curly-tip medullation are extremely interesting in this respect and may throw some light on the study of crimp. It was found that the more heavily medullated the Curly-tip fibres post-natally the less likely was the pre-natal tip to be completely curled. Thus in Valley Arrays checked Curly-tips could have completely curled tips while this feature was absent in the peak Curly-tip fibres.

Thus in the light of the above it may be that this early pre-natal curl may be a relatively accurate indication of post-natal happenings and as such may make it possible to prophesy (from the birth coat) the future non-kemp hairiness situation. Also it may, with further study of this feature, be possible to distinguish between those animals which are accidentally or only just pure woolled from those animals that are definitely free from medulla by a wide margin.

This is frankly speculation but in that the study of Curly-tip form has these possibilities it is considered that it should not be neglected, even if from the point of view of the architecture of the fleece, it does not present the most pressing problem for elucidation. Such a study would forge a valuable link between kemp and non-kemp medullation.

A possible criticism of the above can be made in the light of a previous statement (page 79) in this section, where, in the discussion regarding size of curl, it was stated "tip form is considered to be relative to the degree of medullation and not medullation to tip form". This criticism is valid within animals but is considered not to hold when applied to "between animal" comparisons. This judgment is due to the fact that many arrays in which medullation is extensive have a lack of apical curls while in similar arrays with a lack of Curly-tip medullation the curls are definite despite the fact that the pre-natal region appears to be little different.

Further work that stresses the importance of the birthcoat curl is that of Lockner (34) who, from his study of the first fleece of the Scotch Blackface considered that tip curl was an indication of later happenings in the growth of the fleece, notably the distribution of Kemp. He recognised four different types of curl and comes to the conclusion that in the Scotch Blackface, "a straight-to-wavy type of birthcoat is the most desirable as it indicates early shedding of deciduous fibres with consequent lack of kemp later in the fleece".

In relation to what may be termed the neck region of the pre-natal portion of the Curly-tip fibres it has been remarked early in this section that wide variations in crimping were found in this region. This observations is by no means new and these differences were remarked some years ago by Dry (29). Further, as has been pointed out, Dry correlated these differences in pre-natal crimp form with coarseness. More recent observations of the crimp in Plateau and other arrays have confirmed this generalisation to such an extent that in some Wensleydales the Curly-tip fibres were classed on pre-natal crimp form only, with completely satisfactory results.

In the Wensleydale the medullation is either entirely lacking or is very weak and for this reason considerable difficulty was encountered in classifying the fibres into their correct order. It is notable that despite the weakness of the above medullation these arrays were often deemed to be Valley. In such a classification difficulty was encountered in distinguishing what amounted practically to degrees of coarsensss amongst virtually non-medullated fibres. This difficulty can be readily appreciated when it is realised that the checked Curly-tip fibres were often very scarce. This is apparent from the following arrays which are typical of the Wensleydale truncated Valley Arrays.

Sheep	Fine Sickles	Checked C.T.	Total C.T.	Hist.
W.1.Bk.	6	21	209	4
W.2.Bk.	16	24	245	109
W.3.Bk.	21	16	238	5
W.6.Bk.	23	35	178	25

This method of classifying on crimp was found to be eminently successful as is apparent from a note appended to the analysis of sheep W.6.Bk. (see above) which reads, "no notice was taken of features other than pre-natal crimp, and although length and coarseness were totally neglected the fibres classified out automatically as to these features.

This same method of classification of Curly-tips has been used in the Plateau Array with success although difficulty is often experienced due to the fact that, what may be termed the "character" of the crimp, which involves evenness of wave length and amplitude, is often irregular or "plain". The reasons for this are considered to be due to the coarseness of the Curly-tip fibres in the Plateau Arrays, which coarsenss appears, as is clear from the above, to be responsible for a general tendency to "plain" or "characterless" crimping. This tendency is particularly noticeable in the post-natal region where crimping is completely absent in Curly-tip fibres chalky after birth but appears again when the fibre loses its medullation at the crisis period.

In relation to the above, differences between the neck crimpiness of the Hairy-tip-Curly-tip and other Curly-tip fibres are worthy of note. In the Hairy-tip-Curly-tip fibres it is not unusual to find the curls reduced in number but increased in amplitude when compared with fibres which, judged from their general macroscopic structure are regarded as coming later in the arrays. That this judgment of position in array is correct gains support from fibre type associations, shedding, and the fact that the same effect is found in Super-sickle fibres.

Whether curl size and amplitude vary proportionately is not known and no extensive counts or length measurements were made. It is, however, considered that in general they vary inversely. Further, the extent of the variation from what may be termed normal for the array is in part a peculiarity of the animal as distinct from coarseness. Normality is judged from the great majority of the Curly-tip fibres deemed to come late in the array. Thus some Saddle Arrays which, of course, have suffered a considerable pre-natal checking effect, have Curly-tip curls which appear not dissimilar from those found in Plateau where the check is relatively negligible.

At present, however, the study of the curls and the neck crimps of the Curly-tip fibres, both in the Plateau and in other arrays, is in no way complete and it is apparent that further study of their detailed structure in relation to array, array type, and medullation of the pre-natal, post-natal and post crisis periods of the Curly-tip fibres is required before any definite generalisation can be attempted. However, despite the above it is notable that the pre-natal portion of the Curly-tip fibres at least appears not to agree with the theory developed by Norris and Van Rensburg (30) that crimp is a periodic function of time but rather to lend support to the conception of Swart and Kotze (31) that the formation of crimp is correlated with diameter. The fact that Waters and Elphick (unpub.) showed that medullated fibre grew faster than non-medullated fibre appears, at first sight, to explain the pre-natal crimping in the light of the former (Norris and Van Rensburgh). This support is upset, however, by the fact that the crimps become so extremely scarce in some of the Hairy-tip-Curly-tip fibres which are little longer in pre-natal length than some later Curly-tip fibres with considerably more crimps.

Thus it is apparent that neither of these theories appear absolutely satisfactory and with further facts it may be, as mentioned abové, that new generalisations will be evolved which may, in turn, throw light on the apparent anomalies which exist between the theories for the formation of crimp.

Post-natal Structure.

The post-natal variations in Curly-tip fibres have been treated very fully by Dry in various papers, both published and unpublished. In these he stresses the wide variations that can exist in the degree, extent, and continuity of medullation in Curly-tip fibres. A further type of variation which is treated separately (see the section on The Precipice) is the variation in continuity of medullation along the array and is apparently unrelated except in a general way to the extension and continuity of medullation down the staple. The relation between these two is simply that when the medullation in the staple is particularly chalky, whether or not it extends below the crisis level, then both pre-and post-precipical portions of the array are medullated, and when medullation is weak and continued to, but rarely extending below, the "crisis" period then the post-precipical series are non-medullated. Wide variations are possible and occur within these generalisations.

A feature that has been stressed by Dry (29) as important is what he has termed, the "Crisis thinning". This he describes as it occurs in Sickle fibres, but later he notes that it is also found in Curly-tip fibres. When discussing crisis thinning he notes that many fibres have medulla free thinning in place of cessation of growth below below which they are coarse again and proportionately more of the persistent chalky Sickle fibres than fibres coming later in the array show this crisis thinning. He thus takes the view that this crisis thinning is a thinning of vigour and fibres showing this must be regarded as more vigorous than fibres not showing it. In a later section, when describing the variations occurring within the Curly-tip fibres,he notes that, "in many lambs medulla stops at the crisis level, and it is a common happening for abundant medulla to extend a little beyond this point to become reduced very soon afterwards. Often medulla is produced for but a short time after birth, ceasing definitely before the crisis level". Observations on the Plateau Array agree entirely with the above and it has been found that a series of effects depending on what is regarded as follicular vigour can be found.

This series is by no means a regular feature between arrays as there are wide variations in pre-natal medullation and also in shedding. Thus in one array some Hairy-tip-Curly-tip fibres, and even Curly-tip fibres shed in a normal manner. Thus in classifying a series that can be applied to all arrays, it is clear that post-natal medullation alone must be used as a basis for classification. When the fibres were classified it was found that they depended on the extent of the crisis thinning. Those fibres which had but a narrow crisis portion were found to be closely associated with those fibres which shed, while those fibres with a wide crisis thinning came later in the Curly-tip series as judged by tip form and associations. The extremes therefore are the normally shed Curly-tips, and the fibres in which crisis thinning is not followed by any medullation at all. Actually it is clear that these latter are directly related to those fibres that have weak pre-crisis medullation, and thus become continuous with completely fine Curly-tip fibres.

Dry (20) has remarked the fact that crisis thinning is a very common feature indeed, and further, that it is a feature peculiar to a certain stage of post-natal growth. He notes that the third month is probably the time when crisis thinning occurs. The exact period over which this feature can commence is unknown, and a special survey would be required for its definition. This has not been done, but in analysing arrays it is apparent from the position of the butts of the shed fibres that crisis thinning and shedding take place at approximately the same time. There appears, however, to be a rather indefinite period for crisis thinning between fibres and this indefinitness in samples where the period of medullation loss is short, tends to mask the clarity of the crisis pause in a sample in benzol. Analyses of the sample, fibre by fibre, usually indicates that a crisis is present. It is notable that the method of treating a sample before placing in the benzol tray necessitates the teasing of the sample with consequent slight disarrangement of the individual fibres. Despite the above the former statement that the crisis thinning occurs about the time when the lamb is three months old is still considered valid.

The fact that this is so has been explained on purely nutritional grounds as the result of the check in growth of the lamb at weaning. This is doubtful, for the reason that nutritional work on the milk yield of the ewe, both calculated and observed, suggests that lambs under good managemental conditions do not usually suffer a very severe check at this period as the ewes tend to be almost dry at weaning. A more definite test of the correctness of the above statement was, however, considered to be necessary before the crisis thinning could be considered as due to something innate.

To do this animals were sought that had not suffered the supposed check of weaning, and who had been kept on a reasonably high plane of nutrition. Fortunately 18 pet lambs were available which had all been fed together and had not been weaned when the samples were taken on the 20th. February, 1938. Unfortunately early samples of these lambs were not available and thus the arrays could not be determined, but the February samples were quite satisfactory for the crisis thinning determinations.

TABLE II.

Sheep.	Back Crisis Situation.	Side Crisis Situation	Britch Crisis Situation.
P 1.8	slight	hairy throughout	hairy throughout.
P 2.8	no medullation	no medullation	definite.
P 3.8	no medullation	definite	hairy throughout.
P 4.8	definite	slight	definite.
P 5.8	hairy throughout	hairy throughout	hairy throughout
P 6.8	no medullation	no medullation	slight.
P 7.8	definite	slight	hairy throughout.
P 8.8	no medullation	slight	" "
P 9.8	slight	definite	" "
P10.8	slight	definite	" "
P11.8	definite	definite	" "
P12.8	no medullation	slight	" "
P13.8	no medullation	no medullation	definite.
P14.8	slight	slight	slight
P15.8	slight	slight	hairy throughout.
P16.8	slight	slight	definite.
P17.8	definite	definite	hairy throughout.
P18.8	definite	slight	hairy throughout.

Summary.

5	definite	5 definite	4 definite
6	slight	8 slight	2 slight
6	no medullation	3 no medullation	0 no medullation.
1	hairy throughout	3 hairy throughout	12 hairy throughout.

In relation to the terminology used in the above it is notable that they are benzol tray determinations. Therefore, in those types graded "hairy throughout" it means that medullation in many fibres shows no crisis pause and these in the mass mask the crisis thinning which occurs in some of the weaker medullated fibres. The term "no medullation", is clearly necessary and indicates that although a crisis may exist in diameter it is impossible to distinguish it from medullation determinations. The term "slight" indicates that an indistinct crisis exists. It is notable that the reason for this indistinctness may be due to (a) medullation tending to mask the crisis pause in the less heavily medullated fibres. (b) weakness in medullation calibre tending to make a complete loss difficult to distinguish.

The results of these observations are set out in Table II. From this table it is apparent that some of these lambs showed no medullation and thus could show no crisis thinning, while others had medullation so heavy that crisis thinning tended to be masked. In these latter, fibres were found, often in abundance on Britch samples showing no crisis thinning at all. It is, however, clear from the Table that crisis thinning was found extensively in these lambs and it is, therefore, safe to conclude that weaning and, therefore, possible environmental conditions as a whole can be neglected as a cause of crisis thinning.

Further, it is notable that some of these animals showed a loss of medullation early in life - somewhat before the time normal for crisis thinning. Thus the samples evidenced what could be termed two crisi or critical periods. The first thinning was regarded as due to the early vicissitudes that some of the lambs underwent between loosing their mothers and being artificially fed. This thinning varied in timing and intensity even between the few lambs in which it occurred. Thus the difference between a nutritional check and crisis thinning is emphasised and is commensurate with the type of check resulting from severe but limited environmental conditions.

No Plateau animals were found having Curly-tip fibres in the back position without crisis thinning. Absence of crisis thinning was, however, found to be common in the Side and more especially the Britch samples of animals with Plateau at the Back positions.

As persistent Halo-hairs have been found to be of relatively common occurrence on the Britch and this, together with the fact that Dry (unpub. Kemp Report) found a lack of secondary kemp at this position, it may well be that there is a relation between shedding and crisis thinning. In future work on this feature a possibility of such a relationship must not be neglected.

Possible causes of crisis thinning were considered, and in the light of Galpin's work (22) on the pre-natal check it was thought that a sudden checking force, caused perhaps by the growth of new fibres in the coat - Histerotrichs - would be a possible explanation. The possibilities of this being the correct explanation were slender as it appears that such a check would result in a limitation of vigour and not in an excess of vigour as Dry regards crisis thinning. However, despite this a survey of Histerotrich populations as to length and regularity of fibres was made and from this it did not appear that these features played a part. This was due to the fact that the analyses of October and November samples with reference to the density and lengths of Histerotrichs showed that it was highly improbable that Histerotrich development was important at the crisis period.

Thus the explanations and implications of this phenomenon must remain as yet unsolved. It is likely, however, that its solution will have a very definite bearing on the understanding of the working of the forces in the post-natal fleece of the sheep. Further, it is probable that its elucidation may throw light on what has been termed smoky shedding etc. and such problems as yolk exudation. In relation to the latter, Sutton (32) showed that a peak of activity was found in the yolk glands at shedding. As regards the former, it is important to note that a relationship may be established between crisis thinning, smoky shedding, and what is termed 'break' in wool.

Dry considers that the crisis thinning may well be explained on follicular vigour alone, but from evidence quoted below this may not be the whole story. The reason for postulating that a relationship between crisis thinning and 'break' exists is that in the following array there appear two crisis thinnings, both accompanied by smokily shed Curly-tip fibres and the crisis that comes latest in the year is also accompanied by what in practical terms is called a 'break' in the staple. Thus it is considered that there is perhaps some evidence for regarding nutrition as merely one component factor necessary for a break in wool.

Sheep 1068.

	H.H.	S.S.A.	S.S.A-.	S.S.B.	H.T.C.T.	C.T.	G2.	G3.	Hist.
Persist.	0	0	0	0	0	224	18	71	542
n.shed.	41	11	3	0	30	0	98	23	0
"sm." shed.	0	0	0	0	6	47	1	0	0

In this array many Curly-tip fibres were medullated to the butt although all Curly-tips showed two distinct breaks in medullation, one the normal crisis type of medullation loss, the other a typical nutritional break with fine crimping described by Waters and Elphick (unpub.) and also by Lockner (35). Both these periods coincided with normal* type shedding together with abnormal or smoky* type shedding. Details of this shedding are important and can be summarised thus :

Curly-tip fibres, shed at 1st. Crisis	14	All Curly-tip fibres shed smokily.
Curly-tip fibres, shed at 'Break' period	33	

These latter show crisis thinning and subsequently recover chalky medulla. It is also notable that shedding at the break period is noticeably less orderly as regards time than at the first crisis period.

Six persistent G2 fibres, which are definitely medullated, show distinct thinning at the 2nd. Crisis period. This period is judged by the position in the staple of many "Normal type" shed typical G2 Kemps. One of these typical G2 kemps is shed smoky fashion after a period of no medullation.

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* Note:- See Halo-hair Section, page 30 for definitions of these terms.

The remaining G2 fibres that are termed persistent are actually shed in normal fashion at the same time as the G3 fibres. These G2 fibres also show a loss of medullation that is identical with that described for the Curly-tip fibres. It is, therefore, suggested that these fibres are prevented from shedding at the normal time by the poor nutritional conditions but that the urge to shed at this time has played an important part in bringing about this temporary loss of medullation which in common terms is called 'break'. Further, it is suggested that the same effect, but at a lower vitality scale, is responsible for the smoky shedding of the Curly-tip fibres.

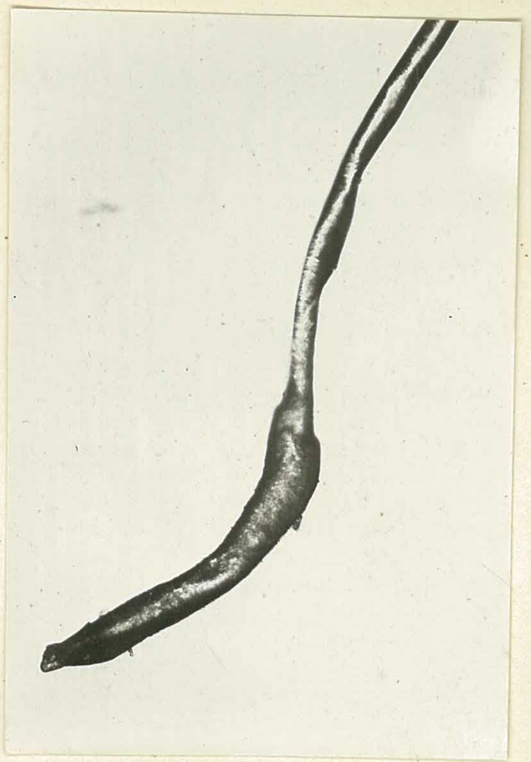
In relation to the above it is of interest to note that Roberts (33), in studying the fleece of the Welsh Mountain sheep concluded, "that evidence points to variable factors which act during a susceptible period on sheep of varying individual susceptibility". Also Lockner (35) in his study of cotts in the fleece of the Scotch Blackface refers to what he terms "the susceptible period" which, he holds, differs in time of incidence between individuals and is largely influenced by the constitutional and hereditary characters of the animal. Thus it is apparent that the study of the crisis opens up a wide field which leads on naturally to the physiology of the growth of the fleece in the widest sense.

Shedding in the Curly-tip Fibres.

The freedom of shedding is dealt with under the heading of "Shedding in relation to Array toughness", and the types of shedding have been described previously. A reitteration or anticipation of these descriptions and generalisations is not considered necessary and thus this section consists merely of a few points that have been observed but have not been treated elsewhere.

Dry (19) has described and figured a type of shedding which he notes as the normal type for mammalian hairs and the typical mode of shedding found in kemp. These he figures with

FIGURE. VIII.



Normal Shedding with a sheath.

FIGURE IX.

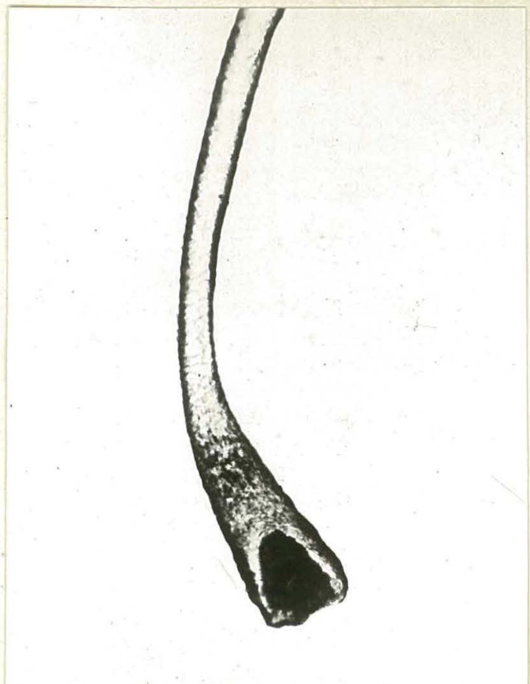
Normal shedding with no sheath.

two variations, with and without the presence of the sheath which, he notes in discussing baby Halo-hairs and Super-sickles, as definite evidence that shedding has taken place. These two types are featured in Figures VIII and IX., these plates being made so that comparisons with what is termed "smoky" shedding is possible. As has been mentioned before, in the section on Halo-hairs (page 30), these types of shedding are typical of Halo-hairs, the larger birthcoat kemps and secondary and post birth coat kemps in general. Whether the presence or absence of a sheath has any significance is not known but, judging by the presence of the two types apparently occurring indiscriminately throughout the Halo-hair series which is, of course, more prone to shedding than any other type, it is unlikely that the presence of a sheath can be regarded as anything but a chance happening. The sheath is firmly attached to the shed end and it was found impossible to dissect it off.

In relation to the Curly-tip fibres, however, it is notable that this type of shedding so typical of the Halo-hairs is typical of the shed Hairy-tip-Curly-tip fibres of many of the coarsest Plateau Arrays and is also occasionally found in shed Curly-tip fibres in such arrays. Shedding with a sheath appears less common than shedding without the sheath. This observation must, however, be regarded as merely opinion and is not backed by any considerable number of counts. Such counts would have to be made on microscopic observations as it is impossible to distinguish the two types of normal shedding with the naked eye.

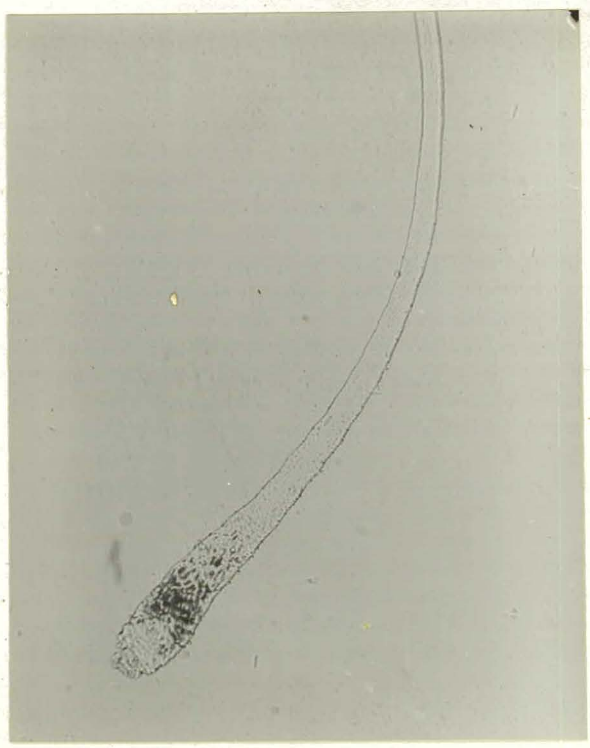
There is a further type of shedding which is important in the Curly-tip fibres. It is, however, not confined to Curly-tip fibres except in the Plateau Array where it never occurs in the pre-Curly-tip fibres. This type of shedding has been mentioned previously (page 30) and also briefly described and, due to the existence of smokiness in the shed butt, is termed smoky type shedding. This type is figured in Figure X. In some arrays this type assumes importance, mainly by reason of the number of fibres involved. It appears to be limited to fibres that shed by

FIGURE X.



Smokey shedding - normal type with hollow end.

FIGURE. XI.



Smokey shedding - near "normal" type shedding.

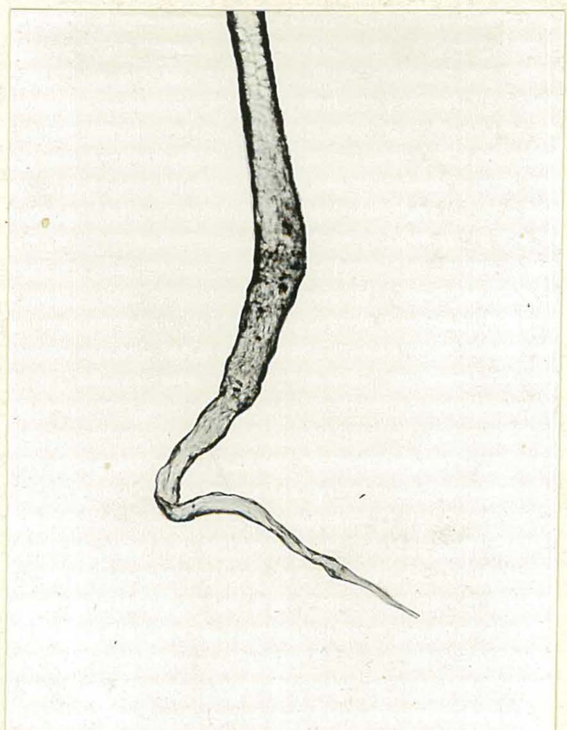
accident in that it is confined to fibres that are, at the most, only weakly medullated. As is mentioned previously in this section, the numbers shed may be influenced by environment, such environmental effects being particularly effective at different rhythmical periods. Also, it is important to note that Rudall (24) obtained smokiness (23) by merely tugging at fibres, but he does not mention actual shedding. However, fibres have been found with a smoky swelling identical with that of smoky shedding (Fig. X), but complete, with the fibre continuing in length after the swelled portion. When these fibres were broken at this smoky position the butt appeared identical with that figured for the shed fibre. This, in the light of Rudall's work, is thought to provide evidence for regarding smoky shedding as due to some adverse environmental effect. Thus the apparent regularity of abundance of smoky shedding in particular animals (see page 92) provides a problem which must not be neglected in a study of the fleece which pretends to be in any way complete.

The actual smokily shed butt has various recognisable differences within the smoky classification and these differences can apparently be classified into a definite series which appears to lead through continuous intermediates from the hollow type Fig. X , described in the Halo-hair section (page 30) to a type of shedding, Fig. XI , which appears not unrelated to the previously described normal type of shedding. The implications of this grading are important in that they suggest that the forces responsible for all types of shedding, whatever their initial causes, act similarly to each other. If this is so then time of reaction may be responsible for difference between the extremes. In the light of Rudall's work mentioned previously intensity of reaction also is likely to be of considerable importance. In regard to the conception of the importance of the time of reaction of the forces, the explanation is that in those smokily shed fibres with the hollow ends there is no visible Catagen phase, (16), and it is therefore postulated that the

FIGURE XII.

Smokey shedding with fibre size diminishing gradually and terminating in a somewhat rounded knob.

FIGURE XIII.



Smokey shedding with the post smokey length of the fibre gradually diminishing.

force resulting in shedding is sufficiently intense to cause a sudden and complete cessation of growth with consequent shedding. In the next type of smoky shedding, Figure X, the force is less effective at first and only gradually results in a relatively prolonged upset of folliculat metabolish which culminates after a period in this type of shedding. Actually in some fibres this effect is very marked and the fibre may remain attached for a considerable time, finally shedding either as a somewhat rounded knob, (Figure. XII), or diminishing gradually till it is either broken or sheds without a visible shed butt. Such a postulation may well be extended to include the normal type of shedding, Figure VIII and IX, in which the Catagen phase is distinct and occupies a considerable length of the fibre. In this type it may be that the forces culminating in shedding act over a considerable period and in an ordered manner eventually resulting in a type of shedding which, judging by the vigour of many of the successors of these fibres has no deleterious results on the follicle.

Numbers of Curly-tip Fibres.

It is apparent from the previous sections that the numbers of the Curly-tip fibres constitue the base by which the population of other fibres in the fleece are judged. For this reason, therefore, it is impossible to discuss variations in Curly-tip numbers unless they are judged by some criterion other than that depending on fibre type. Such a standard would be supplied by density determinations but these have not been made. Density measurements in relation to the total fibre population have, of course, been made by numerous workers who have studied a large number of different types of sheep. However, work on the Romney has been so occupied with fibre types and their meanings that this important method of wool research has been necessarily neglected.

Despite the above difficulties, comparisons were made between the Curly-tip populations of Plateau and the Truncated

Valley and Plain Arrays of the Wensleydale and Stud Romney Hoggets. The Curly-tip fibres were for this comparison expressed as a percentage of the total array population and comparisons were made between these percentages. From these the following results were obtained :

	Plateau Arrays.	Wensleydale	Stud. Romney Hgts.
Mean (Curly-tips as % of the total array population).	40%	74%	67%
Coefficient Variation	14.0	18.6	20.4
Standard Error	1.17	2.91	5.6
Standard Deviation	5.6	5.6	13.74

From the above it is apparent that the Wensleydale and the Stud Romney Hoggets are not significantly dissimilar but both are significantly different from the Plateau Arrays. This is due to differences in the Histerotrich populations, (see later) and is, therefore, of importance in the study of the mode of growth of the fleece in relation to the development of new fibres with consequent variations in fleece density before and after birth. Thus it appears that in Plateau the follicular development at birth is less complete than in the finer more heavily checked arrays of a Truncated Valley or Plain. This is understandable in the light of Galpin's work (22) as it is compatible with a lack of pre-natal follicular density in the Plateau and a heavy follicular density in the Truncated Valley and Plain Arrays typical of the Wensleydale and the Stud Romney Sheep. The above appears to throw some light on the type of follicular development responsible for these particularly fine Truncated arrays as it appears possible that the development of the follicles may take place relatively late but that when development does commence it may be that the follicles are added quickly and without a break in continuity. This would presumably be due to the trio and nine stage follicles being difficult to distinguish pre-natally in fine material, or perhaps to a high initial density of the primary follicles. In the light of Galpin's work it is considered that a combination of the two is most probable.

S U M M A R Y.

1. Reference is made to Dry's descriptions of Curly-tip fibres and the general similarity between Curly-tip fibres in Plateau and other Arrays is pointed out.

2. It is concluded that pre-natal tip form of Curly-tip fibres is largely influenced by pre-natal medullation.

3. The tip form of Curly-tip fibres in Plateau Arrays with a close association between Halo-hairs and Curly-tip fibres is described and it is suggested that these fibres may develop in trio stage follicles.

4. It is suggested that tip form may be dependent on period of development and evidence is presented in support of this.

5. It is considered that in a study of tip form in relation to fibre types these very coarse Curly-tip fibres will merit considerable attention.

6. The range of variation within and between Plateau Arrays is particularly wide.

7. It is concluded on evidence from both Plateau and other arrays that the presence of complete curls is associated with medullation of Curly-tip fibres and position in the array rather than on kind of array.

8. From observations on stud Romneys, Wensleydales and Merino samples it is concluded that the complete curls found in these arrays are due to a compression of a spiral tip.

9. It is considered that pre-natal curl may be an indication of post-natal happenings.

10. Dry's generalisation that there is a correlation between pre-natal crimp and fibre coarseness was supported by classifying Wensleydale arrays for fibre coarseness by tip curl alone.

11. Unevenness of wave length and amplitude in the Plateau array were found to make pre-natal crimp classification difficult.

12. It is concluded that variations in frequency and amplitude of neck crimps is in part a peculiarity of the animal as distinct from coarseness.

13. Crisis thinning as described by Dry in arrays other than Plateau is found to be comparable with observations in Plateau.

14. Width of crisis thinning appeared to be associated with distance along the array. Those fibres closely associated with shed fibres had narrow crisis periods.

15. Crisis thinning and shedding appear to take place at a similar time - at about three months of age.

16. From observations on samples from pet lambs it is concluded that weaning and therefore possible environmental conditions as a whole may be neglected as a cause of crisis thinning.

17. A thinning previous to that typical for the crisis is described for some lambs and the difference between the typical crisis and this environmental check are described.

18. Observations on Side and Britch Positions suggest that shedding and crisis thinning may be related.

19. Possible causes of crisis thinning are discussed and the growth of Histerotrichs is not considered to be a cause.

20. An array is quoted and discussed in which there appears to be a relation between crisis thinning and "break".

21. Two types of normal shedding are figured and discussed.

22. Examples of smoky shedding are figured and its occurrence is discussed.

23. It was found possible to trace a grading from smoky to normal type shedding. The implications of this in relation to the causes of shedding are discussed.

24. Difficulties in assessing Curly-tip population are described and the need for density measurements are discussed.

25. The abundance of Curly-tip fibres are expressed as a percentage of total array population.

26. Plateau, Stud Romney and Wensleydale samples are compared as to Curly-tip abundance and significant differences are found between Plateau and the other types. The implications of this in relation to the pre-natal check are discussed.

HISTEROTRICH FIBRES.

These fibres have been defined by Dry (unpub. paper) as "any fibre not the successor of a shed fibre, beginning to grow later than the Curly-tip fibres, from which they are distinguished by not possessing well marked and even curls at the apical ends". Thus it is apparent that the tip form of these fibres is of extreme importance as regards their classification and Dry in concluding that this difference in tip form is closely connected with birth, quotes evidence obtained from dyeing lambs shortly after birth to show that if not grown entirely after birth then "only the earliest of these fibres protrude from their follicles a little before birth". Therefore, although these fibres play an important part in the fleece when it is regarded as an entity, they do not affect the judgment of an array. This is an important concept as it demonstrates that any variation in the numbers of Histerotrichs between arrays can be taken as a function of these arrays.

The above classification as defined by Dry, is, however, not as clear cut as it would appear from the definition. In a previous section on Curly-tip form (page 79) it is apparent that the tips of the Curly-tip fibres vary considerably as to the degree of curl. Further, the statement was made that the further the Curly-tip fibres from the pre-curly tip portion of the array, the less definite the curls become and the nearer the fibres approach the Histerotrichs in macroscopic structure.

Thus it is apparent that the classification of the Curly-tip and Histerotrich fibres is often by no means easy and when it is remembered that the Curly-tip form in the Plateau Array is particularly weak, it is apparent that a definite distinction between Histerotrichs and Curly-tip fibres becomes particularly difficult. It is in an endeavour to obviate this difficulty of classification between these two fibre types that many comparisons between fibre numbers have been calculated on the total numbers of Histerotrichs and Curly-tip fibres.

When the similarity between Curly-tip and Histerotrich fibres is studied in the light of the fact that, with few exceptions (see Curly-tip form, page 78) the amount of curl is an indication of fibre age it is apparent that in many animals there can be little if any break in the founding of follicles about the time of birth. In discussing this, in an unpublished paper, Dry quoted animals which has grown particularly badly, as having a break in continuity between the Curly-tip and Histerotrichs. This break has on occasion been found in animals in the present material but it has been concluded that it was due to a delayed precipice, (see Precipice) and not particularly associated with poor growth.

The reason for concluding that the break in continuity between Curly-tip fibres and the Histerotrichs is not the result of the environment is that lambs 68.5 II Ravine and 36.5 I Valley showed a very distinct discontinuity but, from weight data, grew particularly well and definitely better than the average. This is evident from the following :-

Weight gain per day of the low grade lambs	(21 lambs in all)	= 4.1 oz
" " " " "	lamb 68.5	= 5.5 "
" " " " "	lamb 36.5	= 5.1 "

The above weighings were made about 230 days from the date of birth, theexact period varying with the date of birth. Further, in the light of the above, it is notable that difficulty was experienced in classification in animals which grew somewhat badly. However, in the material studied there were no animals that grew as badly as those studied by Dry. It thus appears that there may be a threshold effect in relation to environmental influence on the distinction between Histerotrichs and Curly-tip fibres. Although this is not more than a suggestion, it is put forward the more readily because recent (unpublished) statistical work by Dr. P.R. McMahon makes it prdable that non-genetic factors are more important than was realised in determining the degree of non-kemp hairiness. The attention of workers in the College, more interested in heredity, has thus been forcibly directed to environment, with special reference to developmental events before birth or in the young lamb.

Despite this general lack of association between the Histerotrichs and the Curly-tip fibres it is notable that the 'birth check' may have a distinct effect on the Curly-tip, Histerotrich relationships. It has previously been noted that the effects of birth on the coat of the lamb may be responsible for the frequent thinning followed by a sudden thickening of the fibre, typically exemplified by the Super-sickle A- fibres. Thus in the light of Dry's findings regarding the environmental effects on the Curly-tip- Histerotrich associations, it may be that this checking force is effective in permitting a distinction to be made between the 'low' end of the Curly-tip series and the Histerotrich fibres. If this is so, one would expect to find a lack of relationship between Curly-tips and Histerotrichs in fibres showing a considerable number of Super-sickle A- fibres. On studying such arrays, however, this was not found to be the case and in some arrays fibres judged on tip form to be Histerotrichs were found that were distinctly larger than some Curly-tip fibres.

Thus it appears that although this checking force is sufficiently effective to cause some Curly-tip fibres to be distinctly checked in length and also probably some Histerotrichs it is of insufficient intensity to cause a break in continuity at birth. Further, in the light of the exceedingly chalky immediate post-natal region of many Super-sickle A- and Curly-tip fibres, it may be that the acceleration of growth that this suggest is sufficient to cause some Histerotrichs developing shortly after birth and thus presumably not affected by the birth check, to be actually longer than these fibres that grow immediately prior to birth.

This may well be a further effect of that check (page 66), which is postulated as being the result of the change in environment of the lamb at birth. That this check is particularly important in the necks of the Super-sickle A- fibres has been noted already (page 56), and in again drawing attention to the importance of this environmental change tribute must be made to Duerden who, first pointed out the possible importance of birth in relation to fibre form.

Thus in the light of the above it is apparent that length measurements cannot be relied upon to distinguish between those fibres which develop before and those fibres which come after birth.

An example of such an array, where some Histerotrichs were definitely longer than some of the Curly-tip fibres, is that of sheep 904, Grade VI!, a weak Plateau :

	H.H.	S.S.A.	S.S.A-	S.S.B.	S.	C.T.	Hist.
Shed.	31	0	8	0	0	0	0
Pers.	0	0	9	14	3	372	320

It is apparent from the above array that there is an unusual number of Super-sickle A- and Super-sickle B fibres, while there is a complete absence of Super-sickle A fibres. Thus it appears from the above analysis that there is a distinct break in continuity between the Halo-hairs and the Super-sickle A- fibres, and this break is amply evident when the macroscopic appearance of the fibres is studied. It is, therefore, postulated that the birth check has been particularly heavy in this animal. Thus it is considered that this animal lends very definite support to the above discussed postulation that the 'birth check' can effect the length of fibres and thus fog the clarity between the Histerotrichs and the Curly-tip fibres.

In some cases the Histerotrichs appear quite distinct from the Curly-tip fibres due to a lack of intermediates between the two fibre types. This lack of intermediates is particularly noticeable in the Back sample of the Wensleydale sheep H.20, which has the following analysis.

Sheep H.20 Bk. Plain Array.

Sickles	Curly-tips.	Large to Medium Hist.	Medium Hist.
10	177	33	138

To this array the following remarks have been appended "The Curly-tip fibres over the greater part of the series have distinct apical curls but these become less distinct as the Histerotrich end of the series is approached. Intermediates between the two types are found, but these are scarce. There appears to be an abundance of what may be termed medium sized Histerotrichs with but a few fibres that are sufficiently large to link them with the Curly tip fibres".

Thus it is apparent that the Histerotrichs, from the macroscopic structure of their apical ends, present distinct difficulties in definite classification. However, it is considered that with practice and the exercise of care, it is improbable that the errors of classification except in a few unusual arrays are particularly great. The accuracy of classification is apparent when stored samples are studied and compared with analyses that were completed some considerable time before. When this is done the counts were found to be remarkably similar and the description of the tip form in the two samples was found to be almost identical. In this respect the following duplicate samples are notable.

Sheep	H.H.	S.S.A.	S.S.A-	S.S.B.	S.	C.T.	Hist.
59.5 VI!	27	2	0	1	0	200	190
59.5 Plat.	36	5	1	0	0	261	237
78.5 VI!	36	3	7	5	0	194	238
78.5 Plat.	51	6	5	1	0	305	409
1404 VI	13	3	6	17	24	332	400
1404 Saddle	69	17	30	36	14	1495	1935
56.5 II	0	0	0	0	16	156	179
56.5 Ravine	0	0	0	1	12	150	187

The arrays that are most liable to error are those that have medullation extending into the Histerotrichs without a pause in intensity. This is not surprising in view of the remarks regarding the perfection of the curled tip of of some of the hairy Curly-tip fibres (page 78).

It is, however, clear that accuracy of classification is increased by comparing animals at the same period. In relation to the choice of this period it is obviously important to be certain that the development of the new follicles is complete and therefore it is important to study the development of Histerotrichs for this, if for no other reason.

That in the absence of superimposed checks fibre robustness grades off evenly from the earliest to the latest developing follicles, is one of the basic concepts of hair growth and is fully supported by the knowledge of the growth of the fleece. Thus it is apparent that the Histerotrich fibres that are the last to develop will be the least robust of all fibres in the array and it would, therefore, appear that general appearance is an efficient criterion of period of development. However, Histerotrichs are usually fine throughout the series and it is, therefore, difficult without tedious measurements to distinguish between the fibres on the score of coarseness. Length determinations, therefore, come to be relied on almost exclusively.

The Histerotrich series is, however, merely one section of the total fibre series and therefore wide variations in growth rate cannot be expected and are not found. This is evidenced by the fact that when Histerotrichs in samples taken some months after birth are studied there is,little difference in fibre length and negligible difference in fibre diameter.. Therefore, in the light of the above it is felt that there is sufficient justification for supposing that when very small Histerotrichs are found, development of these follicles is still taking place, or conversely, when the shortest Histerotrichs are a reasonable size - at least one cm. in Plateau - it may be assumed that development of Histerotrich follicles had ceased when the sample was taken.

There are, however, certain limitations in judging the period of development of Histerotrichs by the above method, as it is probable that there is a minimum size of fibre that is retained in the cut sample. The exact size of this minimum will vary with the type and the condition of the wool. Thus smaller Histerotrichs have been found in Wensleydale than in the Romney perhaps not because the growth of Histerotrichs in the Wensleydale is continued later than in the Romney but because the Wensleydale tends to have a less free type of staple than the Romney and thus is probably more retentive of short Histerotrich fibres. A similar type of variation is probably found within the Romney sheep.

It is doubtful whether this retentive power can be associated with arrays, as very small Histerotrichs have been found in Plateau which, from the abundance of G4 kemps combined with the usual general heavy medullation of the persistent pre-curly and Curly-tip fibres, would be expected to have the type of open fleece sample facilitating fibre loss. Thus it would appear that proneness to loss may be a function of the lack of medullation combined with density and yolk secretion. In the Wensleydale, in which the smallest Histerotrichs are not uncommon these three factors appear to operate for their retention, but in the N-type they are never found combined, and thus in the Plateau Arrays due to the possible loss of the smallest fibres it becomes more difficult to judge whether follicular development has ceased or was still taking place when the sample was taken.

In the light of the above, observations were made on many arrays in an endeavour to ascertain when Histerotrich development ceased or, in other words, at what stage in the early life of the lamb the addition of new follicles was completed. From these it was found that there appeared to be no regular rule in relation to fibre types or array fineness. Thus in the following assortment of arrays Histerotrich development appeared to be complete approximately ten weeks after birth.

Sheep 96.5 Grade II Valley. Medullation about half-way along the Curly-tip Series.

H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	Hist.
1	2	1	1	31	239	223

Sheep 76.5 Grade VI! Weak Plateau.

H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	Hist
56	26	16	16	4	291	349

Wensleydale, H.23 Back. Plain Array.

Sickles	Curly-tips	Histerotrichs.
6	369	223.

In contrast the following arrays sampled on the same day as those quoted above and approximately the same age have extremely small Histerotrichs present and were thus assumed to have only recently completed follicular development or perhaps even to be still adding new follicles. In relation to the similarity of ages between these contrasted sheep it is to be noted that Dry's lambs were numbered consecutively as to their birth dates.

Sheep 92.5 Grade II Valley, Medullation about half-way along the Curly-tip Series.

H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles.	C.T.	Hist.
0	0	0	1	34	199	62

Sheep 78.5 Grade VI! Plateau.

H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	Hist.
87	9	12	6	0	534	622

Wensleydale H.15 Back. Plain.

Sickles.	Curly-tips.	Histerotrichs.
9	591	112

Thus it appears that there is a certain individuality between sheep as to when the follicles cease to develop. Whether this apparent individuality is connected with density or not is unknown but density determinations with this in view may prove illuminating in that they may show that development proceeds until a certain optimum is reached. On the other hand it may be that follicular development continues until the animal becomes "mature" when it ceases regardless of the density then reached.

In the above, Histerotrichs appear to be considered to develop in new follicles presumably not associated with previous follicles except as a portion of a grouping, say a 27 stage (Galpin 22). In relation to this work was carried out by dissection and later by sectioning. This work elicited the fact that at least some Histerotrichs develop after birth in daughter follicles, but due to the fact that considerable difficulty was experienced in distinguishing between true daughter follicles and those growing in close proximity, time proved too short for answering the detailed questions which naturally present themselves. A special investigation covering the complete hogget year is required.

Variations in Histerotrich Density.

It has been suggested and evidence has been presented that in the Plateau Array follicle development is retarded so that in the absence of excessive competition from other nearby follicles those that do develop are permitted to fully express their potentialities. If this is so and if Plateau Arrays are not less dense than the other more heavily checked arrays then it would be expected that the Histerotrichs which commence development post-natally and therefore are unlikely to play a part in the pre-natal check would be more numerous than in other more heavily checked arrays. To provide evidence for or against this, Table III (see also appendix I) has been appended to show the concentrations of the Histerotrichs. In the compilation of this Table care was taken to compare animals of a similar age on samples that were taken when there is reason to believe that all Histerotrichs have completed development.

The Histerotrich population has been expressed as a percentage of the total fibre population in the respective arrays.

This has been done in order to make clear that the array must be looked on as an essentially complete whole, and to further stress that growth of Histerotrichs must be regarded as the last act of completion of an essentially continuous follicular development starting early in the life of the lamb (Galpin 22) and continuing into a definite post-natal period. Whether there is a further development of fibres later than those considered to come under the heading of Histerotrichs is unknown, but it appears to be doubtful in the light of analyses made on the full fleece where no new fibres have been found.

TABLE III.

Array.	Mean.	Standard Error.	Coefficient of Variation.
Plateau	51.43	1.31	12.26
Saddle	42.29	4.39	27.51
Valley	31.11	2.49	24.02
Wensleydale (truncated Valley)	20.6	3.0	65.75
Romney Stud Ewe (truncated Valley)	20.17	4.6	55.99

Histerotrich fibres expressed as a percentage of the total fibre population.

From this table it appears that there are wide differences in Histerotrich concentration within arrays but that Plateau Arrays, despite the fact that they are not significantly different from the Valley Arrays, tend to have more Histerotrichs than the finer non-Plateau Arrays. As regards the Saddle Arrays, it is notable that these also are not significantly different from the Plateau Arrays. However, the fact that most of these Saddle Arrays are from closely related animals prevents them from being considered as a reliable sample and, therefore, they may not show the true position of the Saddle Arrays in general. However, despite this the fact remains that wide variability was found between samples. It may be that in the light of the wide variations in Halo-hair grading that occur that the Saddle Array can be regarded as a weak Plateau in some cases, and a medullated Plain in other cases, and thus wide variation would be expected. A similar viewpoint can, it is considered, be extended to explain the variations occurring within the Valley Arrays.

In relation to the Wensleydales, it is notable that some sheep have exceedingly few Histerotrichs and from fibre form appear to have completed fibre growth. However, other have many small Histerotrichs present and these have been included in the otherwise random arrays used as it was considered that the figures would otherwise lead to erroneous differences between array types.

It is notable that the Coefficient of Variation varies considerably on a high level from array to array, the lowest being for the Valley and the Plateau Arrays, the highest being found in the Saddle, Wensleydale and the Stud Ewe Hoggets. This high Coefficient of Variation in the Saddle Arrays is easily understandable from the reasons advanced previously, in that the Saddle Array is capable of obvious variation but it is less easy to understand in the arrays of the Wensleydales and Stud Romneys where the arrays were very similar in all features other than Histerotrich numbers. An explanation of this is not attempted, except to suggest that the abundance of Histerotrichs may be due to a general lateness in fibre development. If this is so, and if there is no apparent precipice, as appears to be the case then, with reference to an argument treated more fully later (pg. 147) it may be that follicular development starts late in the life of the lamb and continues evenly at a pace sufficiently rapid to cause the array to be checked. Here the initial late start in development would necessitate large numbers of Histerotrichs for 'normal' follicular density to be attained. This is particularly noticeable in the Wensleydales where, although many arrays were found which had virtually no Histerotrichs, a few had quite appreciable numbers. In both these extreme types the arrays are very regular and there did not appear to be any precipice.

While considering the Histerotrichs in the Plateau Arrays it may be desirable to discuss some arrays as individuals. Throughout this whole thesis there has been an endeavour to study the detail of particular animals and to relegate averages to the background. This outlook has been, as pointed out previously, the guiding principal of Dry's work and it is therefore considered to be not inappropriate to apply the same type of outlook to the study of Histerotrich numbers in the Plateau Array.

From Table III it is apparent that considerable variations occur in Histerotrich populations within the Plateau Array. The extremes are Sheep 29.5 with the least, and sheep 1280 with the most (see Appendix I). For these the complete analyses are as follows :

Sheep.	H.H.	S.S.A.	S.S.A-	S.S.B.	S.	C.T.	Hist.
29.5 VI!	15	7	5	7	4	266	224
1280 VI!	27	13	16	4	1	180	436

These arrays exhibit from both their fibre type associations and their numbers a considerable check and would actually be placed close together in respect to array "toughness" (pg. 123). Thus it is apparent that the check cannot be regarded as important in relation to the Histerotrich concentrations in the Plateau Array.

These two arrays have, however, a point of difference in the presence of a distinct precipice. This precipice is particularly noticeable in Sheep 1280 where two such breaks, one within the Curly-tip series and one within the Histerotrich series, were thought to exist. In the early sample from this animal the bulk of the Histerotrichs appear as a distinct undercoat virtually unconnected with the Curly-tip and Histerotrich-near-Curly-tip fibres. This undercoat effect was less noticeable in a later sample. Similarly in odd Wensleydale samples which had appreciable numbers of Histerotrich fibres this lack of association appeared.

That the precipice is not a complete explanation is, however, plain from Sheep 1327, a "tough" Plateau with a distinct precipice but with relatively few Histerotrichs. The analysis of this animal is :-

Sheep.	H.H.	HS.S.A.	S.S.A-	S.S.B.	S.	C.T.	Hist.
1327 VI!	27	6	0	0	0	250	245

In this array it is notable that despite the fact that the Histerotrichs are dense in relation to the Curly-tip fibres, the addition of the pre-Curly-tip fibres reduces the percentage to 45%. Thus it may be that the work on the concentration of Histerotrichs must not neglect the numbers of pre-Curly-tip fibres. Actually in the Romney it appears as if this does not play an important part. Thus when the Plateau and Saddle Arrays are compared it is found when the pre-Curly tip fibres are neglected, and the Histerotrichs expressed as a percentage of the Curly-tips, that the concentration of these fibres are comparable between some Saddle and Plateau Arrays. Thus :-

Plateau.				Saddle.			
Sheep	C.T.	Hist.	Hist.%*	Sheep	C.T.	Hist.	Hist.%*
58.5	404	348	86	68.5	310	79	26
59.5	200	190	95	29.5	143	194	136
73.5	534	622	116	1343	224	198	88
76.5	291	349	120	1278	228	162	71
77.5	327	374	114	1404	332	400	120
18.5	280	445	159	1307	162	179	110

*Hist. % = Histerotrichs expressed as a percentage of Curly-tip fibres.

From the above it is clear that the concentration of Histerotrichs expressed as a percentage of the Curly-tip fibres, makes it appear that the Histerotrich concentrations in Saddle Arrays may be similar to those of Plateau, but that the concentration reaches higher limits in the Plateau than is possible in Saddle, while lower concentrations are possible with Saddle than in Plateau Arrays.

Possible reasons for this excess of Histerotrichs in the Plateau Arrays have been considered and no satisfactory explanation has been found. Any speculation as to their importance of differential growth rates as, for example, supposing that the early development of follicles is retarded in Plateau thus necessitating much late development, appears to involve an assumption of a specific individual follicular density for such animal. It is, however, considered that such a speculation, while pointing out a very grave gap in our knowledge of the growth of the fleece of the sheep, is at present totally unsupported by facts and cannot therefore be seriously introduced as a basis for argument.

SUMMARY.

1. Dry's definition of Histerotrichs is quoted and it is pointed out that the Histerotrich fibres do not effect array classification and, therefore, any consistent variation in the numbers of Histerotrichs between arrays can be regarded as a function of these arrays.

2. Difficulties of distinguishing between Histerotrichs and Curly-tip fibres are described and the importance of intermediates in relation to continuity of fibre growth is discussed.

3. Animals in which discontinuity exists between Curly-tip and Histerotrich fibres are described and from weight data it is concluded that a threshold of enviromental effectiveness may exist.

4. It is concluded that length measurements cannot be relied on to distinguish between those fibres which develop before and those fibres which develop after birth.

5. Examples of duplicate analyses are given which show that despite difficulty in exact differentiation, classification is relatively accurate.

6. Histerotrich length is regarded as an indication of earliness of growth due partly to difficulty of classification on fibre diameter.

7. The retention of very small fibres in the sample is discussed and it appears to be due to factors other than array type.

8. From arrays which are quoted it is concluded that there is a certain individuality between sheep as to when the follicles cease to develop. The implications of this are discussed in relation to follicular development and density.

9. Dissections and sectioning elicited the fact that at least some Histerotrichs develop after birth in daughter follicles.

10. A table summarising comparisons between Histerotrich numbers in Plateau, Saddle, Valley, Wensleydale and Stud Ewe samples is presented and discussed.

No significant difference was found between Plateau, Saddle and Valley as regards concentration of Histerotrichs.

12. The Coefficients of Variation for the array types are discussed.

13. Plateau Arrays are quoted from which it is concluded that the check cannot be regarded as important in relation to the Histerotrich concentration.

14. Differences in Histerotrich concentration when expressed as a percentage of the Curly-tip Fibres are discussed for Plateau and Saddle Arrays.
