

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

A STUDY OF THE PLATEAU ARRAY.

VOLUME II

1522

1522

1522



MASSEY AGRICULTURAL COLLEGE  
LIBRARY

PALMERSTON NORTH. N.Z.

Number	Class	Location
17356	2200	Thesis
	Sub	Sub

### SECTION III

Page

#### THE PLATEAU ARRAY

##### Introduction

The Fibre type arrays of the Romney Marsh  
lamb

117

(a) Plateau

(b) Saddle

(c) Ravine

(d) Valley

(e) Plain

(f) Escarpment

(g) All in

Intermediate arrays

119

The Plateau Array

119

Summary

122

#### TOUGHNESS IN THE PLATEAU ARRAY

The judgement of toughness within the Plateau  
Array

123

A. The number of fibre types present

124

B. Associations between fibre types with  
special reference to those fibres  
which are intermediates

125

C. Freedom of Shedding in the Plateau  
Array and its importance in regard  
to the judgement of toughness

128

Summary

#### FEATURES ASSOCIATED WITH TOUGHNESS OR WEAKNESS IN THE PLATEAU ARRAY

A. The abundance of the Super-sickle A  
fibres in relation to the Halo-hair  
numbers

142

	Page
B. The presence of distinct break or precipice in the continuity of the Curly-tip fibres	148
Summary	
<u>THE FORCES AT WORK WHICH PLAY AN IMPORTANT PART IN THE DETERMINATION OF THE ARCHITECTURE OF THE FLEECE</u>	162
Summary	174
<u>IN-PARALLELISM IN THE PLATEAU ARRAY</u>	176
Summary	180

SECTION IV

	Page
<u>THE GENETICS OF THE N-TYPE COAT AND HORNS</u>	181
Introduction	181
The expression of the N-factor	182
<u>HORNS</u>	
Introduction	183
The inheritance of horns	184
Phenotypic expression	184
Genetics	187
Summary	204
<u>THE INHERITANCE OF THE N-TYPE COAT</u>	205
Summary	222
Sire 735	223
Summary	232
Sire 1059	233
Summary	238
<u>GENERAL SUMMARY</u>	239
<u>ACKNOWLEDGEMENTS</u>	
<u>BIBLIOGRAPHY</u>	
<u>APPENDIX A</u>	

Plateau Array analyses in order of toughness

SECTION III.

THE PLATEAU ARRAY.  
=====

INTRODUCTION.

In the previous section the fibre types found in the Romney have, except for the Sickle fibres, been treated fairly completely. In this treatment it has been necessary on occasion to anticipate a description of the Arrays. Thus it is that the present brief description of the Arrays recognised and described by Dry (19) tends to be a repetition of what has gone before. However, despite this it is considered that for completeness these arrays should be described in brief as it has been found necessary both in relation to the descriptive and the genetical section of an account of the Plateau Array to discuss at length the types of Non-Plateau Arrays and their relationships both to each other and to the Plateau Array.

The Fibre Type Arrays of the Romney Marsh Lamb.

The Arrays as recognised and defined by Dry (1) in order from the least to the most checked are :-

Plateau.  
Saddle.  
Ravine.  
Valley,  
Plain.

With these are included two unusual arrays also described. These are :-

All In.  
Escarpment.

Plateau:

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

Saddle:

An array in which chalky Sickle fibres are found but in which there is a complete or almost complete lack of Sickle fibres fine after birth. This array also depends on the absence

of a fibre type - namely fine Sickles - and is dependent for its reality on the supposition that events happening pre-natally - the check - can effect fibre growth taking place post-natally. This point will be dealt with later and is of considerable importance in the study of the architecture of the fleece.

Ravine:

An association of fibres in which fine Sickles but no checked Curly-tip fibres are found. This definition anticipates the definition of the Valley Array.

Valley:

An array in which the pre-natal check has been of sufficient intensity and duration to give fine Sickle-fibres and checked Curly-tip fibres, these latter, followed later in the array by Curly-tip fibres that are definitely more robust.

Plain:

An array in which there is little or no increase in coarseness from the fine Sickle fibres to the Curly-tip fibres.

Escarpment:

Recognised and described by Galpin (22) who found it confined to the Poll except for one animal, where it occurred on the Britch. In this array there are Halo-hairs and Chalky Super-Sickle fibres present but no Sickle fibres and no chalky Curly-tip fibres. There is thus a very marked and unusual break in continuity of robustness along the array.

All In:

Described by Dry (19) as having a transition from small ended chalky Sickle fibres to Chalky Curly-tip fibres. Shedding of these fibre types is particularly free in the relatively small number of lambs studied. Together with the above Saddle characteristics there are superimposed Valley characteristics. These are an association between large and small ended fine Sickle fibres and a small number of checked Curly-tip fibres.

All these arrays have been described by their essential fibres and those types developing previous to these essential fibres, for example, the Super-sickles and Chalky Sickle fibres may or may not be present in the Valley Array. If they are absent

the array may be termed "truncated". This term is usually reserved for the Valley Arrays, in which arrays this truncated condition is most common. In a truncated Valley Array the first fibres found are fine Sickle fibres.

#### Intermediate Arrays.

Intermediates do occur but these are relatively unimportant due in the main to their scarcity. The intermediates are more prevalent in the heavier checked arrays, that is, Valley and Plain, than between the less checked arrays, Plateau and Saddle. This appears to be due to the general low plane of medullation in the former resulting in a lack of fibre individuality with consequent difficulties of classification. The question of intermediates will be dealt with in more detail later.

#### The Plateau Array.

From the above it is clear that the Plateau Array is the least checked of all the arrays. It has, from the definition, no Sickle fibres but, from the Fibre type Section it is apparent that although the Sickle fibre is the type showing a definite check it is not peculiar in this respect. The Super-sickle B fibres are often closely related to the Sickle fibres, while even the Super-sickle A- fibres may show a very distinct neck thinning but without loss of chalkiness.

Thus the definition of the Plateau Array depends on the presence or absence of one fibre type only, whereas the Super-sickle fibres showing definite check characteristics do not effect the classification. It is clear, therefore, that there is a wide variation within what may be termed the "Plateau Array Series".

In the study of the Plateau Array a theoretical objective of which is to decided how much variation in characterization is due to variation in what may be termed the 'inherent coarseness' and how much to variation in the intensity of the pre-natal check, it is clearly imperative to study the various grades. The study of these grades is complicated by the fact that there appears to be no sharp distinctions within the array. Intermediates of all types can be found and thus any attempt to classify the Plateau series

into distinct grades or to recognise a new array does not appear to be warranted.

The difficulty is not due to intermediates between fibre types but rather is it due to variation in the concentration of fibre types between arrays, in other words fibre population rather than the macroscopic appearance of the individual fibres. This is clear in the Plateau Arrays that are quoted below which represent three types, closely related by intermediates but nevertheless arrays in which there was little difficulty in fibre classification.

<u>Sheep.</u>	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist</u>
71.5	11	19	3	12	40	280	186
62.5	35	32	17	13	14	324	503
1402	45	25	29	14	88	445	570

From the above it is apparent that it is impossible to recognise a further array within the definition of Plateau dependent on the abundance of Super-sickle A- and Super-sickle B fibres. The implications that may be drawn from the variations between these two fibre types are treated fully later under the heading of 'Variations in the pre-natal check'.

There is one possible exception to the above, and that is the possibility of a definite super-Plateau Array, an array in which there are no Super-sickle A- or Super-sickle B fibres. This type of array is scarce but appears to have less intermediates than array types based on either of these two fibre types separately. Even in this classification intermediates exist and the ideal together with intermediates is linking it with other Plateau Arrays is figured below :

<u>Sheep</u>	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>S.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
1327	56	13	0	0	0	173	331	247
59.5	54	5	0	1	0	98	342	331
1238	41	5	10	0	0	84	190	380
62.5	35	32	17	13	0	14	324	503
76.5	56	26	16	16	4	139	182	349

Thus it becomes apparent that an indefinite grading within the Plateau 'series' is the most, satisfactory type of classification. The Plateau Arrays have, therefore, been classified not as separate and distinct sub-arrays but merely into what has been termed, the "Degree of Toughness". This takes into account the relative numbers of fibre types and is not dependent on any strict presence or absence of a particular fibre type as are the arrays and thus it indicates the effects of an apparently continuously variable check within the wide Plateau classification.

---

S U M M A R Y.  
=====

1. The fibre type arrays found in the New Zealand Romney Marsh lamb are briefly described.
  2. Intermediate arrays are briefly discussed.
  3. It is pointed out that due to its definition and standards of judgment, wide variation is possible within what is termed the 'Plateau Array Series'.
  4. The variations within the Plateau classification are essentially continuous and arrays are quoted to show that variations appear to be due to an interaction of an apparently continuously variable check.
  5. The term "toughness" is used to designate the degree of effectiveness of check in the Plateau Array.
-

TOUGHNESS IN THE PLATEAU ARRAY.  
=====

As explained, the degree of toughness in the Plateau Array is the measure of difference within the array and the arbitrary practice is to term that array which shows the least amount of check, that is, the array with the closest association between the Halo-hairs and the Hairy-tip-Curly-tip fibres the toughest and the array most nearly approaching non-Plateau, the least toughest or the weakest.

The degrees of toughness are by no means capable of particular expression numerically and consist merely of a handy term to distinguish arrays when more than one is being discussed, or to distinguish between a particular array and what has come to be regarded as the average or typical Plateau Array. This latter is purely a judgment of experience and although capable of expression by relative numbers of fibre types constituting the array it is essentially a wide average. Despite this fact the concept of toughness is a valuable one as it permits the easy recognition and facilitates reference to arrays that are regarded as extremes within the Plateau series.

The Judgment of Toughness within the Plateau Array.

In judging the degree of toughness within the array certain points have come to be regarded as of importance. There is, however, a difference within these points in that some provide the criteria by which the array is judged while others appear to be associated with toughness or weakness.

In the following enumeration these two relatively distinct associations have been separated.

- A. Criteria of judgment of toughness of the Plateau Array.
- (a) The number of fibre types present or the simplicity of the arrays.
  - (b) Associations between fibre types with special reference to those fibres that are intermediates.
  - (c) The freedom of shedding in the pre-curly-tip fibres and the extent to which shedding is extended into the Curly-tip series.

B. Features of the Plateau Array associated with toughness or weakness as judged by the above criteria.

(d) The density of Super-sickle A fibres in relation to the Halo-hair concentration.

(e) The presence of a distinct break or precipice in the continuity of the Curly-tip fibres.

These points vary in importance and as they throw some light on the working of the "N" factor on the inherent capabilities of the animal they are treated below in order of enumeration.

A. (a) The number of fibre types present;

Although not the most important factor in determining the toughness or weakness of the Plateau Array this factor is of major importance. The fewer fibre types present in the Plateau Array the less the effects of the pre-natal check. The effectiveness of the check becomes more marked the further the pre-Curly-tip fibres deviate in macroscopic appearance from the Halo-hairs. Thus it is apparent that the fewer the Super-sickle B fibres present the less are the effects of the check and the closer does the array approach the ideal Plateau, or in other words the tougher the Array becomes. This condition is paralleled by the Super-sickle A fibres. However unless the Super-sickle A fibre type approaches the Super-sickle A- or the Super-sickle B fibres by having the check region weakly chalky the reduction is negligible.

The above applies to Plateau Arrays and is not applicable to other arrays. Actually it is perhaps not out of place to observe that this feature - the feature of the lack of fibre types - is in other arrays an indication of weakness. The occurrence of variations in the numbers of fibre types present is very interesting when applied to other arrays. When comparisons are made between arrays much

light is thrown on the working of the check as distinct from the inherent potentialities of the animal.

The effects are enumerated below under their respective Arrays. This discussion does not involve shedding which, although not unconnected is treated under the heading of "Shedding" (pg. 128 ).

#### Saddle Array.

In what may be termed the typical Saddle Array all fibre types are found, except the fine Sickle and Checked Curly-tip fibres. Thus in the following arrays of animals regarded as typical high grade Saddle Arrays it is apparent from the numbers of Halo-hairs present that they may be regarded as potentially Plateau animals on which there has been superimposed a check sufficient to cause the array to be classified as a Saddle Array.

<u>Sheep.</u>	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>Ch.S.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
1404	28	14	6	23	14	26	791	837
1246	23	2	4	2	40	11	290	208
1343	6	7	1	8	8		224	198
1252	11	0	2	4	4		209	182
85.5	63	12	24	7	36		625	255

This significance of this is discussed under the heading of 'the Genetics of the N-type Coat' (pg. 205). It is, therefore, sufficient to say here that this particular combination of checking force and inherent capability of the animal appears to have a definite genetic basis as Saddle Arrays similar to the above have been produced in breeding experiments, mating Saddle on Saddle.

A. (b) Associations between fibre types with special reference to those fibres which are intermediates.

It has been pointed out in the description of fibre types that intermediates are scarce. However, although scarce these fibres are of great importance in array classification in that they are indicators of associations between fibre types. It is notable that these intermediates are of a somewhat different type to those previously dealt with in this section as they are intermediates within, rather than between, arrays.

In the following array it is clear that the presence of intermediates between the Super-sickle A and the Hairy-tip-Curly-tip fibres, especially noticeable because of the difficulty of classification of these two fibre types, demonstrates that they are closely related. However, there is one Super-sickle B fibre present that does not resemble either of the above mentioned fibre types. This fibre has, therefore, been regarded as 'in Parallel' a concept of Dry's <sup>(unpub)</sup> and despite the presence of this Super-sickle B fibre the array is regarded as a tough Plateau.

<u>Sheep</u>	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>S.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
59.5	27	2	0	1	0	51	200	190

Arrays similar to the above, although uncommon, can be found. Further arrays of a similar nature are quoted below :

<u>Sheep</u>	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>S.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
18.5	31	8	0	1	1	51	200	190
750	23	8	0	2	1	52	233	
68.5Br.	15	26	0	4	0	44	280	119

From the above arrays, all regarded as tough Plateau despite the presence of Super-sickle B and odd Sickle fibres, it is apparent that the associations between the Halo-hairs, Super-sickle A, and Hairy-tip-Curly-tip fibres have played a major part in array appraisal. Fibres that do not fit into the above series as indicated by intermediates are regarded as 'in parallel' and thus are virtually neglected. This 'in parallel' concept appears to relegate variations in fibre type populations to a position of less importance than that of association between fibre types.

It may be remarked here that the necessity for the above conception is not the result of an arbitrary definition of an array or of an arbitrary distinction between fibre types but is a real effect - an effect that is based on unmistakeable associations between fibre types. These associations are occasionally so definite and close that considerable difficulty is experienced in their classification.

The Pre-Curly-tip break in continuity of fibre types in a tough Plateau Array although a common feature is not a feature that is absolutely associated with 'in parallelism'. Rather is it an expression of the fact than when 'in parallelism' is found the fibres affected are scarce. Thus in the following array fibres which are essentially 'in parallel' have been classified into Super-sickle A- and Super-sickle B.

Sheep 1279 VI! (D)

Halo-Hairs:

	Tips whole with Sickle shaped distal extremities.	8
	Tips broken with a number of crimps in the neck	<u>17</u>
	Total Halo-hairs	<u>25</u>
S.S.A.	Appear like small Halo-hairs	2
S.S.A-	Like complete H.H. except for the neck and tip	1
	Resembles H.T.C.T. with crimped neck	1
S.S.B.	Like H.T.C.T. with weak Sickle shaped tip	<u>1</u>
	Total Pre-curly-tip fibres	<u>30</u>
 Curly-tip fibres.		
	Very near Halo-hairs	3
	Hairy-tip-Curly-tip fibres near Halo-hairs	22
	Non-Hairy-tip-Curly-tip fibres	<u>131</u>
	Total Curly-tip fibres	<u>156</u>
Histerotrichs		186

In the above array in 'in parallel' fibres are of a somewhat different type to those of the previously described arrays in that they are linked with Halo-hairs or the Hairy-tip-Curly-tip fibres. However, they are essentially 'in Parallel' in that they are scarce and show less relationship to the Halo-hairs than do the Hairy-tip-Curly-tip fibres.

It is also apparent from the above analysis that the array is essentially a tough Plateau Array despite the fact that if classified on numbers of fibre types alone it would be regarded as a weakish Plateau Array due to the presence of both Super-sickle A- and Super-sickle B fibres. Thus it is that the fibre type associations must be regarded as of major importance in Plateau Array appraisal.

'In Parallelism as it occurs in the Plateau Array is dealt, with more fully under the heading of 'In Parallelism'. (pg. 171)

(c) Freedom of shedding in the Plateau Array and its importance in regard to the judgment of toughness.

It is the rule in the Plateau Array that shedding tends to be free. It is thus not unusual to find a large proportion of pre-Curly-tip fibres that persist. In some Plateau Arrays some pre-Curly-tip fibres do persist. Examples of such arrays are :-

	1278	1175	1308	(Saddle). 1404
Sheep				
Halo-hairs	17	18	21	13
Super-sickle A	14	2	10	3
Super-sickle A- n. shed	3	3	2	6
persistent	0	2	0	0
Super-sickle B n. shed	15	0	4	7
persistent	9	4	5	10
Sickles n. shed	3	0	1	2
persistent	2	3	4	22
Curly-tip Fibres				
Hairy-tip C.T. n. shed	0	0	2	
persistent		19	0	
Total Curly-tips		342	231	332
Histerotrichs		101		399

Such arrays, when judged by both fibre type association and numbers, are regarded as weak Plateau Arrays. Also all the arrays contain Sickle fibres which are in series with the Curly-tip and Super-sickle fibres. This latter is evidenced by the lack of Curly-tip fibres.

For comparison the following arrays, regarded as Tough, are featured.

Sheep	1327	1238	
Halo-hairs	27	41	
Super-sickle A	6	5	
Super-sickle A-	0	10	
Super-sickle B	0	1	
H.T.C.T.			
n. shed	11	73	
persistent	38	0	
Cutly-tip	250	274	11 C.T. normally shed.
Histerotrichs	245	380	

In these arrays it is apparent that shedding has been continued well into the Hairy-tip-Curly-tip fibres and in Sheep 1238 even chalky Curly-tip fibres, without medullated tips are shed "normally" (see page 93). Thus it would appear that there is a relationship between shedding and array toughness; tougher the arrays the freer the shedding, and conversely, the weaker the arrays the greater the density of persistent Super-sickles and the lower the probability of there being any normally shed Curly-tip fibres present in the array.

A further search of tough Plateau Arrays revealed an apparent exception - sheep 541:

	<u>Samples.</u>			<u>Sheep 905</u>
	<u>I.</u>	<u>II.</u>	<u>III.</u>	
Halo-hairs shed.	15	104	104	66
Super-sickle A shed	1	32	32	3
persistent	1	3	3	0
Super-sickle A- shed.	0		0	0
persistent	0		0	0
Super-sickle B				
Sickles	0		0	0
Hairy-tip C.T.		No Curly-tips counted.		
snokey shed	14			n. shed 17
persistent	23	Successors		pers. 62
Curly-tips	93	shed kemp	10	
Histerotrichs	x	medullated but persistent	113	
Successors		less hairy persistent	45	
G2.				

n. shed	5	Total	<u>168</u>
smokey shed	2		
persistent	<u>24</u>		successors <u>56</u>
Total	<u>31</u>		

Sheep 905 has been included in the above to demonstrate the normal type of Plateau Array with shedding free when there is a lack of Super-sickle fibres. This array is regarded as a very tough Plateau as it has an almost complete lack of Super-sickle fibres and also great difficulty was experienced in distinguishing the Hairy-tipped-Curly-tip fibres from the Halo-hairs. It is not surprising, therefore, that shedding is sufficiently free to be continued into the Curly-tip series.

When compared with the array of sheep 541 it is apparent that as regards fibre type numbers sheep 905 is not greatly dissimilar in array type yet the freedom of shedding in the two arrays is very dissimilar due to the absence of free shedding in the former. In this respect it must be noted that smokey (see page 30) shedding, which is extremely common in the Hairy-tip-Curly-tip fibres of sheep 541, is regarded as not comparable with that type of shedding which is normally found in chalky kemps. This is dealt with more fully elsewhere and it is sufficient to note that Rudall (24) obtained a similar fibre appearance in fibres which had been tugged. Thus in the above statement on the freedom of shedding in this array these 'smokily' shed fibres are neglected and are regarded as virtually persistent. Thus to sum up, sheep 541 appears to be a clear cut exception to the rule that free shedding accompanies toughness in the Plateau Array.

In a previous section it was noted that fibre type associations are of vital importance in array appraisal and it is therefore necessary to analyse this array in the light of fibre type associations as well as fibre type numbers. When this analysis was completed it was found that this array is a most unusual type of Plateau Array as, although there is an almost complete lack of Super-sickle fibres there is also a lack of intermediates as judged by macroscopic appearance between the Halo-hairs and the Curly-tip fibres. This makes any confusion virtually impossible in

classifying these two types. This array, therefore, must be regarded as a weak Plateau Array, an array which exhibits an early check which is sufficient to cause a complete break in the continuity of the Pre-Curly-tip fibres. This break is sufficient to cause the complete absence of all fibres prior to the Super-sickle A fibre type. This array appears to stress the importance of fibre type associations at the expense of the relative fibre type numbers, in that despite the absence of all the Super-sickles except a few Super-sickle A it is regarded as a Weak Plateau Array. The implications of this are important but they will not be discussed here as they are more closely related to the problem of 'in parallelism' which is treated later under its appropriate heading.

In relation to the converse effect, that is; that the weaker the array the greater the density of the persistent Super-sickle fibres and the lower the probability of there being any normally shed (see page 93) Curly-tip fibres present in the array, a study of the Plateau array in relation to other arrays is of interest. The following discussion has been largely confined to the relationship between Saddle and Plateau, other arrays which are less commonly associated with Plateau being largely neglected. This is due to the fact that in general the same remarks apply to these associations as to those between Plateau and Saddle.

If the above generalisation is correct it would be expected that the Saddle Array would have a complete lack of shed Curly-tip fibres and even the Sickles would not be expected to shed. For this discussion the Saddle Array is regarded as an extremely weak Plateau - a perspective which is somewhat different from that of Dry (19) who, of course, approached the Plateau Arrays from the finer, more heavily checked arrays. The relationship between Plateau and Saddle is, however, very close, and as has been pointed out previously, difficulty is sometimes experienced in array classification. There is thus some justification for the view that the Saddle Array may be regarded as a super-weak Plateau Array.

Thus it is apparent that the shedding situation in the Saddle Array is pertinent to the study of shedding in the Plateau

Array, regarded as a gauge to toughness in that array. If shedding of the Super-sickles is not free in the weak Plateau, as it would appear from previously figured arrays, one would expect a complete absence of normally shed Hairy-tip-Curly-tip fibres in the Saddle Array. This is not always the case, however, and it would appear that shedding is merely shy and not absolutely lacking as regards these fibres. In this respect my observations, although meagre, agree with those of Dry (unpub.) who, in the light of many Saddle and other non-Plateau Arrays was able to say :- "Shedding corresponding with that of Chalky Sickle fibres occurs in large Curly-tip fibres but not in many lambs, and then usually only a few Curly-tip fibres are shed. Shed Curly-tip fibres are found only when shed Sickle fibres with small ends are plentiful". To this latter generalisation he notes two exceptions, which he remarks "involve a small number of Curly-tip fibres". He enumerates these exceptions thus :-

"The exceptions are as follows :

"(1) A single Curly-tip fibre was shed, and that in an apparently normal manner, in a Valley Array. (He remarks that one may regard this as just an odd happening).

(2) One Ravine Array, with shedding and a 'crisis series' in the Sickle fibres early in the array, had no shedding or crisis features in the Sickle fibres on the late side of the Ravine, but amongst the big Curly-tip fibres a single shed fibre was found, and associated with this fibre were hairy tipped Curly-tip fibres showing crisis thinning (with restoration of coarseness and medullation below the thinning.)"

Later in the same paper Dry states:- "When shed Curly-tip fibres are relatively abundant, that is, from a fifth as numerous as shed fibres up to equality in numbers, the Array is Saddle or All-in. With shed Curly-tips present but less plentiful, the array has been a Saddle or a Ravine". He notes at this juncture that it is his impression that shed Curly-tip fibres are scarce in the Ravine Array but remarks that this array is comparatively rare. Continuing he states:- "Often, however, when a large proportion of the small ended chalky Sickle fibres in a Saddle or a Ravine Array are shed,

no shed Curly-tip fibres are discovered".

In the following arrays a series of types is figured which vary from Plateau-Saddle with free and weak shedding to typical Saddle Arrays with either free or weak shedding.

Sheep 1308 VI! (D) Plateau-Saddle. Shedding extended into C.Ts.

	H.H.	S.S.A.	S.S.A.	S.S.B.	Sickles		H.T.C.T.	C.T.	G2.
					Lge.	Sml.			
shed	21	10	2	4	1	0	2		
pers.	0	0	0	5	4	0	0	231	30

Sheep 1342 VI Ordinary Saddle.

shed.	5	3	6	2	5	9	0	0	X
pers.	0	0	0	0	0	7	10	188	X

Sheep 755? Plateau-weak

shed.	490	26	30	8	0	0	1	Only a little	
pers.	0	11	31	56	0	1	159*	G2 kemp.	

Sheep Voss 6. "Many Halos" Saddle. Shedding remarkably free.

shed.	34	11	5	7	15	15	32	X	41
pers.	0	0	0	0	1	1	49	X	97

Sheep 1307 VI ord. (D) Saddle. Normal Saddle Array rather typical

shed	7	13	0	1	0	0	0	0	0
pers.	0	0	1	6	5	46	0	162	30

\* These Hairy-tip-Curly-tip fibres were obtained from about three quarters of the total analysis counts.

In the above Sheep 755 and Voss 6 are remarkable extremes of shedding in the Saddle Array and have been chosen for this reason from a very large assortment of Saddle Arrays. It is considered that these arrays probably represent the maximum extreme in the Saddle arrays at the Standard Back position as regards freedom of shedding.

From the above it is apparent that shedding in the Saddle Array is by no means limited to the Super-sickles but is often free in the Sickles and further, it is not unusual to find free shedding extending into the Hairy-tip-Curly-tip fibres. In this latter it

is important to note that the Hairy-tip-Curly-tip fibres in the Saddle Arrays are usually somewhat less robust than they are in many of the Plateau Arrays and thus shedding may be said to be occasionally extended into the Curly-tip fibres in the Saddle Array as the medullation responsible for the difference between the Hairy-tip-Curly-tip and the Curly-tip fibres is often of a fine "sparkling" type.

It was thought that the Halo-hair grading of a Saddle Array may be of importance in respect to shedding within that array but this possibility was upset by Sheep 612 which, although it has a Saddle Array that is remarkable for its freedom of shedding, it is only graded IV on Dry's Halo-hair grading ( 19 ). This array is most remarkable and is treated more fully later but its analysis is thought to be not out of place at this juncture.

Sheep 612 Grade IV. Saddle.

	H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles Lge.	Sml.	H.T.C.T.	C.T.
shed.	9	1	3	2	15	28	57	X
pers.	0	0	0	0	0	0	60	X

Thus it is apparent that shedding of Hairy-tip-Curly-tip and Even Curly-tip fibres in the Saddle Array is occasionally very free and it thus becomes necessary in the light of the lack of free shedding in many weak Plateau Arrays to endeavour to explain the apparent anomaly which arises when one regards the Saddle Array as "an extremely weak Plateau" (see page 110).

Such an explanation might well be :-

The check in many of the weak Plateau Arrays, although of insufficient intensity to give Sickle fibres is of sufficient intensity and acts over a sufficient period to prevent shedding of many post-super-sickle fibres. However, in many Saddle and in some of the weak Plateau Arrays the pre-natal check is of such a reduced type that despite low potentialities of the animal for medullation, that is the base on which the check works, the animal is able to shed many of its sickles and even on occasion to have shedding extended into the Curly-tip fibres.

The implications of the above are treated more fully later (page 167) and it is sufficient to note here that evidence is produced to show that there are probably at least two distinct forces at work in the determination of the architecture of the fleece of the sheep.

A further important point that is apparently assumed in the above, is that shedding is more easily effected than the macroscopic appearance of the fibre. Evidence for this is forthcoming from the study of the Plateau Arrays that have been termed a Ravine-type-Plateau. That is, an array that shows definite evidence of a check in that there is found to be a lack of shedding in some fibres that from macroscopic appearance came early in the array while shedding is found in fibres that on similar grounds must be placed later in the array. Such an array is that of Sheep 1239 VI!

Sheep 1239 VI!

	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
shed.	48	13	19	0	42	0	0
pers.	0	0	0	2	15	320	560

Further proof that shedding is in more delicate balance than structure, is obtained from Tough Plateau Arrays where there is free shedding of many Hairy-tip-Curly-tip fibres but some persistent Hairy-tip-Curly-tip fibres are very similar to those shed. This suggests that the weakening vitality along the array is evidenced by persistency before it is sufficiently strong to effect the macroscopic appearance of the fibres.

Such arrays are :-

	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>H.T.C.T.</u>	<u>C.T.</u>
Sheep 905 Br.					
shed	41	0	0	33	61
pers.	0	0	0	26	156
Sheep 1327 VI! Bk.					
shed	27	6	6	11	0
pers.	0	0	0	38	250

Thus to sum up the previous section, it is apparent that shedding in the Saddle Array may be free and thus it appears probable that shedding in weak Plateau with which Saddle is often related, may on occasion be free despite the fact that in some weak Plateau Arrays shedding is definitely not extended into the Hairy-tip-Curly-tip fibres. See sheep 1308 page 133 and also Table IV.

The shedding situation as it occurs in the weak Plateau Arrays is set out in Table IV and it is apparent from this that wide variations in shedding occur between the arrays that are of similar toughness.

T A B L E IV.

Sheep	Halo-hairs.		Super-sickle A		Super-sickle A-		Super-sickle B.		Sickles		H.T.C.T.		Curly-tips.	
	all	shed.	shed.	pers.	shed.	pers.	shed.	pers.	shed.	pers.	shed.	pers.	shed.	pers.
1084	33		16	0	3	0	0	0	0	0	50	28	2	x
1239	48		13	0	19	0	0	2	0	0	39	0	3	285
852	130		10	0	25	0	2	2	0	0	19	41	1	x
1017	41		17	0	4	0	1	0	0	0	27	2	6	x
1308	21		10	0	2	0	4	0	1	4	2	0	0	229
860	150		13	0	3	13	2	10	0	0	1	62	0	x
1175	18		2	0	3	2	0	4	0	3	0	19	0	342
904	31		0	0	8	9	0	14	0	3	0	63	0	297
1278	17		14	0	3	0	15	9	3	2	0	0	0	423
1402	19		6	0	17	0	13	3	1	2	5	0	0	288

The above arrays are in order of toughness from left to right, 1084 being the toughest array figured and 1402 and 1278 the weakest arrays. Both these latter have quite appreciable numbers of Sickle fibres which are closely associated macroscopically with the Curly-tip fibres. They thus closely approach the Saddle Array and are regarded both on the score of fibre type numbers and fibre type association as extremely weak Plateau.

When the above Table is read from left to right it is apparent, as has been pointed out above, that there is considerable variation in the freedom of shedding. Thus 1278 and 1402 despite their weakness have the majority of their Super-sickle B and Sickle fibres shed normally, (see page 93), sheep 1402 even having normal shedding continued into the Curly-tip series. Sheep 860 is regarded as a weak Plateau Array, despite the scarcity of the Super-sickle fibres, because there is a close association between the Hairy-tip-Curly-tip fibres and the Super-sickle B fibres. This array, although somewhat tougher than 1278 and 1402 has the majority of its Super-sickle A- and B fibres persistent as well as having persistent Super-sickle A fibres.

However, despite the above it is of interest to read the situation as regards the Hairy-tip-Curly-tip fibres. This becomes instructive when it is recalled that the arrays are in order of toughness from left to right. When this is done the following is the result :-

n.shed.	50	39	19	27	2	1	0	0	5
pers.	28	0	41	2	0	62	19	0	0

Thus it appears that the original thesis that the shedding of the Hairy-tip-Curly-tip fibres as a guide to the toughness of the Plateau Array may perhaps be substantiated in the majority of cases, but that exceptions may be found in that shedding may be sufficiently free in some of the weaker arrays for shed Hairy-tip-Curly-tip fibres to be found. In this respect it must be noted that in the arrays of sheep 541 discussed above (page 129) which was an apparent exception to the rule that shedding is free in all tough Plateau Arrays, proved, on close scrutiny of the fibre type associations to be a weak array.

In relation to the shedding situation in the weak Plateau Arrays and bearing in mind the remarks on the potentialities of the animal it appears that there is some other factor operating that is unconnected with either the potentialities or the pre-natal check. That such a force exists is further evidenced by the rythmical shedding of the successors, which is briefly touched on in the section on 'Crisis thinning' (page 86). Attempts have been made to explain the shedding at particular periods by variations in nutrition, variations in body expansion, and variations in the development of new follicles or daughter follicles. Although these factors may perhaps have an influence it is difficult to think of them as being a complete explanation. This is due in part to the regularity with which they "march" in step, in part to the accuracy of the prophecy that it is possible to make regarding the shedding situation from a study of the shedding of the birth coat kemp, and in part to certain observations that have been made as regards the crisis thinning. These latter are dealt with in the appropriate section on crisis thinning. The ability to prophesy the kemp situation by the birth coat kemp Dry (19) appears to stress the importance of those factors that are already known to exist and in particular the pre-natal check. However, it is possible to have an array, a Plateau, which by its very nature has a poor pre-natal check, that has poor shedding of the successors Dry (19) while a Valley Array with large ended chalky Sickle fibres shedding may have, Dry (19), free shedding of the successors.

To summarise the above section, it has been shown that shedding in the Tough Plateau Arrays may or may not be free. The implications are discussed and the existence of at least two basic factors in the architecture of the fleece is recognised. Possible methods of distinguishing between these are discussed.

-----

## S U M M A R Y.

\*\*\*\*\*

1. The term toughness is defined and its limitations are discussed.
2. The criteria for the judgment of toughness or weakness are enumerated.
3. Those features which appear to be associated with toughness or weakness are enumerated.
4. It is shown that a limited range in fibre types, that is scarcity of Super-sickle fibres, in the Plateau Array may be regarded as indicating a weak pre-natal check.
5. It is shown that the presence of considerable numbers of Halo-hairs and Super-sickle fibres in a Saddle Array may be regarded as an indication of a weak pre-natal check.
6. The importance of intermediate fibres as indicators of array toughness is discussed and arrays are quoted to demonstrate the salient points.
7. 'In Parallelism', as it effects the appraisal of toughness in the Plateau Array is discussed and illustrated with sample array analyses.
8. Evidence is presented which shows that shedding tends to be more free in the tough than in the weak Plateau Arrays. Possible reasons for this are discussed.
9. An unusual array, apparently anomalous in the matter of shedding, is shown not to constitute an exception to the general theory of shedding in relation to array toughness.
10. Shedding in the Saddle Arrays is discussed and its importance in relation to shedding in weak Plateau Arrays is pointed out.

11. A series of Saddle Arrays are quoted and discussed which show great variation in freedom of shedding.
12. An explanation of the apparent anomaly of free shedding in the Saddle and poor shedding in the weak Plateau Arrays is given.
13. Evidence is presented to show that shedding is more easily affected than the macroscopic appearance of the fibre.
14. A Table showing the shedding situation in weak Plateau Arrays is presented and discussed.

=====

FEATURES ASSOCIATED WITH TOUGHNESS OR WEAKNESS IN  
THE PLATEAU ARRAY.

=====

The foregoing has dealt with those features of the Plateau Array which are considered to aid in the judgment of toughness. In the following there is a discussion of those features which appear to be associated with toughness rather than criteria for that feature. This classification is rather an arbitrary one as it is clear that by their very association these features play a part in the appraisal of the Plateau Array series. They are, however, regarded as of definitely secondary importance when compared to those factors which have been discussed in the previous section. This makes their study none the less important and their description may, it is considered, throw some light on the intricacies of development or point the way to a new method of attack on the problem of the elucidation of the architecture of the fleece of the sheep.

The first point that has been noted in the classification of these features is :-

(a) The abundance of the Super-sickle A fibres in relation to the Halo-hair numbers.

A feature that has some bearing on this section has been treated previously (page 120) where it was suggested that a Super Plateau Array, based on the Halo-hairs and Super-sickle A fibres could possibly be recognised. After brief consideration it was concluded, that since intermediates could easily be found it was improbable that the recognition of such an array would serve any useful purpose. This is especially apparent when it is considered that such an array type receives recognition by its classification as a "particularly tough Plateau". Thus there is a distinct tendency to classify the Super-sickle A fibres and the Halo-hairs together. This tendency appears to contradict the above statement as regards the relative concentrations of these two fibre types, and in that it stresses their close relationship it brings into relief the impossibility of regarding this feature as a criterion of Plateau Array appraisal. The very existence of such a feature is, however, doubtful as is clear from the following arrays. Table V.

TABLE V.

Sheep	H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles	C.T.	S.S.A. as % of H.H. + S.S.A.	Hist.	Total C.T. & Hist.	H.H. & S.S.A. Per 100 C.T. & Hist.
59.5	54	5	0	1	0	440	9	337	777	8
1327	46	13	0	0	0	504	19	247	751	8
18.5	31	8	0	2	1	251	21	190	441	9
1238	77	15	20	2	0	548	16	777	1325	
541	15	1	2	0	0	130	6	x	130 +	x
905	66	3	0	0	0	249	4	806	1055	7
1084	33	16	3	0	0	78 +	33	x	78 +	x
1017	41	17	4	1	0	29 +	29	x	29 +	x
1279	25	2	2	5	0	176	7	186	362	7
750	23	8	0	2	1	285	26	x	285 +	x
860	150	13	16	12	0	63 +	8	x	63 +	x
852	130	10	25	4	0	60 +	7	x	60 +	x
1239	48	13	19	2	0	362	22	560	922	7
1402	45	25	29	11	4	533	36	570	1103	6
62.5	35	32	17	13	0	338	48	503	841	8
71.5	11	19	1	22	0	320	63	186	506	6
1258	20	4	16	8	3	219	17	x	219 +	x
1175	18	2	5	4	3	361	10	101	462	4
1278	17	13	5	20	8	423	43	162	585	5
1343	6	7	1	8	8	224	54	198	422	3
85.5	63	12	24	7	36	625	16	255	880	10
1328	6	4	0	7	46	294	40	103 +	397 +	x
1307	7	13	1	7	5	162	65	179	341	7
1308	21	10	2	9	5	231	32	230	461	8
1342	5	3	6	2	21	188	38	x	188 +	x

The Plateau Arrays are in order of toughness from 59.5 and 1327, the toughest arrays, to 1175 and 1278 the weakest arrays.

=====

In Table V the arrays are in order of toughness from Sheep 59.5 to Sheep 1278. This order is not a strict classification between individually adjacent arrays, because a number of factors have to be taken into account when judging array toughness, (pg.123) However, each array has been classified on these standards of judgment and are thus the classification considered correct as a series.

In some arrays complete Curly-tip and Histerotrich counts have not been made. Where the total fibres were not counted a "+" sign is used. Thus in Sheep 1084, 78+ in the Curly-tip column means that of the total Curly-tip fibres only 78 were counted. In these arrays no Histerotrich counts have been made and therefore "x" appears in the Histerotrich column. This lack of complete counts is, of course, reflected in the "Total Curly-tip and Histerotrich", and "Halo-hair and Super-sickle A per 100 Curly-tips and Histerotrichs" columns, where the "+" and "x" signs are used to denote incomplete counts and an unknown, respectively.

The column expressing the Halo-hair and Super-sickle A fibres as the concentration per 100 Curly-tip and Histerotrichs is appended for comparative purposes and this type of expression is used as it does not necessitate a classification between Curly-tip and Histerotrich fibres, a classification which, it is apparent from a previous section, (pg. 101) is often difficult.

The Saddle Arrays have been added in view of the concept of Saddle Arrays being "super checked Plateau Arrays". These Saddle Arrays are not of the N-type breeding but are all progeny of Sire 1016, who has given a number of what are considered multi-factorial N-type animals with typical Plateau Arrays (see pg. 206).

From the above it is apparent that there is a wide variation in the concentration of the Super-sickle A fibres within the Plateau series. It is interesting to summarise the above Table for this feature by extracting the % of Super-sickle A fibres and classifying them in order of array toughness as judged by those features already treated.

Super-sickle A fibres expressed as a % of S.S.A. and Halo-hairs.

<u>Plateau Arrays.</u>			<u>Saddle Arrays.</u>
9	29	36	54
19	7	48	16
21	26	63	40
16	8	17	65
6	7	10	32
4	22	43	38
33			

Thus it appears that although in general it is true that the density of the Super-sickle A fibres vary with the toughness of the Plateau Array it is by no means axiomatic that there will be few Super-sickle A fibres when the array is tough. In other words, the situation resolves itself into one of a type similar to that previously observed for such features as Halo-hair robustness, medullation of the Curly-tip fibres, and shedding, that is the tough Plateau Array is the extreme, although less tough arrays and even on occasion non-Plateau Arrays can reach this extreme the tough Plateau Array never reaches the low levels that some of the weaker arrays attain.

In relation to the Saddle Arrays quoted it is of interest to note that one array has only 16% Super-sickle A fibres. In this array a particularly large sample was fully analysed. This % is considerably lower than many of the Plateau Arrays. It is suggested that this low percentage could be obtained in a Saddle Array if a heavy check acting on a high potential base is postulated. Thus the early follicles are sufficiently vigorous to grow large numbers of Halo-hairs but the potentialities of the later developing follicles fail to come to expression due to a severe check and thus develop fibres with a completely thinned neck region, that is, Super-sickle A-, Super-sickle B and Sickle fibres.

Referring back to the Table it is of interest to summarise the column showing the Halo-hairs and Super-sickle A fibres per 100 Curly-tips and Histerotrichs.

<u>Plateau Arrays.</u>		<u>Saddle Arrays.</u>
8	7	3
9	8	10
9	6	7
7	4	8
7	5	

The above are abstracted in order of array toughness.

These figures represent only a rough approximation of the real position which would need extremely large counts to attain mathematical accuracy, but they show that there is a high degree of similarity between these arrays as regards this feature. Surprisingly enough there is no real difference between the Saddle and the Plateau Arrays and although the figures for the tough end of the Plateau series are uniform they are by no means as large as one would expect if the tough Plateau Array is regarded as having only Halo-hairs and Super-sickle A fibres because of the lack of check. Or, in other words, it would be thought that owing to the lack of check, fibres which in more heavily checked arrays become Super-sickle B and even Sickle fibres, would remain as Halo-hairs and Super-sickle A where the check is less intense. This effect would, it was considered, tend to raise the figure under discussion and further, it would be expected that the tough Plateau Array would give a higher value than the weaker and the non-Plateau Arrays. The fact that this is not the case calls, therefore, for an explanation and one is forced to conclude that either there is no real difference between the pre-Curly-tip and the Curly-tip fibres in the Plateau Array, or that there is an increase in the number of the Curly-tips and, or, Histerotrichs.

As regards the former, it is of interest to note that Galpin (22) in her study on the pre-natal development of the coat of the New Zealand Romney lamb states: "The particular variety of fibres produced by these first follicles depended upon the pre-natal check (trio Depression). In the coarse animals they were usually Halo-hairs while in the finer breeds they were usually Sickle fibres". She found that the earlier an area commenced

development the more numerous were the pre-Curly tip fibres. Also from the fact that the pre-Curly-tip fibres constituted about a third of the coat she assumed that the pre-Curly-tips were from the trio follicles and the Curly-tips from the additional follicles constituting the nine stages. She did not appear to realise the importance of the Histerotrichs, due probably to the lack of Plateau material (see pg. 101 et seq.), as she regarded these fibres as growing in a few extra follicles after the nine stage. She does, however, note that the occurrence of the 27 stage would greatly increase the Histerotrich numbers to the maximum possible on this type of follicle development, that is, twice as numerous as the pre-Curly-tips and Curly-tips combined.

From the above it appears that the pre-Curly-tips are limited to the trio follicles, but that since the proportion of pre-Curly-tip fibres may be considerably less than a third it is apparent that the trio follicles can contain fibres which are not pre-Curly-tips. Thus in the case under discussion Hairy-tip-Curly-tip fibres may be developed in trio follicles or, in other words, it is improbable that there is any real difference between the pre-Curly-tip and the Curly-tip fibres in the Plateau Array. This is of particular interest in that it stresses our ignorance of the basic causes of the macroscopic difference between fibre types in respect to the shape of the tip as opposed to the robustness of the medullation.

A line on the possible factors at work in this respect has been given by Galpin (22) who from pre-natal work at different regions of the body was able to show that the earlier an area is developed the more numerous the pre-Curly-tip fibres. Thus it may be that differences in time of development between sheep may be responsible for the dissimilarity between arrays in regard to their pre-Curly-tip populations or that there is only a limited period in the early pre-natal life of the lamb that is conducive to the formation of tips other than Curly-tips.

A further factor that is of importance in the similarity between arrays as regards the concentration on Halo-hairs and Super-sickle A fibres per 100 Curly-tip fibres and Histerotrichs is,

of course, the numbers of Histerotrichs. This aspect is treated in a previous section (page 109), and it is, therefore, sufficient to remark that there are wide differences between and within arrays in Histerotrich population.

The second feature that is listed as being associated with toughness or weakness in the Plateau Array as judged by the three major features already dealt with is :-

(b) The presence of a distinct break or precipice in the continuity of the Curly-tip fibres.

Galpin (unpub. paper) defines this feature when she states: "precipice is the term given to the sudden change along the array from the coarse to the fine Curly-tip fibres without intermediate fibres". Further, she states: "we may suppose that the precipice in the array in the coat of the sheep may be correlated with the break between the zigzags and the Hairlets in the mouse coat of Dry (16) and with the lack of connecting fibres referred to by Toldt (17)". In describing the Escarpment Array Galpin (22) draws a parallel between this array and the existence of the precipice in that she explains the formation of this array as an expression of the overlapping of the two forces, the pre-natal check (later considered to be due to the trio stage), and the reduction of inherent coarseness (due to the nine stage), causing all fibres later than the precipice to be fine. Dry, in writing of inherent hairness along the array (unpub. paper) states that Dr. Galpin found a precipice about half way along the Curly-tip series to be a common feature of the Plateau Arrays which she found at the Britch position. Further, he remarks that sometimes in Plateau Arrays there is associated with the drop in coarseness along the Curly-tip series a similarly marked drop in the rate of growth in length.

This latter association is considered from further work on Plateau Arrays, to be a common one and it has proved useful in a search for the phenomenon of the precipice in that length measurements are less laborious than diameter measurements. Where there is a loss of medullation due to the precipice its presence is an obvious feature, but it would appear possible that a precipice may

exist without being sufficiently strong to prevent a very heavy potentiality from coming to partial expression. Such a situation may lead to a masking of the precipice if medullation were the sole criterion. This is unlikely to be a source of error, due to the fact that it is possible to recognise quite fine degrees of medullation with accuracy. On the other hand it is possible, due to the complete fineness of the Curly-tip series, to get a precipice apparently confined to length. Such an array is that of Sheep 1258, Grade VI!, and a weak Plateau. This animal showed a definite precipice in length but has any precipice in diameter masked by the complete absence of medullation in the Curly-tip series. The importance of this array is stressed by the array of Sheep 1239 VI!, a medium Plateau, which has a distinct precipice in medullation but no apparent precipice in length. Thus, if such a precipice occurred in an array similar to that of Sheep 1258 it might very easily be missed unless a large number of measurements were made.

The actual method used was perhaps scarcely subtle but experience showed that it worked well and was quite satisfactory for precipice determinations. It consisted of spreading the fibres out in order of length between two white tapes that were pinned at an angle to each other on top of the usual black velvet background. The actual measuring was simple in the extreme, fibres being grasped at each end with two pairs of tweezers and stretched between the tapes until the crimps had just disappeared. The fibre was placed where the perpendicular distance between the tapes equalled the length of the straightened fibre. Thus it is clear that when the sample had been completely analysed the distribution of the fibres within the tapes gave a pictorial analysis of the distribution of the fibres in the array as regards length and also due to the even spread of the fibres it became unlikely that any precipice limited to coarseness would be overlooked. There was, of course, some error due to variations in the tension of the fibres and also to the difficulties experienced in grasping the fibre at the extreme ends, but these were not considerable and are of a similar type to measuring the fibres on a ruler.

The method was evolved to aid in the search for the precipice which, by its very name, is a distinct feature. This very distinctness may, however, be a difficulty in the study of this feature as varying degrees of perpendicularity were found in observed precipices. If these variations are common for this feature then in those arrays which have an indistinct type of precipice it may be very difficult to be sure that an actual precipice exists unless very careful and minute measurements are made. Thus a complete study of this feature would entail the making of many such measurements but at this juncture such measurements are not thought to be worth while as there are wide fields that with macroscopic determinations alone promise to be more helpful in the study of the architecture of the fleece.

A further qualification of the above is perhaps not unworthy of mention as it demonstrates that a certain individuality exists between follicles even within a very small sample. This modification consists merely of recognising the fact that some Hairy-tip-Curly-tip fibres are shorter than some Curly-tip fibres which are not hairy tipped, and thus the two types are classified on tip medullation as well as on length. To do this considering the presence of an overlap between the two types, the fibres were measured as indicated above and those judged to be hairy-tipped were placed below the lower tape in a position that corresponded with the distance between the tapes at that point. Thus in counting the fibres per inch between the tapes these Hairy-tipped-Curly-tip fibres were able to be included.

The fact that there appears to be an overlap between these two fibre types is an interesting feature in that it either evidences that there is no real intrinsic difference between these fibres that so often grade almost imperceptibly into the Halo-hairs and those fibres that form the bulk of the fleece, which have often been termed, in perhaps a rather loose fashion, the "ordinary Curly-tip fibres", or that this method is so inaccurate that the length measurements cannot distinguish between fibres which are in reality of considerably different lengths.

It is a matter of simple observation that there is a real overlapping between these two fibre types. If this is really so it indicates that there is a certain individuality of reaction between fibres as to the effect of that 'checking force' that is responsible for the difference between the Hairy-tipped-Curly-tip and the normal Curly-tip fibre. Some fibres appear to exhibit the check with special reference to length while in other fibres the loss of medullation in the tip appears to be the more easily effected.

An example of an array in which such an overlap occurs is supplied by the back sample of sheep 678, a Grade VI! with a tough Plateau Array. In this array it is notable that there was a precipice with a short although definite drop in length early in the Curly-tip series but no parallel feature was found for coarseness, medullation being extended for an appreciable period after the break in continuity in length. In brief, the following is the analysis of this array :-

H.H.	S.S.A.	S.S.A-	S.S.B.	S.	H.T.C.T.		C.T.	
					Above	Overlap	Overlap	Below
15	3	5	0	1	21	11	20	179

Thus in the light of the above this array is perhaps a further demonstration that the effects of a check may, on occasion, be confined to one type of reaction that is, either length or medullation. Usually, of course, both factors are effected but, in view of the arrays of sheep 1258 and 1239, quoted previously in this section, it is apparent that this possible differential effect between length and medullation (coarseness) should not be disregarded in the study of the architecture of the fleece.

In the study of the precipice attention has, in the main, been confined to the Plateau Array. Certain observations have been made in different parts of the body but these have been confined to those sheep which show a distinct Plateau on the standard back position. The positions studied are withers, side and five samples off the britch. As has been remarked previously in 'Methods' the britch requires a modification of the covering

technique before an extensive study can be attempted. Also, this study does not pretend to be in any way a complete analysis of the precipice situation in the Plateau Array, and this is especially applicable to the positions other than the back. The arrays for these positions were, in fact, analysed for quite a different reason, precipice determinations coming to hand as a by-product.

At the standard back position it was found that in the Plateau Array the precipice is at least a very common feature. In all those Plateau Arrays in which the Curly-tip fibres were measured as described above, a precipice in length or medullation or both was found. In some the features appeared more as a rapid grading off in robustness along the series than as a typical precipice and in some, its presence was masked by its occurrence at the end or at the beginning of the Curly-tip series. Thus it is that the precipice may be regarded as a feature of probably all Plateau Arrays on the standard back position and it therefore becomes an important feature in the study of this array. On other positions of the body a precipice was found in all Plateau Arrays that were measured.

In arrays other than Plateau it was found that this feature is by no means confined to this array. Distinct precipices were found in Saddle Arrays from the britch and also, although less clearly, at other parts of the body. In regard to arrays other than Saddle, difficulty was experienced in applying the method described above due to the presence of Checked and Peak Curly-tip fibres and perhaps for this reason distinct precipices were found in few arrays other than Plateau and Saddle. It is notable, however, that the search of Ravine Arrays for this feature was by no means extensive. Also, as has been mentioned above, the scanning of many of these non-Plateau Arrays suffers from the inherent difficulty of having all the Curly-tip fibres fine with the result that any variation in coarseness along the array is difficult to detect.

In spite of what has been said it is of interest to note that a very distinct precipice was observed in the britch sample from the Wensleydale sheep W.4. This array is a truncated Valley but is unusually medullated after birth for a Wensleydale, although

the pre-natal portion of the array as usual is entirely free of medulla. The back sample of this animal also showed unusual heavy medullation but the Curly-tip series is particularly even, although there is a distinct break in the continuity of the array between the Curly-tips and the Histerotrichs. A similar drop in continuity between these fibre types is found in the britch sample of another Wensleydale sheep H.4., but this time the array is very finely medullated, medullation being of that weak sparkling type so common in the Wensleydale.

In the above examples it is apparent that the majority of the noticeable precipices in non-Plateau Arrays have been found at the britch position and it appears to be a feature of this phenomenon that this position tends to give a more definite precipice than other more heavily checked positions, Galpin (21). Whether this is an optical illusion due to the concentration of attention on the Plateau Arrays at the back position or not it is difficult to say, but it is notable that those Plateau Arrays which show this feature in the most extreme manner are britch arrays. This very fact led to the conclusion that the presence of the precipice was an expression of the toughness of the Plateau Array but, as will now be apparent, this belief had to be abandoned.

It has been noted previously that there are wide differences between arrays in the position of the precipice and in a study of this feature it is obviously necessary to enquire into the differences which occur. For this reason the samples which have been studied for this feature are figured below in order of toughness. The first column expresses the total pre-Curly-tip and Curly-tip fibres which <sup>are</sup> antecedent to the precipice and, in the third, these are expressed as a percentage of the total fibres in the array exclusive of the Histerotrichs. In the fifth column these are expressed as a percentage of the total fibres in the array.

The chief reason for expressing the position of the precipice in this way is that the precipice can, on occasion, occur

at the beginning of the Curly-tip series and also examples have been quoted above of its occurrence between the Curly-tip and the Histerotrich fibres. In extreme cases the precipice has apparently occurred within the pre-Curly-tip series and it has definitely been observed to occur within the Histerotrich series. It may be remarked that the former position is regarded as rather contrary to the idea of the precipice and it is considered that such pre-Curly-tip breaks in continuity may be due to a rather different set of conditions than the break that occurs after the pre-Curly-tip fibres. However, the precipice is regarded as a feature of the array as a whole and it is thus considered that its position should be expressed as a percentage of the total array.

In regard to the exclusion of the Histerotrichs, this percentage has been included mainly because a number of arrays studied for the precipice did not have the Histerotrichs counted and it was considered that these arrays should be included. Also, it is of interest to note the importance of these fibres in relation to the array and it is possible, with the method used, to note the part these fibres play in the array through sheer weight of numbers.

A further reason for the exclusion of these fibres is the fact that some arrays were ascertained from samples which had been taken in November. It is considered that these are too early for accurate Histerotrich determinations, due to the fact that in some such samples very small fibres have been found, making it at least appear probable that the addition of Histerotrichs is still taking place. It is notable that this rather underlines our ignorance of the important section of fleece architecture concerned with the addition of new fibres after birth.

T A B L E VI.

Standard Back Position.

<u>Sheep in order of toughness.</u>	<u>Col. A. pre-prec- ipice fibres.</u>	<u>Col. B. Total pre-C.T. &amp; C.T.</u>	<u>Col. A as % of Co. B.</u>	<u>Col. D. Col. B + Hist.</u>	<u>Col. A as % of Col. D.</u>
1327	119	283	42	528	23
1068	128	185	69	473	27
94.5	167	283	59	607	27
93.5	75	175	43	477	16
1279	59	190	31	375	16
1238	177	331	53	728	24
1238	171	331	52	711	24
1239	159	444	36	1004	16
1256	97	226	43	512	19
904	100	289	35	x	-
1280	142	251	57	687	21
1402	190	400	48	745	25
1402 x	120	257	47	x	-
1329	318	483	66	998	32
1278	70	225	31	x	-
1258	100	275	36	x	-
1239 x	120	373	32	x	-
678	91	259	35	x	-
Side.					
1327	52	112	46	195	27
1238	27	59	46	140	19
18.5	101	305	33	519	19
59.5	99	140	71	267	37
78.5	89	183	49	221	40
29.5	67	175	38	354	19
1278	75	194	39	286	26
1068	161	315	51	727	22
Saddle.					
77.5	57	146	39	207	27
58.5	95	176	54	367	26

<u>Sheep in order of toughness.</u>	<u>Col. A. pre-precipice fibres.</u>	<u>Col. B. Total pre-C.T. @ C.T.</u>	<u>Col. A. as % of Col. B.</u>	<u>Col. D. Col. B + Hist.</u>	<u>Col. A. as % of Col. D.</u>
<u>Britch.</u>					
18.5	67	91	74	336	20
89.5	111	310	36	526	21
59.5	68	92	74	263	26
1068	118	183	63	525	23
71.5	72	155	47	273	26
<u>Withers.</u>					
1327	56	149	38	386	14
1068	67	157	43	437	15
1238	58	124	47	419	14
<u>Saddle.</u>					
78.5	76	178	43	203	37
59.5	103	236	44	436 +	23 +
77.5	99	350	28	475	21
71.5	253	246	103	336	75
1278	76	241	31	419	18
<u>Valley</u>					
58.5	44	91	48	231	19

In an endeavour to obtain some light on the variability within the two methods of calculating the position of the precipice the Standard Deviation and the Coefficient of Variation were determined for the Plateau Arrays at the back position, which were considered to be free from the objections cited on the previous page. These were :

	<u>Col. A.</u>	<u>Col. B.</u>
Standard Deviation	11.6	5.07
Coefficient of Variation	23.2	22.5

It is thus apparent that the inclusion of the Histerotrichs does not lower the variability of the precipice and it appears unlikely that the pre-precipical fibres constitute a particular fraction of the total array population.

From the above Table it is apparent that the position of the precipice along the array, although erratic, tends to be earlier in the tough Plateau Arrays than in the weaker types. This movement is, however, as is mentioned above, erratic and it is notable that sheep 1329, a medium Plateau, has the precipice earlier in the array than sheep 1327, regarded, as is apparent from its position in the Table, as the toughest Plateau Array figured for the back position. It is also notable that the sample from the withers of sheep 71.5 has the latest precipice recorded - the precipice actually being found within the Histerotrich fibres.

Despite these animals which would assume considerable importance in a complete study of this feature, it is considered that a provisional generalisation that it is more difficult for a weak Plateau Array to have a precipice late in the array than for a tough Plateau Array, can be established. Also to definitely establish the validity of this generalisation it would be necessary to study much larger samples than have been used in the above Table. A further point of importance in regard to the accuracy of this table is that, as has been pointed out previously, the precipice often consists merely of a rapid grading off in continuity along the fibre type series and therefore it is difficult to determine exactly where the precipice is located. This will be a definite source of error in any but large samples which have been measured fibre by fibre. Despite the above it is considered in the light of samples which have been duplicated, that it is improbable that the percentages determined for the above Table are far removed from the true position. Thus both in sheep 1238 and 1402 there is a variation of only 1% between duplicated samples.

It does, therefore, appear that although the above percentages seldom represent the exact position of the precipice it is doubtful if the indicated position is far from the real position. Thus it appears that definite differences do occur between arrays in that an array grading at 59% can be legitimately considered to be different from an array grading 35%.

When the position of the precipice as a percentage of the total fibres in the array is considered it is apparent that there is no difference between arrays. It is a notable fact that the Coefficient of Variation for these two sets of percentages for the back position is practically identical - it being 23.2 for those percentages exclusive of Histerotrichs and 22.5 for those percentages based on the total fibres in the array.

To sum up for the Plateau Arrays at the standard back position, it appears that the precipice is a very common feature and that there may be some relationship between toughness and the position of the precipice as judged by the numbers of Curly-tip and pre-Curly-tip fibres. This relationship does not apparently exist when the total fibres in the array are considered.

From other positions of the body the numbers studied are meagre, but there is considerable variability within, as well as between, both methods of expressing the position of the precipice. This variation is not confined to the Plateau Arrays but is also found in Saddle Arrays, five of which were found at the withers positions. It is notable that <sup>in</sup> these latter, variability reaches extreme limits (see Table VI).

The precipice thus appears to constitute a feature of many arrays in different parts of the body and is not apparently confined to the standard back position, indeed some of the most noticeable precipices were found in exceedingly tough Plateau Arrays on the britch. These britches were of animals which had a Plateau Array at the back position. In regard to toughness it appears that the precipice is a feature of all tough Plateau Arrays. Its exact position varies considerably, both between and within animals, and it seems improbable that this feature, as Galpin (unpub. paper) suggests: "is correlated with the break between the Zig-zags and Hairlets in the Mouse coat of Dry (16) and with the lack of connecting fibres referred to by Toldt (17)".

It is thus apparent from this brief survey that the precipice is a feature which must not be neglected in the study of the architecture of the fleece.

The findings which have been reported emphasise one aspect of our ignorance of the interplay of the forces at work in the coat of the sheep. Further, it makes one wish, besides, that the mathematical studies of Malan (40), who critically analysed measurements of fibre diameter of South African Merino Wool samples, could be extended to Plateau and other Romney material.

---

## S U M M A R Y.

=====

1. It is pointed out that the density of Super-sickle A fibres in relation to the Halo-hair concentration and the presence of a distinct break or precipice in the continuity of the Curly-tip fibres are features which are merely associated with toughness and cannot be regarded as indicators of array toughness.
2. The classification of Halo-hair and Super-sickle A fibres is briefly discussed.
3. A Table setting out Plateau Arrays in order of toughness is given and explained.
4. It is concluded that although in general the abundance of Super-sickle A fibres varies inversely with the toughness of the Plateau Array it is possible to have tough arrays with considerable numbers of Super-sickle A fibres.
5. A Saddle Array with a high Halo-hair concentration but with a low Super-sickle A fibre concentration is described and its significance is discussed.
6. When the Halo-hair and Super-sickle A fibres were expressed as a portion of the total array no real difference was found between Plateau and high grade Saddle Arrays. The implications of this are discussed.
7. Galpin's definition of the precipice is given and her remarks on this feature are briefly reviewed.
8. The occurrence of the precipice in length and medullation is discussed.
9. A satisfactory method for precipice determinations is described.
10. Overlapping in length was found to occur between the Hairy-tip-Curly-tip and the non-Hairy-tip-Curly-tip fibres. The implications of this are discussed.

11. Evidence is presented to show that although a precipice is found in both length and medullation it may be confined to one of these features. This is discussed.
12. A precipice was found in all Plateau Arrays measured.
13. The occurrence of the precipice in arrays other than Plateau and in positions other than the standard back position is discussed.
14. A Wensleydale sample is described in which a distinct precipice occurred.
15. The most distinct precipices found were in arrays from the britch position of animals with Plateau Arrays at the standard back position.
16. A Table showing the position of the precipice in a number of arrays is given and discussed.
17. It appears that it is more difficult for a weak Plateau Array to have a precipice late in the array than for a tough Plateau Array.
18. When the position of the precipice is expressed as a percentage of the total fibres in the array no regular difference was found to exist within the Plateau series or between Plateau and high grade Saddle Arrays.

=====

THE FORCES AT WORK WHICH PLAY AN IMPORTANT PART IN  
THE DETERMINATION OF THE ARCHITECTURE OF THE FLEECE.  
=====

This section is an endeavour, with the aid of the Plateau Array, to throw some light on the working of the gene in determining the architecture of the fleece. The Plateau Array, when it is the toughest type, represents the end point and thus the study of this extreme type provides valuable material for the understanding of the forces at work in the fleece.

In a previous section - "Shedding and its relation to toughness in the Plateau Array" (pg.128), it was postulated that at least two distinct forces were at work in the fleece and the interaction between these forces was proposed as an explanation of the fact that shedding in the weak Plateau Array may be restricted while shedding in the Saddle Array may be very free (see page 131). It is therefore necessary to explore the possibilities of this postulation and to consider how far, in the light of the Plateau Arrays, the recognition of such forces is possible.

The facts of shedding which have a bearing on the possible recognition of at least two forces at work in determining the architecture of the fleece have been stated previously, but in the light of their importance in relation to the present discussion these facts are again considered. It was found that shedding in the Plateau Array may be summed up as:- "Shedding in tough Plateau Arrays is always free and is usually extended into the Curly-tip series but shedding in weak Plateau Arrays may or may not be free". This "may or may not" situation is also found in the Saddle Array and some are remarkable for their freedom of shedding (see pg.133) In that there are distinct grounds for regarding a high grade Saddle as a 'super-checked Plateau' this shedding calls for an explanation.

The problem thus resolves itself into: why, if the check is sufficiently intense to prevent shedding almost completely and also sufficient to give many Super-sickle B and even a few Sickles in weak Plateau Arrays, is the check not sufficient to ~~even~~ prevent

shedding in Saddle Arrays which, from their very classification, necessitate a more intense check? The explanation for this, as has been noted previously, is based on the supposition of the existence of two independent forces. These have been distinguished by the terms "base", representing the potentialities of the animal, and the "check" which is regarded as a limiting force superimposed on the base.

The proposed interaction of these two forces to explain the facts are:- With the free shedding Saddle Array this particular combination consists of a weak base and a check which, although weak, depresses the potentialities sufficiently to cause the array to be a Saddle Array but insufficiently to prevent shedding. With the free shedding weak Plateau the postulated combination is a strong potentiality or base and a relatively weak check, giving both a lack of depression as regards macroscopic appearance and freedom of shedding.

Although this explains the facts it is difficult to advance this as an argument in favour of the existence of two independent forces acting in the development of the fleece of the sheep. There is also an apparent anomaly as regards this explanation of the free shedding Saddle in that it appears that shedding is less easily affected than macroscopic appearance which is contrary to previous statements (see page 135). This is not necessarily the case, however, as it may be postulated that the base is insufficient to give a heavily medullated fibre except for a few fibres which develop particularly early. This is admittedly speculation and it is possible that when the real facts of the development of the fleece are better known, the above explanation will be considerably modified.

The existence of these postulated forces obtains support from the type of Plateau Array that has been termed the Ravine type. These arrays are regarded as having a potentiality for toughness, or a strongly medullated base, but with a check superimposed on them sufficient to give an appreciable number of Super-sickle B and some Sickle fibres, thus causing the array to be regarded as weak.

These arrays, despite this weakness do not have Hairy-tip-Curly-tip fibres as weak as is usual when large numbers of Super-sickle B fibres are present. These Curly-tip fibres resemble the Super-sickle A fibres by having very heavily medullated tips and grossly hairy post natal regions. Thus it appears that there is perhaps extensive 'in parallelism' but it is easier to think of a more general cause in other words, a pre-natal check of a similar type to that occurring in the Ravine Array. These arrays have been shown by their analyses to be definite Plateau. Also, the animals under consideration have been deemed, both from their ancestry and their progeny, to carry the N factor. It is, therefore, considered that they lend support to the contention that at least two factors are at work in the fleece of the sheep - the base, which in these animals must be regarded as of definite Plateau intensity, and the check, which is regarded as sufficiently appreciable to cause the potentialities to be at least partially suppressed for a period. Examples of such arrays are :-

Sheep 303. The original N-Type ram.

	<u>H.H.</u>	<u>S.Sickles</u>	<u>Sickles</u>	<u>H.T.C.T.</u>
shed	157	33	1	0
pers.	0	47	23*	numerous.

\*Note: Some of the sickle fibres are rather fine with imperfect tip form.

This array is considered to be a weak Plateau due to the large number of Sickle fibres which are closely associated with some Hairy-tip-Curly-tip fibres. There are, however, some Hairy-tip-Curly-tip fibres which are distinctly more chalky than these Sickle fibres.

A further array that is of importance in this respect is that of sheep 979, a Saddle animal approaching Ravine, and Graded VI Ord. This animal has the following array at the back position.

	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>Sickles</u>		<u>H.T.C.T.</u>
					<u>Lge. ended.</u>	<u>medium</u>	
shed	18	18	4	2	1	1	4
pers.	0	2	6	3	0	11	96

The Sickle fibres in this array have been termed finely chalky and definitely finer than the Hairy-tip-Curly-tip fibres. There are also two of the Super-sickle B fibres which have a similar scarcity of medullation in post-natal regions. These latter are virtually Sickle fibres with a little fine medullation in the neck region. Despite the above, and also despite the presence of unusual numbers of persistent Super-sickle A- and even persistent Super-sickle A fibres the Hairy-tip-Curly-tip fibres are particularly robust and four of these are shed normally. These fibres are all definitely chalky after birth and, although medullation does not extend into the Histerotrichs, it is apparent from the medullation that does exist in these fibres that the potentialities for medullation is high. Also, the Halo-hairs are of that type that is associated with the tough Plateau Arrays and also they are relatively numerous grading off into the Super-sickle A fibres, which classification includes three short type fibres. Thus this array is regarded as having a coarse base acted on by a checking force sufficiently strong to cause the array to be classified as Saddle near Ravine.

It is notable that the above arrays depend on fibre type relationship as judged by macroscopic appearance, for its importance in the present analysis. However, in the light of shedding (see pg.133) which appears to be more easily affected by a check than is macroscopic appearance, it should be possible, if the above relationship is real, to find a weak Plateau Array with shedding extended into the Curly-tip fibres but with a lack of shedding in some Super-sickle B together with the 'in Parallel' Sickle fibres persisting.

Such an array is that of sheep 1239 and also sheep 1402.

	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>S.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>
Sheep 1239 VI! Regarded as a medium Plateau:							
shed.	48	13	19	0	0	39	3
pers.	0	0	0	2	0	0	320
Sheep 1402 VI!							
shed.	19	6	17	13	1	5	0
pers.	0	0	0	3	2	0	287

From these arrays it is apparent that shedding of some fibres has been prevented while shedding is free in fibres appearing later in the array with consequent lower potentialities (de Meijere 18). It is therefore clear that the potentialities of the persistent pre-Curly-tips have not come to full expression. On these grounds it is considered that these animals provide evidence that at least two distinct factors play an important part in the development of the fleece of the sheep.

That these two factors may vary independently is evidenced by a further study of the Plateau Arrays. Selected arrays are, therefore, placed in order of freedom from checking effect on shedding. Weak and medium arrays have been selected and since shedding may or may not be free in weak Plateau, these arrays are not necessarily in order of toughness.

<u>Sheep :</u>	<u>1017</u>	<u>1239</u>	<u>1308</u>	<u>1402</u>	<u>303</u>	
H.H.	41	48	21	19	157	
S.S.A.	17	13	10	6		
S.S.A-	4	19	2	17		
S.S.B.						Super-sickles not classified.
shed	1	0	4	14		
pers.	0	2	0	3		S.Ss. shed 33 pers. 47
Sickles						
shed	0	0	1	1	1	
pers.	0	0	4	2	23	
H.T.C.T.						
shed	27	39	2	5	0	
pers.	2	-	0	0		numerous-some resemble S.S.

From these arrays it is apparent that there is a definite gradation from those with shedding unchecked through those with some persistent Super-sickle fibres to those with no shedding in the Hairy-tip-Curly-tip fibres and considerable numbers of persistent Super-sickles.

It is suggested that these arrays, or at least those of a sheep 1017, 1239 and 1308, as judged by features such as Halo-hairs and Super-sickle A fibres, are of similar base and that the check has steadily become more intense along the series until in sheep 1308 a considerable number of persistent Sickles are found, with a rise after the check limited to but a few shed Hairy-tip-Curly-tip fibres. In sheep 1402, despite the presence of a distinct check, sufficient to give persistent Super-sickle B fibres, the potentialities are sufficient to give shed Hairy-tip-Curly-tip fibres. Sheep 303 has been dealt with previously and is figured here to show the position of the type of array where the check is sufficient to prevent all shedding but does not prevent some fibres late in the array from exhibiting at least more of their potentialities than was possible for those fibres earlier in the array.

Another notable feature of the above arrays is that it is possible to postulate that the check acts on the base at varying ages and that the length of time during which the check is effective also varies. Thus in sheep 1239 the check is considered to be effective earlier than in sheep 1308, where it appears insufficient at the Super-sickle B stage of development to prevent shedding but of sufficient intensity later in the array to cause the formation of Sickle fibres. It must be understood that the above is merely a discussion based on the effects of the check and thus the base tends to be neglected. It is important to realise that the macroscopic differences within and between arrays represent an interaction between these two forces, either of which may shift. It is, however, considered that the base can be regarded as a total shift with the check acting thereon capable of varying in strength time of onset and length.

An important aspect of the shedding situation in regard to the recognition of the forces at work in the fleece is that in Non-Plateau Arrays the shed birthcoat fibres are appreciably shorter and less stout than those of the Plateau Array. This statement is unsupported by measurements and is determined on macroscopic judgement of post-natal robustness. As has been stated previously, it is considered that this method of comparison between fibres is not greatly at error and considerable accuracy has been obtained in the past with these apparently crude methods. Thus it is that the above may be taken as a statement of fact.

The implications of the above are important in that they involve the recognition of the fact that, although shedding in the Plateau Array is perhaps freer than in any other Array as to the distance along the array to which shedding may extend, this freedom of shedding of fibre types cannot be extended to include fibre robustness regardless of fibre type. Thus it is possible for a Super-sickle to shed normally (page 30) in a non-Plateau Array although it is definitely less robust than a persistent Hairy-tip-Curly-tip fibre in a Plateau Array. This state of affairs required an explanation and it is considered that the explanation lends support to the recognition of the two factors postulated above.

It is thought that the 'base' in these non-Plateau animals can be regarded as weak, thus giving fibres of a less robust type. On this weak base is superimposed a weak check which is insufficient to produce shedding and therefore unlikely to reduce medullation. In this respect it is notable that sheep 612, an animal with a Saddle Array at the back position and with very free shedding (see pg. 134), has very little sign of the checking force in that the Curly-tip fibres which are closely associated with the Sickle fibres in macroscopic appearance.

A line on the possibility of separating these two forces in the fleece may be obtained from the study of the robustness of the Halo-hairs. In the Halo-hairs section (pg. 22 et seq.) it was concluded that there was no regular difference between the Halo-hairs in the different arrays, except that the Halo-hairs of some

Plateau Arrays reached higher peaks of robustness than those of any of the non-Plateau Arrays. It thus appears that as regards Halo-hair robustness there is little ground for the assumption of the existence of a significant, intrinsic difference in the basic potentialities between the Plateau and Saddle Arrays regarded as individual entities. Rather does the study of the macroscopic structure of the Halo-hairs lead one to the conclusion that the check is the fundamental vector, variations in potentialities within the Plateau-Saddle series, if they do occur, being of importance only at the extremities of the series.

The above generalisation is further substantiated when the Halo-hairs are examined of the arrays featured (see pg. 143 and Appendix I) as examples of variations in array toughness. Distinct differences were found between the Halo-hairs of these arrays but these differences with the present knowledge of Halo-hair structure did not appear to have any parallel with the variations in array type, except that the arrays recognised and figured as examples of tough Plateau Arrays, that is sheep 1238 and 1327, have the extremely coarse type of Halo-hair. Other arrays also contained a similar Halo-hair type. These were sheep 1204 and 1404, the former a weak Plateau, the latter a Saddle Array. The weakest Halo-hair types were found in the arrays of sheep 1278, a weak Plateau, and 1307, a Saddle Array with poor shedding. It thus appears that if Halo-hair robustness is a guide to the potentialities of the animal, then the necessary corollary is that there are wide differences in the intensity of the pre-natal check with array types.

The problem thus becomes the fixation of one variable, that is either the check or the potentialities of the animal for coarseness in the large birthcoat fibres other than Halo-hairs which appear to be independent. In this respect it is notable that Leslie (23) presented evidence that the abundance of Halo-hairs was affected by altering the pre-natal environment by improving the plane of nutrition of the ewe. This is an obvious complication in the attribution of the importance in the separation of the above variables by the study of the Halo-hairs.

Two lambs, sheep 93.5 and 94.5, twins, born in the season of 1938 that were very small at birth, weighing only 7 lbs. 9 ozs. and 6 lbs. 4 ozs. respectively, were graded VI! and were found on analysis to be Plateau, are of interest in relation to this enquiry. These lambs were weighed when 226 days old and a comparison between these lambs and other N-type lambs of the same year is made below. The comparison is in weight gain per day and this nullifies the difficulty due to the fact that the lambs, although born during the same season, often have considerable differences in their lambing dates which would be a large source of error when only a relatively short period is being considered.

Wgt. gain per day of 20 N-type lambs over approx. 230 days =	Ozs.	4.7
" " " " " sheep 94.5 over 226 days =		4.8
" " " " " " 93.5 " 226 days =		4.6

Thus it is apparent that these lambs grew normally after birth despite the fact that they were remarkably small at birth. A study of the Halo-hairs of these animals is therefore pertinent to the exploration of the robustness of the Halo-hairs as a possible indication of the potentialities of the animal.

The Halo-hairs of these animals were similar to each other and it was clearly apparent that the prenatal portion was unusually short and weak, while the post-natal portion was of normal length and robustness. It is therefore considered that these animals provide some evidence that poor pre-natal conditions; presumed to be partly responsible for their unusually small size at birth, can effect the expression of the Halo-hair robustness in the pre-natal portion of growth.

Thus it is apparent that the robustness of the Halo-hairs in the light of our present rather cursory knowledge is not<sup>a</sup>/reliable guide as to the potentialities of the sheep for fibre growth.

In the <sup>above</sup> it has been assumed that a difference in the potentialities of an animal, or the base on which the pre-natal

check works, is a definite character, a character which is inherited as a separate and distinct entity and is capable of genetic variation, apparently uninfluenced by those factors affecting the pre-natal check. This is by no means a new conception as both Dry (19) and Galpin (22) have drawn attention to the possibility of the existence of such variables.

A further fact of importance in regard to the existence of these two variables has been supplied by work on sweat glands done by Miss Hefford at this College in 1934. Although this work was limited by its nature to very small numbers of sheep, (four), it is of great importance as it both points the way to a method of research in the fleece of the sheep and throws some light on the presence of two independent factors at work in determining the architecture of the fleece.

One of the sheep studied was E59, a very hairy animal with medullation extending into the Histerotrichs, despite the fact that it showed a very deep and prolonged Valley check. That this checking force was of importance early in the array is evidenced by the fact that large ended, fine Sickleles were found. That the check was effective over a considerable period is evidenced by the presence of fine Curly-tip fibres with a lengthy pre-natal curled region. Also the fact that the check was of sufficient vigour to completely prevent medullation in some Sickleles and early Curly-tip fibres, despite the fact that the vigour of the animal for medullation was sufficient to extend medullation throughout the Curly-tip series to the Histerotrichs, suggests that the check was abnormally severe. The other animals were not exceptional in either array or medullation. Two were Valley, one medullated, one fine, while the remaining array was a Ravine and is described as 'moderately hairy'.

In this work it was found that sweat glands were associated with pre-Curly-tip fibre follicles and many Curly-tip follicles but were never associated with follicles containing Histerotrichs. In a sample from the back position of sheep E59, however, many checked Curly-tip fibres, and these the finest, either lacked sweat glands altogether or had sweat glands which were noticeably small

at about ten weeks. It thus appears, as Dry points out (19), that the pre-natal check can inhibit and limit the growth of sweat glands. Thus, although the birth check in this animal has been sufficient to cause a decrease in size and even on occasion a complete loss of sweat glands, it acted on a substrate that had sufficient potentialities to cause the Curly-tip fibres to be definitely heavily medullated. It is notable that there is a complete lack of precipice in this array.

The failure of this animal to realise its potentialities is even clearer than the above would indicate when the other arrays are described, in that it is apparent that although the pre-natal check has been insufficient to cause the loss of the sweat glands, the arrays are by no means as heavily medullated as that of E.59.

Further work that may have a bearing on the conception of the existence of at least two separate and apparently distinct independent variables is supplied by Rudall (24) who found that epilation of portions of different animals, apparently similar in extent and type of medullation gave different responses in the medullation of the regenerated fibres. These responses varied within, as well as between, sheep. These results led him to conclude that, "by pulling out fibres an estimation of the drive towards hairiness may be obtained from the amounts of medulla in the regenerated fibres". He therefore appears to think that the checking force can effect the medullation of the animal throughout life. The pros and cons of this will not be discussed here and it is considered sufficient to note that Rudall, in attempting to explore differences between sheep in the basic medullation on which the check acts, necessarily distinguished between the two forces. It is of note that Rudall's check appears to be rather a different type of concept to that discussed here but the idea of the base appears to be similar although apparently limited to Curly-tip medullation.

It is therefore probable that the existence of at least two independent basic factors in the architecture of the fleece is a fact. In view of this it is of interest to speculate that the

basic causes of these two independent forces may hinge on the factor in development which is already known to play a part in the pre-natal check, that is, variations in follicular concentration. The explanation is that the basic potentialities are due to the initial concentration of the primary follicles while the check has, of course, been shown by Galpin (22) to be due to variations in later follicular development.

Thus to sum up, it is manifest that there are at least two apparently independent factors at work in determining the architecture of the fleece. Thus the array and array type which the animal exhibits is due to an interaction between these variables. The possibilities of separating these variables has been briefly discussed and the conclusion is that even such methods as are at present available, present a large field for research, a field which it is of the utmost importance to explore in that it is a further step towards the elucidation of the working of the genes.

At present our knowledge is so sketchy that it is difficult to speculate and impossible to dogmatise. However, it does appear that the toughest type of Plateau Array can be the result of either (assuming only two major factors are at work), a very heavy potentiality and perhaps a variable but light check, or on the other hand what may be termed an average potentiality with a lack of pre-natal check.

S U M M A R Y.

1. An endeavour is made by the study of the Plateau Array to throw some light on the physiology of development of the fleece. The theory is advanced that two independently variable forces, called the base and the check, are sufficient to cause variations between and within arrays.
2. The facts of shedding in relation to array and array type are briefly reviewed.
3. An explanation of the apparent anomalies in the shedding situation between Saddle and Plateau Arrays are explained on the "two variable" theory.
4. The variations in shedding within those arrays classed as weak Plateau arrays are discussed and explained on the independently variable base and check theory.
5. Ravine type Plateau Arrays are figured and discussed. Their development is explained on the variable base and check theory.
6. Evidence is presented to show that the check may vary in time of onset as well as in length and intensity.
7. Shedding in relation to fibre size is discussed and the fact that fibres persist in Plateau which would be sufficiently robust to be shed if they occurred in other arrays is explained on the variable base and check theory.
8. From a discussion of Halo-hair size in relation to array it appears that there is little ground for the assumption of the existence of a significant intrinsic difference in the basic potentialities between Plateau and Saddle Arrays.
9. From a study of Halo-hair size in relation to toughness in the Plateau Array series it is concluded that if Halo-hair robustness is a guide to the potentialities of the animal then the necessary corollary is that there are wide differences in the intensity of the pre-natal check.

10. The influence of the pre-natal environment on Halo-hair size is discussed. It is concluded that Halo-hairs do not appear to be a reliable guide to the potentialities of the sheep for fibre growth.
  11. Rudall's epilation work is discussed and it is pointed out that he distinguished between the basic potentialities for Curly-tip fibres and the check.
  12. Miss Hefford's work on sweat glands is discussed and it is concluded that the results may be explained by the base and check explanation.
  13. The mode of working of the basic potentialities is speculated upon in terms of developmental follicular density.
  14. The importance of the two variable forces hypothesis in relation to the Plateau Array is briefly reviewed.
-

IN-PARALLELISM IN THE PLATEAU ARRAY.  
 =====

Dry, in his unpublished paper on the Fibre type Arrays of the New Zealand Romney lamb, first put forward the idea of In-parallelism, to explain anomalous fibres which occurred in some of the Non-Plateau Arrays which he studied. He suggested that In-parallelism might be explained by local follicular concentrations in the skin. He quotes examples in Non-Plateau Arrays to show that In-parallelism is a real phenomenon and he uses this concept to explain the All-In Array.

In earlier sections of this thesis the In-Parallel concept has been used to explain many anomalous cases in the Plateau Array. This is particularly the case in the section on Toughness (page 126) where examples of its occurrence were given. However, In-Parallelism has only been resorted to when a simple explanation is inadequate and it is my belief that In-parallelism in the Plateau Array is as much a fact as in the Non-Plateau Arrays, and that Dry's statement for these latter Arrays that "In-Parallelism is a real phenomenon", definitely applies to the Plateau Array.

In the study of In-parallelism in the Plateau Array it is soon apparent that there are wide variations between arrays in the number of fibres which must be regarded as In-parallel. This is clear from the following arrays where those fibres considered to be In-parallel are underlined.

<u>Sheep</u>	<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>Sickles</u>	<u>H.T.C.T.</u>	<u>C.T.</u>	<u>Hist.</u>
595	27	2	0	<u>1</u>	0	51	200	190
750.	23	8	0	<u>2</u>	<u>1</u>	52	233	---
1279	25	2	2	<u>1</u>	0	25	156	186
76.5	56	26	16	<u>16</u>	<u>4</u>	138	182	349

The array of sheep 76.5 does not appear to differ in numbers in the pre-Curly-tip fibre types from the usual weak Plateau Array in which the In-parallel concept is not evoked.

An example of such an array is :-

<u>Sheep.</u>	<u>H.H?</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>S.</u>	<u>H.T.C.T.</u>	<u>C.T.</u>
1278 VI!	17	14	3	24	5	0	423

The differences between these arrays is in fibre type associations. In the In-parallel arrays there is a close relationship between the Super-sickle A- and the Hairy-tip-Curly-tip fibres. In these latter non Hairy-tip-Curly-tip fibres are found, as for example Sheep 1278.

It is therefore necessary to consider the array of sheep 76.5 in detail so that it may be shown that despite the fact that although it appears to be a normal weak Plateau it is in reality a Tough Plateau Array with large numbers of Super-sickle B and a few Sickle fibres In-parallel.

Array of Sheep 76.5 VI! Plateau.

Halo-hairs

Large and typical of Tough Plateau	52
Near Super-sickle A	4
Super-sickle A	
Shorter than H.T.C.T. and Halo-hairs	26
Super-sickle A-	
Variable in length	16
Super-sickle B	
Similar length to H.T.C.T. and S.S.A (long)	16*
Sickle Fibres	
Similar in length to S.S.B.	4*
H.T.C.T. resembling S.S.A- (very coarse)	32
H.T.C.T. near S.S.B. and Sickle Fibres and post-natal portion similar. Pre-natal portion not long	28
H.T.C.T. Normal type	78
Curly-tip fibres	
Chalky	33
Very few medullated	149
Total C.T. and H.T.C.T.	320

\* Note: these fibres are regarded as In-parallel.

Thus in this array there is a close association between the Super-sickle A- and the H.T.C.T. fibres. The Hairy-tip-Curly-tip fibres which resemble the Super-sickle/fibres, only resemble them in neck medullation and tend to have a shorter pre-natal region and a lack of association with the Sickle tip. They have,

therefore, probably developed after those Hairy-tip-Curly-tip fibres which closely resemble the Super-sickle A- fibres in tip form as well as in other macroscopic features. However, it might be expected that some Super-sickle B fibres may come before the Super-sickle A- fibres in the fibre type series and therefore be regarded as being In-parallel. The fibre type order in this array is therefore considered to be :-

Tough Plateau Array.

Halo-hairs.

Super-sickle A-

In-parallel fibres.

Super-sickle B fibres.

Sickle fibres.

Hairy-tip-Curly-tip fibres which resemble S.S.B.

Hairy-tip-Curly-tip fibres resembling Super-sickle A.

Hairy-tip-Curly-tip fibres resembling Super-sickle B.

Hairy-tip-Curly-tip fibres, normal type.

Curly-tip fibres.

Histerotrichs.

With our present knowledge of the casual forces of the pre-natal check these In-parallel fibres must be regarded as due to variations in pre-natal fibre density unless it is assumed that different follicles have different reactions to a similar checking force. Such an assumption in the light of the work of Galpin (22) working on the Romney and de Meijere (18) on other mammals appears to be untenable for follicles beginning their development at the same time.

The effects of In-parallelism might be classified into two types. These are really extremes of the one effect and are :-

(a) Very restricted, perhaps only one fibre per 500 being In-parallel.

(b) A considerable number of fibres effected.

The former involves the supposition that individual follicles, because of an unusual position in the skin or perhaps due to some accident of development, have come to exhibit a check of an intensity which is considerably greater than that of the other fibres in the array. This check might what may be termed

a check of 'valley' intensity and on this supposition we are indeed actually thinking that on occasion a Valley Array is limited to only one fibre in a sample of perhaps 200 Curly-tip fibres. This line of thought could well be extended to groups of fibres, so that we picture the array varying between adjacent groups. The result would then be a fine mosaic of arrays. In this way a satisfying explanation is given of the All-In Array. It is not,  $\alpha$  it will be observed, two separate depression<sup>s</sup> which are being postulated, but merely local variations in the pre-natal check. An example of such an array is that of sheep 59.5 quoted above.

In the second type of In-parallelism suggested as being due to the type of check which is not dissimilar to that which is responsible for differences between arrays, but on a somewhat lower plane, large numbers of In-parallel fibres are found. In this case it is postulated that these fibres are the result of a weak 'Ravine' or perhaps a 'valley' type check which is superimposed on the Plateau Array check. In this latter type it would be expected that the checking effect would be extended into the Curly-tip series and would thus give rise to high grade checked Curly-tip fibres which would be expected to grade into peak Curly-tips as the check diminished. If the basic potentialities were of a high order as they would be in many potentially Tough Plateau Arrays and if the check does not extend far into the Curly-tip series then the "Peak" Curly-tip fibres may come to closely resemble the Halo-hairs and Super-sickle A and A- fibres.

Such arrays are scarce and no such array has been found at the back position. An example of such an array has, however, been found at the withers position of Sheep 54/39 VI! No appreciable (D)\* which has the following analysis.

H.H.	S.S.A.	S.S.A-	S.S.B.	Sickles. chalky fine	Ch.C.T.	Peak C.T.	
8	6	1	1	1	4	34	27

\*Note: (D) means a decrease in Halo-hair abundance at the withers position when compared with the standard back position.

The above sample was not completely analysed but was a large sample. This array has very definite Valley characteristics

but there are insufficient Sickle-fibres for it to be classified as such. It is therefore regarded as a weak Plateau closely associated with Valley and as such the Sickle fibres are regarded as In-parallel. In this particular array the checked Curly-tip fibres are too numerous for the Peak Curly-tip fibres to resemble the larger pre-Curly-tip fibres.

Note :- When compared with the pre-Curly-tip population the Sickle-fibres are too numerous for a Plateau Array but in relation to the Curly-tip population these Sickle fibres are quite scarce. The reason for the low pre-Curly-tip counts is considered to be due to loss previous to sampling. In this sample (November) two of the Halo-hairs and five of the Super-sickle A fibres are shed.

-----

S U M M A R Y.

=====

1. Dry's observations on In-parallelism in Non-Plateau Arrays are briefly discussed.
  2. Examples of In-parallelism in Plateau Arrays are given and discussed.
  3. It is suggested that In-parallelism may be due to a localised pre-natal check.
- =====

THE GENETICS OF THE N-TYPE COAT AND HORNS.  
=====

INTRODUCTION.

The inheritance of the N-type coat has been the subject of breeding experiments at Massey Agricultural College by Dr. F.W. Dry. This work has shown that the coat type of the original ram (sheep N.303) was inherited as a single dominant factor. The evidence that Dry was able to present from such a clumsy experimental animal is uniquely conclusive and almost perfect 1 : 1 ratios were obtained with both sons and grandsons of the N-type ram in backcrosses. Thus in his unpublished report on "Recent Research in Kemp" he quotes the results from breeding experiments with the original N-type ram, N.303 as :-

39 N-type : 42 Non-N-type.

This must be regarded as a definite 1 : 1 ratio.

However, some of the results obtained from Dry's early experiments tend to be indefinite, due to the fact that the presence of a simple Mendelian factor was not realised, and for this reason back crosses were only done incidently, as in an endeavour to show the existence of the postulated multifactorial situation the breeding programme was to mate Many Halo-hair animals on Many.

Dry tabulates these early results thus :

	<u>VI.</u>	<u>V.</u>	<u>IV.</u>	<u>III.</u>	<u>II.</u>	<u>I.</u>	<u>Av. Grade.</u>
"42 non-N-type lambs	1	2	8	8	17	6	2.67
"Parents of above lambs	2	6	10	3	16	15	2.81
"Parents of 38 N-type and							
"near-N-type lambs. (lambs	3	7	12	2	7	8	3.31
"grade VI and VI!							

He notes the important fact that "the parents of the non-N-type lambs average not lower in Halo-hair grade than their lambs" and thus suggests that the genetic cause of the N-type or

near-N-type, as distinct from the Not-N-type has played no part in determining the abundance of Halo-hairs of the Not-N-type lambs.

In further experiments with N-type descendants of the original ram more evidence was obtained, resulting in a total of 121 lambs divided into the proportions of 62 and 59. The details of these results are given below as they demonstrate the lack of intermediates between the high and the low Halo-hair gradings.

Thus :-

<u>N and near N-type.</u>		<u>Not N-type.</u>				
VI!	VI.	V.	IV.	III.	II.	I.
48	14	3	10	11	25	10

From this the distinction is not absolutely complete as 3 grade V animals appear. However, these three animals appeared in the original N.303 mating and two of these had definitely high grade dams while the remaining animal had a low grade dam. This latter is continuous with the high, but is discontinuous with the low grades due to a lack of Grades IV and III in the experimental mating in which it appeared. (See page 218 for a more complete discussion of this animal). The significance that may be attached to this break in continuity between Grades will be apparent later (pg. 218).

Also, Dry obtained virtually a 3 : 1 ratio when mating N-type rams with N-type ewes. Thus he was able to conclude that the N factor acts as a single dominant factor.

#### The Expression of the N-factor.

This has been treated quite fully in a previous section and it is sufficient to note here that the N-factor is capable of a slight variation in array expression, a variation which appears to parallel the expression of the Halo-hair gradings treated above. Thus it is possible for the N-factor to give rise to a Grade VI Saddle Array. Evidence for this contention is forthcoming from the ratios quoted above, where there is a distinct break in the continuity of Halo-hair grading in that Grade V is virtually absent. It is notable that Grade VI Halo-hair abundance is generally

associated with a Saddle or perhaps a weak Plateau Array on the standard back position.

Similar variations are found in the recessive of the N-type. These are in Halo-hair Grading, from I to IV, together with wide variations in array. Despite the fact that Leslie (35) has shown that pre-natal environment is not unimportant, there are definite grounds for believing that this variation is largely due to genetic factors not individually recognised. However, due to the fact that Dry found that the N-factor does not influence Halo-hair grading in the recessive condition, the pros and cons of nature versus nurture in relation to variations in Halo-hair grade and array are not treated here for these recessive types.

#### HORNS.

A feature which is often associated with the N-factor is the presence of Horns. These are outstandingly large in rams and were well developed in the original ram, N.303. This association led to the belief that horns were a further expression of the genotype responsible for his coat. However, Dry (41) has been able to produce crossovers, that is Non-N-type animals with horns and therefore concluded that the genes were merely linked.

The fact that linkage does occur is important in the study of the genetics of the N-condition, because the gene for horns can be used as a "marker", when it is suspected that the N-genotype has not come to complete phenotypic expression. Admittedly the occurrence of crossovers must not be neglected but it is considered that the crossover value is sufficiently small not seriously to affect this important use of the horned gene. The phenotypic expression of the horned genotype is subject to some complications and it is, therefore, considered necessary to survey the genetics of the horned condition before treating the genetics of the N type.

## THE INHERITANCE OF HORNS.

Horns in sheep as in other animals are a most noticeable feature and as such have received attention from geneticists. The fact that Polled and Horned are regarded as breed characters has made them important considerations in selection. This selection has made available animals which are virtually homozygous for the polled or horned condition.

### Phenotypic Expression.

The inheritance of hornedness has not, on close inspection, proved to be as simple as it would appear in the light of the inheritance of horns in cattle animals. Thus Wood (42) is quoted by Landauer (43) as noting that "the factor for horns may fail to come to complete expression". Wood's evidence for this is that in breeding experiments he found F1 ewes developing scurs at two or three years of age. Further, he found rams in which scurs appeared. These animals when regarded as horned enabled him to obtain almost perfect ratios. Landauer (43) himself notes that considerable variation in horn size occurs in the Merino, both between and within sexes. Further, Arkell (44) from breeding work based on crosses between the Merino and a hornless breed, concluded that, what he termed knobs, that is, apparently hard horny structure but not true horns, are the expression of homozygosity, while "scurs" are the phenotype of heterozygosity in the ewe.

Similar variations in phenotypic expression are noted by others, i.e. Russell (45 and Thilo (46).

In the N-type ewe the factor for horns (see later) appears to be almost completely recessive to polled, with the result that except in odd ewes which from their breeding appear to be homozygous only one previous to the 1938 season exhibits more than what has been termed "buttons". In 1938 matings were made with the definite object of obtaining homozygous animals. In these matings scurs appeared in four N-type ewe hoggets, while one when 6 months old had 2 to 3 inch horns which were distinctly weaker than the horns found in the ram hoggets of a similar age. These animals have not

yet been tested for homozygosity but as there is good reason to suppose that some at least of these are homozygous it may well be that even in the homozygous state the expression of the factor for horns is repressed in the ewes below the expression in the heterozygous phenotype in the males.

In relation to the expression of the factor for horns in the ram all workers appear to agree that castration has a very distinct limiting effect on the phenotypic expression and therefore the progeny of breeding experiments have almost invariably remained entire until the presence or absence of horns is definite.

This lack of expression in castrated males presents a distinct difficulty with the present material. The reason for this is that animal husbandry considerations have necessitated the castration of rams considered unnecessary for the experiments dealing with the elucidation of the N-factor. Such rams have constituted most of the recessive type animals. This is particularly so with crossovers recessive N-type animals with horns, as inbreeding experiments dealing with the N-factor these have been avoided because their use would impair, or at least greatly complicate the use of the factor for horns as a marker for the N-factor.

In the study of horns in the N-type animal variations are found in horn structure and even in classifying rams such terms as "knobs" and "scurs" have been necessary.

Thus for a complete study of the inheritance of horns it is essential that these variations in phenotypic expression should be recognised. At present in the breeding experiments conducted at Massey Agricultural College the inheritance of horns is merely an incidental feature and, although observations have been taken from time to time during the life of the animal, these have not been sufficiently numerous to form a complete record. Further, the actual records have tended to be colloquial expressions which, while extremely useful for a general expression of the condition of growth are not considered to be sufficiently critical

for accurate work. It is felt that for a complete study photographic records should be made.

However, to facilitate reference a brief description of the actual terms used is considered necessary. These terms are :-

(1) Hairy Wells - These are merely distinct holes in the wool at the position where horns are found. These "wells" are filled with heavy kemp which is often quite long. There is no sign of wool in these "wells", despite the fact that the remainder of the head is heavily woolled.

(2) Buttons - These are usually associated with Hairy Wells. they are typically found in new born lambs which will develop horns. Their importance in this classification is their occurrence in lambs which are some months old. In such lambs they may indicate the presence of the horned genotype (Wood 42). It is common for these lambs to have Hairy Wells in November and to develop Buttons before March.

(3) Scurs - These are horny structures which can be sloughed off if rubbed or scratched. Due to the fact that considerable variation can be found in the size of scurs this classification is a wide one. Some scurs consist merely of large cornified buttons, while others are large and have been found to develop into small although definite horns.

(4) Knobs - These are hard horny structures which develop into distinct although weak horns in the adult. Knobs constitute rather a difficulty in classification in that they appear in some sheep to be a development of scurs while in others they may well be damaged horns. Evidence to be presented later leads to the conclusion that knobs are an indication of the horned genotype.

(5) Horns - These vary considerably in size between lambs of similar ages and are classified as to length and general strength. Thus in the ewe hogget the horns, although of considerable length in March, are weak and would be easily broken, while in many ram hoggets horns of similar length are found to be exceedingly strong and capable of withstanding a considerable amount of "boxing"

Genetics.

The inheritance of horns, as is noted above, has received the attention of numerous workers. This work has been consistent in that it is shown that horns in sheep are inherited on a single factor basis. The actual expression of the genotype has been shown to be sex influenced and this classical work is included in textbooks as an example of sex influenced inheritance. (Babcock and Clausen pg. 549).

However, in the study of the inheritance of the horns associated with the N-type coat it is clear from the preceding section that there may be considerable variation in phenotypical expression. This variation does not appear to be unassociated with the genetics of the coat and although more types of variation are recognised to-day than in the past it is considered that the simple explanation of the text-books may not be a complete explanation of the inheritance of horns, as they occur in the experimental sheep at Massey Agricultural College. It is considered that the N-factor may not be entirely passive in respect to the expression of the horned genotype. That the problem is not simple is evident from the fact that various results have been obtained in different N-type matings. Further, the fact that the exploration of the horned condition is not regarded as of primary importance practical considerations prevent breeding experiments confined to its elucidation. Thus it is that the material for the study of the inheritance of horns in these sheep suffers from some distinct disadvantages.

In a previous section it is mentioned that Dry obtained crossovers between the genotype for the horned condition and the genotype for the N-type coat. Such crossovers are :-

Ram 1221 IV	-	By 852 VI!	/	Ex. Grade I ewe
(big horns)		(big horns)		(polled)
Ram 64.5 II low	-	By 1084 VI!	/	Ex ewe X.1259
(small horns)		(big horns)		(polled)

Both Sire 852 and 1084 obtained numbers of VI! horned rams and low grade polled rams. However, many of these polled animals had soft scurs, buttons or hairy wells. Thus with close observation of the total experimental results, together with the fact that sheep 64.5 had only small horns at approximately 6 months of age this crossover is not as definite as could be desired. In relation to ram 1224 it is important to note that this animal is a definite Grade IV animal and is therefore not sharply contrasted.

These objections appear for most crossovers of this type. A further example is that of sheep 1297 III with  $\frac{1}{2}$  inch scurs at approximately 6 months of age. This animal appeared in a backcross from Sire 904 VI! which resulted in a ratio of 14 Grade VI and VI! to 15 Grade I, II and III, which of course, is a perfect 1 : 1 ratio. The horned results of this backcross are :-

Grade VI! rams with definite horns at least 2 in. long at 6 mths.	5
Grade VI and VI! ewes polled at 6 months	6
Grade VI and VI! ewes with hairy wells at 6 months	<u>3</u>
Total high grade animals of both sexes	<u>14</u>
Low Grade (I, II, and III) rams with distinct scurs ( $\frac{1}{2}$ in.) at 6 months.	1
Low grade rams with small scurs at 6 months	2
Low grade ewes with small scurs at 6 months	0
Low grade ewes with hairy wells	1
Low grade completely polled rams	2
Low grade completely polled ewes	<u>8</u>
Total recessive type animals (Grades I, II and III)	14

Note: One lamb died at birth but was nevertheless graded for Halo-hair abundance.

Thus it appears that this type of crossover has distinct disadvantages and it is considered worth while to explore the situation in other types of crossovers. If crossovers occur at all they should occur in both directions and it should be possible to obtain polled non-N-type animals. Such an animal is :-

Ram 1279 VI! By 1084 VI! / Ex. ewe 698 I.

This sheep has a typical N-type coat. It was classified some months after birth as having slight scurs and as a two-tooth these "slight scurs" could still be found. When compared with the usual N-type for horns and noting the fact that it appeared to be a perfectly complete ram although not used for breeding, it must be regarded as a crossover, that is, a polled N-type animal. It is notable that in this case early scurs must be regarded as merely fortuitous and not as indications of the presence of the factor for horns. This is particularly significant in relation to the previously mentioned fact that low grade rams with scurs were not uncommon in the progeny of 1084. In this respect it is notable that sheep 64.5, the previously quoted example of crossing over, though having scurs not unlike those of sheep 1279, developed definite horns. The implications of this fact will be treated more fully later and it is, therefore, considered sufficient to note that scurs cannot always be regarded as indications of the presence of the horned genotype.

It is therefore clear that the genetics of horns may not be as simple as Dry supposed. However, despite this the fact remains that crossing over does take place and thus it is probable that the inheritance of horns in the Romney is basically simple. Dry, from breeding results quoted below, tentatively concluded that, "horns depend upon H, a single sex influenced factor, dominant in the male, recessive in the female, and that the N and H factors are linked."

This conclusion was based on the following unpublished results :

"N-type or Near-N-type, Horned 18 N-type, Hornless 2.

"Not-N-type, Hornless 17 Not-N-type Horned 2

Thus neglecting the crossovers, which appear to occur in about 1 in 10 matings, he obtained a ratio of 18 : 17, a perfect 1 : 1 ratio. Further, the fact that the two types of crossovers are equal in number is at least significantly in favour of the above conclusion.

The main consideration that prevents the unqualified adoption of the above conclusion is the fact that scurs, regarded

as an expression of the factor H by overseas workers, due to their effect on the ratios obtained in breeding experiments, appear to be a complication in the Genetics of horns in the N-type Romney. If the factor for horns in the Romney is regarded as similar to that in sheep studied elsewhere, then it must be assumed that the H factor may fail to come to expression sufficiently to cause the ram to grow scurs and not horns.

The complications arising out of scurs have been anticipated previously in describing the scurs in sheep 1279 VI!, which was discussed as an example of<sup>a</sup> crossover. A further factor of importance is that scurs are extremely common in some backcrosses using a heavily horned N-type ram. Both these considerations are closely associated with the further fact that in low Halo-hair grade Horned animals the factor for horns appears to come to relatively incomplete expression when compared with its phenotypic appearance in the N-type animals.

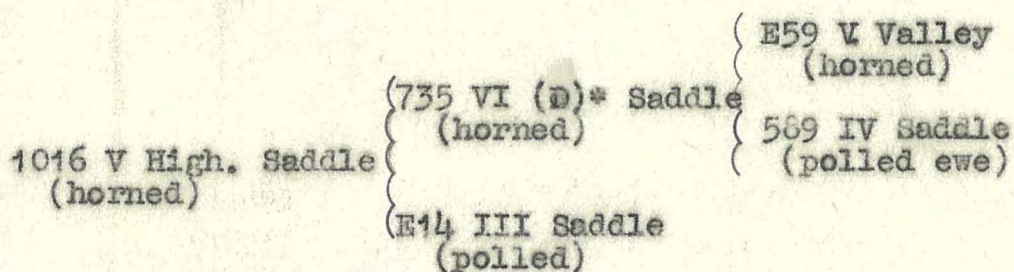
That the expression of the Horned factor is sex-influenced there is little doubt. Dry (unpublished paper) in concluding this is the case quotes his evidence as "two N-type Hornless ewes sired by an N-type Horned ram each had a ram lamb by a none-N-type Hornless ram. These ram lambs were both N-type and horned." This suggests that the factor under review is identical with that studied overseas. Whether the development of this horned factor is prevented by castration, as is the factor studied by overseas workers, is unknown. However, attention has been confined to male animals which, if not actually mated, must be regarded as sexually normal by the presence of other characters.

In relation to the effect of the presence of the N-factor in the phenotype of the factor H, the following breeding results are important.

The progeny and pedigree of Sire 1016 Grade V Valley. This animal is regarded as not carrying the N-factor, while exhibiting high Halo-hair abundance. It is also closely related to the N-type animals and is descended from a horned ram who received his horns from his sire. Thus it is that 1016 has a pedigree for

the factor H which is not associated with the N-factor. Unfortunately the factor for horns was not explored in this strain by breeding and the sire of 735 was dead before the N-factor was recognised and the importance of horns therefore was not even guessed. Thus it is that no real backcrosses were done with this sire and he was used merely as a demonstration that by mating Many on Many for Halo-hair grading high Halo-hair concentration could be obtained.

Pedigree of Sire 1016 V high. Saddle. Horned.



\*Note:- (D) signifies a reduction in Halo-hair abundance at the withers.

Progeny of Sire 1016. V, high, Saddle. Horned.

Mated with low grade ewes. Some of the ewes graded as high as VI. Ord. but such ewes were of low grade breeding and therefore definitely unlikely to carry the N factor. These high grade ewes are unrelated to N-type animals. Only male progeny are quoted.

1324 V.	Saddle.	Scurs.	1307 IV	Saddle (high)	horns
1350 III	Plain	Scurs	1343 VI	Saddle (high)	horns 3"
86.5 VI	Saddle-Valley	Scurs	1342 VI	Saddle	horns
80.5 III	Saddle	Scurs	1253 VI	Saddle	horns
			1314 V	Ravine-Saddle	knobs
			1315 V	Saddle	horns
			1292 VI	Plateau	horns 6"
			1286 III	Valley	horns
			1287 VI	Saddle	horns
			81.5 V	Valley-shadow	horns
			61.5 VI	Valley	horns
			82.5 VI	Saddle	horns

## Summary :

1 VI! horns (6 in.)	
10 not VI! horns	{ 9 quite small horns 1 VI high Brd. P.N. def. 3 in horns
1 V knobs	
<u>4</u> Scurs.	
Total	16 rams.

The Grade VI high animal with the 3 inch horns is a coarse Saddle near Plateau and has the following analysis :

<u>H.H.</u>	<u>S.S.A.</u>	<u>S.S.A-</u>	<u>S.S.B.</u>	<u>Sickles</u>	<u>C.T.</u>	<u>Hist.</u>
6	7	1	8	8	22½	198

Thus it is clear that this animal, both in Halo-hair Grading and Array approaches closely to the Plateau or N-type. The VI! animal is a definite although weak Plateau animal. The remainder which are regarded as definitely horned have the following arrays :-

Saddle-near-N-type	2
Saddle. definite	5
Not Saddle	3

This analysis shows that in those animals in which the factor H has come to most complete expression - particularly sheep 1343 - the array appears to closely resemble Plateau.

In relation to the animals with scurs the following is what is found :-

Sheep

1350 III	Slight scurs or buttons	→ Plain
86.5 VI	Scurs	Saddle-Valley
80.5 III	Scurs	Saddle-typical
1324 V	Scurs	Saddle-typical

In these animals the size of the scur appears to be roughly paralleled by the array.

It is therefore possible to trace a gradation in type of horned structure from the definitely horned N-type animal to the

slightly scured Grade III Plain animal. Variations occur within this series, especially in array, but it is considered that these do not seriously impair the continuity.

The occurrence of such a series in a backcross raises important questions as to the expression and the inheritance of the genotype for horns. If Arkell (44) is followed then scurs will be regarded as the heterozygous expression of the factor for horns and all these animals must be regarded as carrying the factor H. In this case it is clear that if the monofactorial basis of inheritance is to be substantiated then Sire 1016 must be regarded as homozygous for the factor H.

An alternative explanation is that many of the ewes are heterozygous and through chance pass their single factor on to their offspring. An analysis of the chances involved was made and the inheritance of the ewes was studied with the object of determining whether any of these lambs had any chance of obtaining the factor for horns from that source. In most cases the records of the maternal grandparents were available but in no case was it possible to obtain complete records in a further generation. In some cases the records did not extend past the ewe, but in these cases the ewe was <sup>an</sup> introduced ewe from a stud Romney flock where mass selection is practiced by culling the ram lambs that show scurs or horns. Thus after a few generations of such selection within a limited population it is probable that a low frequency for horns is obtained and therefore the possibility of these ewes carrying the factor for horns has been neglected. Further, in the remainder of the ewes in which only the maternal grandparents are available, it is improbable for the same reason as that given above, that the grand-dam carries the factor for horns. However, it was found that seven of the dams used in backcrosses had a horned sire. Thus these ewes, neglecting their dams, have one chance in two of carrying the H factor and therefore one chance in four of being responsible for the occurrence of horns in their male progeny.

Summarised the two types are :-

Rams regarded as probably entirely dependent on 1016 for horns	6
Rams with 1 chance in 4 of obtaining the horned factor from their dams, and one chance in two of ob- taining the factor from Sire 1016	<u>8</u>
Total	14

These chances were analysed by the Chi-square test and the greatest possible gene frequency was assumed for the factor H. This frequency assumes that all the ewes are heterozygous. On this assumption when acurs are regarded as due to the factor H, the chances of Sire 1016 not being homozygous are <sup>only</sup> about 7 in 100. Actually, of course, the chances are probably considerably greater than this, as it is highly improbable that all the ewes are heterozygous. Thus it is apparent that even if the ewes are all heterozygous that the only tenable explanation of the single factor theory is that Sire 1016 is homozygous for the factor for Horns.

If sheep 1016 is homozygous for the factor H, then on the theory that the factor for horns is dominant in the males and recessive in the females, all the female progeny will be polled and all the male progeny should exhibit horns. The best method of determining whether these ewes are heterozygous, that is if recessivity is absolute, is to backcross them with a sire that is polled and therefore cannot carry the H factor. In such a mating half the rams should be horned if the ewes are heterozygous and any particular ewe that produced a horned ram lamb in such a mating would be regarded as carrying the factor H.

No such mating has been done with the ewe progeny of sheep 1016 but in the light of such possible matings being made in the future the ewe lambs were studied carefully in an endeavour to determine whether it may be possible to recognise the factor for horns in the heterozygous state in the ewes or, in other words, whether the horned genotype is completely recessive in the ewes. This exploration has a definite practical application as horns are a source of loss to the Romney breeders and although all ram lambs that show horns are rigidly culled, it is impossible to cull the

the ewe lambs until they, as ewes, have produced a horned ram lamb. Thus it is considered a duty to explore the possibilities of recognising the factor H in the heterozygous state in the ewe lambs.

A summary of these observations is :-

1937 ewe lambs :-

<u>Sheep</u>	<u>As judged at 10/12/38.</u>	<u>As at 7/1/39.</u>
1329 VI! Plateau	Hairy Wells	Dead
1330 IV Saddle	Not horns	Hairy wells.
1308 VI! Plat.-Saddle	Not horns	1" Scurs.
1340 VI Valley-Saddle	Hairy Wells	Hairy wells.
1328 VI Saddle	--	Hairy wells.
1252 VI! Plat.-Saddle	Hairy wells	Hairy wells.
1290 IV Saddle	Hairy wells	Hairy wells.
1406 V Ravine-Valley	Hairy wells	Hairy wells.
1306 IV Saddle	Not horns	Hairy wells
1320 V Saddle	Not horns	Hairy wells.
1291 IV+ Saddle	Not horns	Not horns.
1405 VI Saddle	Not horns	Not horns.

From the above it is apparent that all the ewe lambs except two exhibit Hairy Wells. The uniqueness of this result is evidenced by the following high grade animals of the same year :-

*1303 VI! Plateau	Not horns.	Not horns.
*1318 VI! Plateau	Not horns	Not horns.
1322 IV Saddle	Not horns	Not horns.
1404 VI Saddle	Not horns	Not horns.
1246 V (high) Ravine	Not horns	Not horns.

\*Note: Both 1303 and 1318 are of N-type breeding being daughters of Sire 904, himself an N-type son of E303 the original N-type ram.

Three of these animals (the non-N-type) are, from their breeding, quite unlikely to have the factor for horns. The N-type animals have been included to demonstrate that the appearance of Hairy Wells is not merely an influence of the high Halo-hair grading the 1938 ewe lambs are not included as they are essentially

identical with those quoted above. It is, however, notable that one definitely Horned ewe was obtained. This ewe is descended from ewe 661 VI and thus has the horned ram E59 as its maternal grandsire. It is therefore easy to suggest that this ewe lamb is homozygous for the factor for horns.

In the light of the above it is considered that the factor for horns may not be completely recessive in the ewe, and its complete expression may in the heterozygous state be the appearance of Hairy Wells. In some cases, however, the factor appears to be completely recessive and it is suggested that this complete lack of expression may in some way be associated with Halo-hair grading. It is, however, apparent from the above that a very high Halo-hair grading (N-type) is not alone the cause of Hairy Wells in the ewe. Neither is the appearance of Hairy Wells limited to the high Halo-hair grades, as three Grades IVs. are found with Hairy Wells. It is, however, notable that of the N-type ewe progeny of Sire 1016, two have definite Hairy wells developed early, while the other has 1 inch scurs.

The foregoing discussion is based on Arkell's assumption (44) that the factor for horns can come to incomplete expression and that scurs must be regarded as the phenotype of the heterozygous condition. With this assumption it is considered that the breeding experiments of Sire 1016 provides evidence in favour of Dry's tentative conclusion that the inheritance of horns in the Romney is dependent on a single, sex influenced, factor.

A possibility is that scurs are fortuitous and not due to the presence of the N factor. On this suggestion the breeding results of Sire 1016 are :-

4 non-horns : 12 horns.

If this is a real backcross, as there is every reason to believe it is, this should be a 1:1 ratio. The chances that so wide a deviation from a 1:1 ratio could be obtained through random variation or sampling error was found by the Chisquare test to be of the order of 4 in 100. Further, the fact that scurs have been shown (page 186 ) to be closely associated through a graded series

of intermediates with real horns, suggests that the distinction between the horned and the polled phenotype would be arbitrary.

Thus it is legitimate to consider scurs <sup>in non-N-type animals</sup> are not "merely fortuitous" growths but are the expression of the "something" which can give horns.

That the Horned phenotype is capable of considerable variation is apparent and in the discussion of this variation evidence was presented that led to the conclusion that, "in those animals in which the factor H has come to most complete expression ....the array appears to closely resemble Plateau". It has also been shown that in the ewe progeny of Sire 1016, "the N-type coat is not alone the cause of Hairy Wells". It is therefore proposed to survey the appearance of horns in the N-type animals and to compare them with the occurrence of horns in the Non-N-type animals as typified by the progeny of sheep 1016.

The material available is for the most part confined to rams as it is clear that the presence of the factor H in the ewes may on occasion be completely recessive. Difficulty is immediately encountered, due to the fact that it is unknown whether the sire is homozygous or heterozygous. If, as has been suggested, the factor for horns is not completely recessive in the ewe, it may well be that it is not completely dominant in the ram. If this is so it should be possible to obtain rough ratios of particularly large specimens where there is reason to believe that a heterozygous or homozygous ewe has been used. However, most of the following are the result of backcross matings, that is, N-type sires mated with low grade polled ewes. Actually, however, it must be remembered that many of these backcross matings involve the use of ewes that are recessive N animals and it is therefore conceivable that some at least of these may carry the factor for horns as a recessive. Such ewes are probably scarce as they could only occur in a crossover or in the progeny of a crossover. Thus :- Sire 1016 V high Saddle.

The male progeny of 1016 have been quoted in full previously (pg.191 ) and therefore a summary is considered

sufficient for present purposes.

Sire 1016 V high. Saddle. Horns rather weak.

6 inch horns	1	N-type VI!
3 inch horns	1	Grade VI high. Border-line N-type
small horns	9	Grades VI, V and IV.
scurs	<u>4</u>	Grades VI ord. V and III
Total	15	

Sire 735 VI (D). Horned. Saddle near Plateau.

This animal is the sire of ram 1016 and it is considered that perhaps it carried the N genotype which may not have come to complete expression (see later). Unfortunately the records of horns in the progeny of this ram are rather meagre, due mainly to the fact that of the total sons, which only amounted to six, one was castrated and one died at birth. A further source of difficulty is that it was not then realised how much variation there may be in the Horned genotype and thus an analysis similar to that made above for the progeny of 1016 is impossible. However, this is not a really serious disadvantage, as records were made late in the first year when the horned genotype would at least be expressed by the occurrence of scurs which are distinguished.

The results are :-

1084 VI!	Plateau.	Large horns.
1016 V high	Saddle.	Medium horns.
1085 V high	Valley	Polled.
1072 VI	Valley	Polled.

In the above it is apparent that the only animal with large horns is a Grade VI! Sheep 1016 has been treated previously but it is considered necessary to remark that despite the fact that it is probably homozygous for horns this Grade V animal has only medium sized horns which are definitely smaller than those of its half brother sheep 1084.

Sire 1204 VI (D) Saddle. Borderline N-type. Horned.

1204 VI (D) Saddle. (horns)	{	852 ♂ VI! Plateau (horns)	{	Sire N.303 VI! Plateau-Saddle (horned).
				Dam Voss.184 I Valley.
		624 ♀ IV Saddle.		

Sheep 1204 was at first typed as having scurs and thus the factor for horns appears to have been slow in reaching full expression. This animal gave breeding results which lead to the conclusion that it may well carry the N genotype. In brief these results are :-

Mated with ewes of unknown birthcoat.

VI! and VI for Halo-hairs	10
V. and IV " " "	3
Below Grade V " "	18 (14 Grades I and II)

In relation to horns the results do not cover the total sheep sired as 20 of these are 1939 lambs and therefore no observations have yet been made on their horns.

50.5 VI!	Plateau.	Big horns.	(March 1939)
97.5 VI!	Plateau	Heavy knobs	(March 1939) Damaged horns.
54.5 II	Valley	Small scurs	(March 1939)
45.5 I	Plain	Trace of scurs	(March 1939)

This animal is particularly important when studied with the results obtained from Sire 1015 IV Saddle, Horned, which are quoted below. Unlike its contemporary this animal is not regarded as having the N-factor as it has produced no Grade VI! and only one Grade VI animal in backcrosses (see later).

Pedigree of Sire 1015 Saddle, Horned.

1015 IV. Horned.	{	750 ♂ VI! horned.	{	N.303 VI! Horned.
				541 VI. Plateau.
	{	678 ♀ VI!	{	N.303 VI! Horned.
				886 V. Saddle.

This animal is therefore regarded as a crossover for the Horned and the N-factor. It is notable that the VI! Plateau parents are regarded as having factors other than N tending to the abundance of Halo-hairs which are covered by the N phenotype.

The male progeny of this animal, when summarised for horns are:-

Backcrossed to low Grade ewes:

60.5 I Valley. small scurs.

73.5 II Valley. polled.

74.5 III Valley. polled.

32.5 III Valley. polled.

If scurs are regarded as due to the presence of the factor H as from the discussion of Sire 1016 there is evidence to believe they are, then this is a 1 horned: 3 Non-horned, ratio. However, this case in itself does not constitute evidence that scurs may be so regarded as with such small numbers a ratio of 4:0 is not significantly different from a 1 : 1 ratio.

Thus it appears in the light of the past discussion of sheep 1016 that the factor for horns may have been passed on to sheep 60.5 which, due to its low Halo-hair grading fails to permit the genotype to come to full expression. This view obtains support from a consideration of the progeny of Sheep 1204 where, as is pointed out, the N-type animals have distinct horns and the low grade animals, despite the fact that they probably carry the same factor, merely have small scurs similar to those found in Sheep 60.5.

It is considered necessary in order to clarify the position as regards the possible association of the horned phenotype and the N-type coat to summarise the above observations by tabulating the variation in the horned phenotype with the Halo-hair grading. Non-N-type.

These are entire ram lambs and the grading for horns is a January or February grading.

Grade VI.*	1 with 3" horns.	Grade VI!	2 with 6" horns.
	1 with 1" horns.		1 with heavy knobs (damaged).
	3 with 'small' horns.		
Grade V	3 with 'small' horns.		
	1 with big scurs.		
Grade IV**	1 with small horns		
Grade III	1 with 1½" horns.		
	1 with buttons.		
Grade II	2 with small horns.		
Grade I	1 with small scurs.		

\* All these Grade VI and Grade V animals are the progeny of Sire 1016.

\*\* This Grade IV animal is a son of Sire 1016.

From this it may well be that the N-type coat assists in the complete expression of the horned genotype.

In a later section evidence is presented which leads to the conclusion that there are probably two distinct types of inheritance responsible for the N-type coat. It is shown that one of these is probably multifactorial while the other is due to a single factor or to very few closely linked factors. The results quoted above are in the main from the former type of inheritance and it is thus important to explore the possibilities of any differences occurring in the horned phenotype that can be associated with these two postulated differences in the N genotype. In this respect the study of the horned condition in Sire 1084 is illuminating.

Sheep 1084 VI! is a son of Sire 735 and is therefore a half-brother of Sire 1016. When backcrossed this animal, although giving rather imperfect ratios must be regarded as dependent for its N-type coat on the single factor N-genotype hypothesis.

Classified as to horn size on March determinations the VI! male progeny of Sire 1084 for 1939 are :-

Grade VI! rams -

6" horns or more	5
3" horns	1
2" horns	1
Small or damaged horns	2
$\frac{1}{2}$ inch scurs	2
scurs	1
Buttons	1*
Polled	<u>1</u>
Total VI! rams	14

\*Note: This animal was only observed once as it died previously to March. However, in the light of the previous discussion of the expression of horns in the N-type animals this animal may well be regarded as a cross-over.

Thus it is clear that when these animals are compared with those quoted above that there is no real difference with the present rather meagre material between the expression of the horned genotype in what may be termed the multifactorial N-type and the single factor N-type.

An interesting feature of the progeny of Sire 1084 in relation to the expression of the factor for horns is apparent when the low Grade progeny are studied.

When tabulated these low grade scored animals are :-

<u>Sheep.</u>	<u>Horned condition</u>	<u>Sheep</u>	<u>Horned condition.</u>
36.5 I	small scurs	1333 I	scurs
43.5 II	scurs	1316 I	scurs
56.5 II	scurs	1237 II	1" horns
64.5 II	small horns	1338 II	scurs
		1257 III	scurs

These animals do not represent all the low grade progeny of 1084, but only those which cannot be termed polled. Actually there are 23 completely polled progeny of this sire and 9 of these

are rams. It is, however, significant that these animals quoted above are all rams and that all the female progeny are completely polled.

The explanation of the above presents a very definite problem and until this is solved all theories of the expression of horns in sheep must be treated with caution. That the explanation is not to be found in the homozygosity of Sire 1084 is apparent from the fact that 9 completely polled rams were found and in view of the discussion of the horned phenotype in Sire 1016 it is definitely improbable that these polled animals carry the horned genotype.

An obvious explanation is that the horned genotype is obtained from the dams of these lambs. The pedigrees of these ewes were therefore studied as far as possible (two were flock ewes) and it was found that in no case did any horned sire appear in these pedigrees. Admittedly not more than grandparents were available but, as is reasoned in the discussion of the progeny of Sire 1016, it is improbable that the frequency of the horned factor is sufficiently high to explain the facts, when it is remembered that experimental sheep were obtained from Stud Romney flocks in which there is rigid selection against horns.

That the appearance of these scurs is associated with sex there seems to be little doubt, but their complete explanation cannot be attempted at present, due to the absence of sufficient material. It is, however, clear that such a study is urgently necessary if the inheritance of horns in the Romney is to be clarified and it is further considered that light may be thrown on the working of this gene and would thus constitute a valuable addition to our capital of knowledge of the physiological genetics of the sheep.

---

S U M M A R Y.  
=====

1. Dry's evidence that the N-type coat is conditioned by a single factor, dominant in the Non-N-type, is briefly discussed.
2. Gradations which occur between N and Non-N-type coat are briefly described and discussed.

Horns.

3. The importance of the gene for horns in relation to the study of the inheritance of the N-type is briefly discussed.
4. Reference is made to past work on the inheritance of horns in sheep other than the Romney. Special attention is directed to those observations dealing with the failure of the factor for horns to come to complete expression.
5. In the homozygous ewe the horns appear to be smaller than in the heterozygous ram.
6. Variations in the expression of the horned phenotype in the Romney are discussed, classified and described.
7. The material available for the study of horns in the Romney is described.
8. Horned Non-N-type progeny with N-type horned fathers are described and discussed.
9. A polled N-type animal is described and discussed.
10. Evidence is presented to show that scurs in the Romney cannot always be regarded as an expression of the genotype for horns.
11. In the progeny of Sire 1016 the factor for horns comes to the most complete expression where there is Plateau at the Standard Back Position.

12. If scurs are regarded as the heterozygous expression of the factor for horns, Sire 1016 is considered to be homozygous for the factor for horns.
13. The ewe progeny of Sire 1016 are classified for the phenotypic expression of horns. It is found that the factor for horns may, in the heterozygous state in the ewe, be phenotypically expressed as Hairy Wells.
14. The presence of the N-type coat is found to aid the expression of the factor for horns.
15. No real difference was found between the appearance of horns in those animals with the N-factor and those animals with a multifactorial N-type coat.
16. The scurred Non-N-type progeny of Sire 1084 are tabulated and briefly discussed.

=====

THE INHERITANCE OF THE N-TYPE COAT

This section is partly anticipated in the previous section when it pointed out that Dry has produced evidence that the N-type coat may be inherited as a simple dominant mendelian character. That this is the type of inheritance in some N-type animals, there appears to be little doubt and admirable 1:1 ratios have been obtained and are quoted by Dry in his unpublished report. However in certain N-type animals distinctly poor 1:1 ratios have been obtained from backcrosses and these necessitate further study. Dry (unpub.) quotes results which lead him to conclude that, "it is possible that the N-type may have a multifactorial basis as usually understood, depending upon the additive affect of a number of factors".

He does however suggest the alternative that "restricting factors may have prevented the grade being as high as VI". Further he notes that "we can depend upon it that neither parent of N.303 was of the N-type". Thus it is clear that the inheritance of the N-type presents definite problems and this section is an endeavour to analyse and add to the explanations of these problems with the object of some tentative conclusions which may indicate future breeding experiments.

Dry's results are quoted in the previous section, but for completeness are re-stated here. They are:

"The original ram N.303 and an N-type son of his from a No-Halo ewe were mated with Not-N-type ewes, ewes that were neither N-type nor Near-N-type, and three N-type daughters of the original ram from Not-N-type ewes were put to a Grade II ram".

"The combined results were:

N-type	25 )	
	)	39
Near-N-type	14 )	
Not-N-type	42	

Further he quotes evidence which leads him to state, "It will be seen that these fact suggest that the genetic cause of N-type or Near-N-type as distinct from Not-N-type has played no part in determining the abundance of Halo-hairs of the Not-N-type lambs".

Thus it is considered that Dry has presented fairly conclusive proof that the coat of Sire N.303 was conditioned by a single dominant factor.

Dry in the same paper quotes the results of other experiments designed to study the inheritance of Halo-hairs abundance and from the results tabulated he concludes that the only logical explanation is a multifactorial type of inheritance. He points out that these experiments are with animals unrelated to the N.303 animal and although high grades were used, none of these animals had a Plateau Array at the Standard Back position. In the same paper (p.18) he tabulates the arrays of these animals and in the discussion points out that the Valley Array is by far the most common array. He discusses the wide variations which can occur within the Valley classification and mentions that at this time (1937), Saddle by Saddle matings had not been made.

These Saddle matings have since been completed and have confirmed his multifactorial explanation. From the point of view of the inheritance of the N-type, these matings are particularly important as typical N-type progeny were obtained.

These results are;

E 59 V Valley	)		
	)	E 735 VI (D)* Saddle	)
E 589 IV Saddle	)		) E 1016V high. Saddle
	)	E 14 III Saddle	)

---

\* (D) signifies a drop in Halo-hair abundance on the withers position.

## Breeding results:

1937

<u>Ewes:</u>		<u>Progeny</u>	
Plateau	0	Plateau N-type VI!	3
Saddle	12	Saddle	9
Ravine	4	Ravine	2 (both near Saddle)
Valley	0	Valley	1
Plain	0	Plain	1
Total	<u>16</u>	Total	<u>16</u>

1938

<u>Ewes</u>		<u>Progeny</u>	
Plateau	0	Plateau N-type VI!	1
Saddle	9	Saddle (one N-type)	6
Ravine	0	Ravine	0
Valley	0	Valley	2
Total	<u>9</u>	Total	<u>9</u>

The reason for the small numbers of ewes used in 1938 was the shortage of Saddle ewes in the experimental flock.

Note: In both these experiments where a ewe has produced twins the ewe is counted twice.

All the N-type animals except one have definite although weak Plateau Arrays. This animal, Sheep 85.5, is a most unusual type, in that despite the fact that it had a typical VI!birthcoat, it had a quite definite Saddle Array.

It therefore appears that the N-type can be built up "brick by brick" as it were, by mating animals which do not carry the N-factor, but with an apparently multifactorial genotype for high abundance of Halo-hairs. The same result would be obtained if a multifactorial limiting factor situation were postulated, only in this case there would be a loss of these when mating "Many" on "Many", thus permitting the N-factor to come to complete expression. In this case "Many" is regarded as being due to a genotype with few limiting factors, while "Few" has many limiting

factors. The separation of these two contrasting possibilities is not easy, but will receive some attention later when further material will be presented and discussed. However the fact that N-type has never appeared in low grade by low grade matings of animals unrelated to definite N-type. This together with the fact that Dry has found the high grade N.303 type coat to be dominant over the low grade type makes the limiting factor explanation improbable.

Further support for this multifactorial hypothesis is obtained from matings of sons of 1016. These matings consist of backcrosses with flock ewes, and due to the fact that they have been obtained in the current season, the arrays have not been determined. These are:

Sire	VI!	VI	V	IV	III	II	I
1342 VI Ord.* Saddle	6	5	1	1	4	8	0
1343 VI high. Saddle- Plateau	0	3	1	0	6	8	2
1307 VI Saddle (near Plateau	0	2	2	2	2	4	1
Total	0	10	4	3	12	20	3
Dry's grading		Many		Medium		Few	None
		14		15		20	3

From Dry's gradings of these animals it is apparent that there is no trough in the gradings as would be expected if a single factor was important. These are similar to Dry's results for the inheritance of Halo-hair grading other than the N-type VI! which he interpreted as multifactorial and therefore it is considered that these matings provide evidence for the multifactorial interpretation of Sire 1016.

A further explanation is that Sire 1016 carried the N-factor together with a limiting factor or factors which prevented the N-genotype from coming to complete expression. On this theory, the explanation is that when mated these limiting f

\*Note:- The term "Ord." means "ordinary" and is used to denote that Grade VI is distinctly not Grade VI!

factors were lost and typical N-type animals appeared. It must be pointed out that this conception is rather different from the previous limiting factor theory, as 1016 himself is here regarded as carrying limiting factors and this does not involve the genotype of the ewes who are therefore regarded as merely high grade and not as limited N-genotype.

Evidence in support of this explanation comes from the mating results of Sire 1342. This ram is the son of Sire 1016 and his dam is ewe 661, a Grade VI Saddle animal.

with  
When mated/Saddle ewes, the following results were obtained:-

VI!	Plateau	5
VI	Saddle	1
V	Ravine	2
IV	Saddle	1
III	Valley	2

Thus this sire gives definite N-type progeny when mated with high grade Saddle ewes. These N-type progeny may be simply explained on the assumption of limiting factors, especially as the ratio of VI! to non-VI! is 5:6. However, in view of the fact that the N-type is the top grade, it may be that the facts are not incompatible with a multifactorial situation, some N-type being tough and therefore well within the Plateau series, others being weak and thus forming a series from the typically tough Plateau N-type to the VI Saddle and the other Non - N-type animals.

Further support for this limiting factor explanation is forthcoming from Sire 1084 who is a half brother of Sire 1016. This animal is treated more fully later and is regarded from breeding results as probably carrying the N-factor.

If both 1084 and 1016 carry the N-factor, then it is possible that they obtained the N-factor from their common sire, Sheep E 735. The supposition that the sire would be responsible for the N-factor of 1016, if he carries it, is strengthened by the fact that the breeding results of E 14, the dam of 1016 make it unlikely that she carried the N-factor.

The breeding performances of this ewe and her progeny are therefore definitely pertinent.

Pedigree of ewe E 14 III Saddle:

"Very Hairy" ram	)	
	)	E 14 III Saddle
E 286 "Very Hairy" ewe	)	

Note;- These "Very Hairy" animals were Stud Romneys that were part of the original experimental flock collected by Dry for the study of wool characters. They were non kempy, but from microscopic determinations were shown to be heavily medullated. (Note: The benzol test was unknown in these early days). It is very improbable that either of these animals carried the N-factor as being Stud animals, they would have been definitely culled at docking, if they had shown any N-type characteristics.

Before detailing the progeny of E 14, it is considered worth while to survey briefly the breeding record of Sire "Very Hairy" when mated to "Very Hairy" ewes. This is;

Grades	Numbers of animals
I	3
II	3
III	16
IV	10
V	7
VI	2

This is not in the least like a 1 Many : 1 Many ratio and it is therefore unlikely that this sire carried the N-factor. Due however to the earliness of the array determinations, (the Halo-hair grading was essentially the same as now) and to the fact that the "Very Hairy" dam of E 14 is virtually an unknown quantity, it is necessary to survey the progeny of this ewe.

## The progeny of Dam E 14 III are:

1932	To M.A.C. 745 IV	639 ♀ probably Valley
1933	To E 59 V Valley	*E 741 ♀ IV
1934	To 611 II	977 ♀ II Ravine, nearly Saddle 976 ♀ II Ravine
1935	To 735 VI	1016 ♂ V high. Valley
1936	To 852 VI!	*1158 ♀ II Valley (backcross 852 gave a good 1:1 ratio) 1159 ♀ VI! Plateau

## The grandchildren of E 14 are:

639 ♀ IV Probably Valley.

1934	To N.303 VI!	868 ♀ IV Valley (backcross)
1935	To 767 I	*1009 ♂ IV Valley
1936	To 915 I	*1132 ♂ II Valley

868 ♀ IV Valley (Note this animal is the grandchild of E 14)

1936	To 864 II	1153 ♂ II Valley
------	-----------	------------------

It is therefore unlikely that ewe 639 IV carried the N-factor.

977 ♀ II Ravine, nearly Saddle.

1936	To 852 VI!	1189 ♀ VI! Plateau (backcross)
1937	To <u>1016</u> V	1314 ♂ V Ravine-Saddle
1938	To <u>1016</u> V	1315 ♂ V Saddle 79.5 ♀ III Saddle 80.5 ♂ III Saddle

Thus ewe 977 Ravine is a typical low grade animal.

976 ♀ II Ravine

1936	To 852 VI!	1146 ♂ VI Array not determined (dead)
------	------------	--

This appears to be a typical back cross result.

From this evidence it appears to be very unlikely that E 14 carried the N-factor, and therefore if Sire 1016 is regarded as a limited N-type animal, it must be assumed that the N-factor was obtained from Sire 735.

A further fact of importance as to whether or not Sire 1016 carries the N-factor is that in a previous section, it has been shown that this animal is probably homozygous for horns.

---

Note: Those animals marked \* were not used for breeding purposes.



If the N-type which 1084 exhibits is dependent on a single factor, then he must have obtained it from either his sire or his dam. It is therefore proposed to explore the possibilities of his having obtained this single factor from his dam.

Pedigree of Ewe E 164 V Valley near Saddle (born 1930)

"Very Hairy" ram	)	
	)	
	)	E 164 V ♀
	)	
"Very Hairy" ewe E 264	)	

The term "Very Hairy" has been previously dealt with and therefore will not be discussed here. It is notable that ewes E 164, and E 14, which is discussed as the dam of 1016, are paternal half sisters and therefore it is unlikely that E 164 obtained the N-factor from her sire. In relation to her "Very Hairy" dam even less material is available as this ewe was only used in the experimental flock for one season. It is therefore apparent that little can be found from the pedigree and as with E 14, attention must be focused on the progeny of Ewe E 164.

The progeny of Dam E 164 V Valley-Saddle are:

1932	To E 59 V Valley ♂	641 II Valley (concluded*) ♀
1933 and 1934	no lamb.	
<del>1935</del>	To E 735 VI (D) Saddle	1084 VI! Plateau ♂
		*1085 V high. Valley (shallow**) ♂
1936	To E 669 V Valley	*1192 IV Valley ♀
		*1193 IV Valley ♀

\*Indicates that these animals were never mated.

†The term "concluded" is a common term for 1932 samples as it was about this time that Dry first recognized that arrays existed in the coat of the sheep and the samples for that year (1932) were slightly damaged due to late sampling. Thus it is improbable that any serious error was made, but due to the lack of certainty these arrays carry the term "concluded".

\*\*Valley (shallow)" indicates that the array approaches a Saddle Array, due to the fact that the effects of the pre-natal check although sufficient to give some fine Sickle fibres and checked Curly tip fibres, has been insufficient to give numbers typical of the Valley Array.

From the above it is apparent that no mating even resembling a backcross has been made, and the general programme has been to mate Many on Many. This type of mating has given one VI! ram which appears from the mating to be similar to Sire 1016. From this it appears unlikely that this ewe carried the N-factor. However, further exploration is possible, as ewe E 641 has been backcrossed, and therefore its breeding record is of definite interest to this problem. This ewe is particularly important as its sire is E 59 who is also the sire of Ram 735 IV.

The progeny of Ewe 641 II Valley (concluded) are:

1934	To 611 II Valley	921 I Ravine ♀
1935	To 995 II Valley	*1103 II - ♂ 1104 III Valley ♂
1936	To 827 II Valley	No lamb
1937	To 1084 VI! Plateau	1327 VI! Plateau ♂
1938	To 1084 VI! Plateau	86.5 II Ravine ♀

\*This animal died before a sample was obtained for array determination. It is apparent from the above that this ewe has

obtained no intermediate progeny in either Halo-hair grading or array when mated to her maternal half-brother Sire 1084 VI!

Further in the Few to Few matings for Halo-hair abundance, she has always obtained the expected type of progeny. Thus this animal appears to be a typical non-N-type ewe despite the fact that she was produced in a mating of Many on Many and that one of these, her sire, is E 59 who as the sire of 735 must be regarded with suspicion as regards the N-type genotype.

The evidence for or against 1084 having obtained the N-factor from his dam, is not conclusive and there appears to be no means of obtaining positive evidence. It does however seem unlikely that the dam was responsible. Further evidence, but of a rather negative type is provided by a comparison of matings of Few on Few for Halo-hair abundance, which matings have given results that are very similar to those obtained when ewe E 164 was mated to high grade sires.

It is therefore clear that in a study of the inheritance of the N-type coat that the progeny of 1084 are important.

## Progeny of Sire 1084 VI!:

1937

<u>Dams</u>		<u>Progeny</u>	
I Valley	12	I Valley	1
Ravine	2	II Valley	9 (plus 1 dead)
II Valley	9	III Valley	1
Ravine	2	Saddle	1
		IV and V	0
		VI Saddle	0
		Plateau	1
		VI! Plateau	7
<b>Total</b>	<b>25</b>	<b>Total</b>	<b>25</b>

Ratio = non N-type 17 : N-type 8

1938

<u>Dams</u>		<u>Progeny</u>	
I Valley	6	I Valley	3
II Valley	12	II Valley	3
		Ravine	1
		III Ravine	1
		Valley	1
		IV and V	0
		VI Plateau	1
		VI! Saddle	1
		Plateau	7
	<u>18</u>		<u>18</u>
Unknown ewes	7	II Valley	3
		Ravine	1
		III Valley	1 (plus 1 dead)
		IV and V	0
		VI! Plateau	1
<b>Total</b>	<b>25</b>	<b>Total</b>	<b>25</b>

Ratio = non N-type 15 : N-type 10

1939

No arrays have as yet been determined for these animals. They are therefore classified on Halo-hair grades alone. The ewes used were College flock ewes - definitely not N-type - and as their birthcoats or arrays are unknown, they cannot be classified.

Halo-hair grades	Progeny
I	4
II	10
III	3
IV	2
V	0
VI	0
VI!.	11

Ratio = non N-type 19 : N-type 11

From the above, there are several features of importance.

These are: (1) That the ratio between N and non N-type is by no means a perfect 1:1 ratio.

(2) The variation in the ratio is due to a consistent deviation in favour of the non N-type animals. The chances of this deviation being a real departure from a 1:1 ratio have been estimated by the Chi-square test.

	Low	High	Chi-square
1937	17	8	3.24
1938	15	10	1.00
1939	19	11	2.13
Total			6.37

This with three degrees of freedom = 9.8%

These chances are of a similar <sup>order</sup> ~~ratio~~ from year to year and total 9.8% that they are a 1:1 ratio. This is not significant - 5% significance.

However owing to the fact that the matings in the three years are similar, it is possible to add the results and test the total.

When this is done the following results are obtained.

Low	High	Chi-square
51	29	2%

This is a distinctly significant departure from a 1:1 ratio.

From these ratios therefore it appears that the chances of 1084 carrying the N-factor are not good.

(3) That there is a distinct break in the continuity between the N and Near-N-type and the non-N-type animals. This break in continuity is a consistent feature from year to year, and is particularly distinct in that it involves two whole grades. In this respect it is illuminating to compare these results with those obtained from N.303 and his descendants. Massed results of Sire N.303 and his sons, Sires E 852, E 980 and E 904

Dams	VI!	VI	V	IV	III	II	I
N.303							
Many Halo-h. ewes	11	0	2 <sup>+</sup>	1	2	4	0
Med. Halo-h. ewes	7	0	0	4	2	1	1
No Halo-h. ewes	3	1	1 <sup>*</sup>	0	0	5	1
E 852							
Med. Halo-h. ewes	6	1	0	3	0	2	1
Few and no Halo-h. ewes	6	7	0	1	4	6	3
E 980							
Med. Halo-h. ewes	4	0	0	0	0	1	0
No Halo-h. ewes	0	0	0	1	0	0	0
E 904							
Med. Halo-h. ewes	3	0	0	0	1	0	0
Few and no Halo-h ewes	6	4	0	0	2	6	4
Plus VI! Daughters mated to E 869 I	2	1	0	00	0	0	0
	<u>48</u>	<u>14</u>	<u>2</u>	<u>10</u>	<u>11</u>	<u>25</u>	<u>10</u>
		<u>62</u>			<u>59</u>		

From this table it is notable that, with three exceptions, there is a complete break in continuity in the Halo-hair grade series, in that Grade V is missing. Even in the experiments in which these animals occurred there is a complete gap. Thus in that experiment where  $V_s^+$  occurred it is apparent that there are no Grade  $VIs$  and this lack produces a complete break in the continuity of the series. In regard to the Grade  $V^*$  animal, from the no-Halo-hair ewes there is a complete lack of Grades III and IV. It is therefore considered that this animal may be regarded as a  $VI!$  which has not come to complete expression and therefore it is legitimate to regard this animal in the final ratio as an N-type. This gives a revised ratio of 63:58. It is notable that this Grade V animal is regarded as a poorly expressed N-type, and as such it will receive further discussion later in the appropriate section.

It is considered that this parallelism between N stock and 1084 as to the break in continuity provides evidence that Sire 1084 carries the N-factor.

(4) The fourth feature of importance is found in the arrays of the progeny of 1084. These arrays have been analysed in an attempt to ascertain whether the discontinuity in Halo-hair grading is a real or a spurious one and whether the break in continuity is merely masking an essential continuity of the pre-natal check between animals.

Summarised the result of this analysis of arrays is:

<u>Dams</u>		<u>Progeny</u>	
Arrays	Numbers	Arrays	Numbers
Plateau	0	Plateau	18
Saddle	0	Saddle	2
Ravine	2	Ravine	3
Valley	26	Valley	23
Plain	0	Plain	2
*Unknown Grades I and II	15	Dead	
Flock ewes	7	+ Grade II	1
		Grade III	1
	<u>50</u>		<u>50</u>

\*These are early experimental ewes and the arrays were not determined.

†These lambs died soon after birth and therefore although graded for Halo-hair abundance it was impossible to analyse samples for arrays.

Note:- Where a ewe has had twins she is counted twice.

Note:- From analyses of a large number of almost completely non medullated arrays, I consider that the Plain Array is a very unusual array and that arrays in which no sign of a pre-natal check can be found with close scrutiny are very rare indeed. Therefore in the light of the appearance of Valley Arrays in No-Halo-hair Stud Romney sheep, I consider that the Valley Array might be regarded as the typical recessive N-type.

From this summary, it is apparent that although two Saddle Arrays appear in the progeny there is an essential discontinuity between the typical N-type Plateau and the typical recessive type Valley. This distinction within the arrays is particularly noticeable when the results are compared with the array results of Sire 1016, which are:

Dams		Progeny	
Plateau	0	Plateau	4
Saddle	21	Saddle	18
Ravine	4	Ravine	2
Valley	4	Valley	4
Plain	0	Plain	1
	—		—
Total	<u>29</u>	Total	<u>29</u>

A criticism of this comparison is that in 1016 high grade Saddle ewes were used, while in 1084 low grade Valley ewes were the dams, and therefore it would be expected that there would be less Saddle Arrays in the progeny of Sire 1084 than in Sire 1016. However it may be argued that 1084, despite the fact that he received no assistance from the ewes, produced seventeen Plateau Arrays like himself, while 1016 despite definite assistance from the ewes, obtained only four N-type progeny, which

appear as the top end of an essentially continuous series, and not discontinuous as are the arrays of the progeny of 1084.

Thus to sum up it appears from the above discussions, that Sire 1084 VI! actually carries the N-factor, but the ratios make it appear (see page 215) that there is some complication that completely prevents the N genotype from being passed on or from coming to expression.

In an endeavour to throw further light on the question as to whether 1084 carried the N-factor or not, his N-type son 1238 VI! was backcrossed. The ewes used for this mating were flock ewes of unknown birth coat. Observations for kemp and medulla were made on these ewes and it is unlikely that any carried the N-factor. These matings were made in 1939, so it has been impossible to make array determinations as yet, and therefore observations are limited to Halo-hair gradings. However, this is not a serious objection, as it is apparent from the results quoted below that there is a distinct break in the continuity of the Hal-hair gradings.

The breeding results of Sire 1238 VI! Plateau are:

VI!	VI	V	IV	III	II	I
10	0	0	0	0	7	0

This is a clear cut 1:1 ratio. It is therefore safe even with this meagre material to regard this sire as having the N-factor typical of the original N-type ram N.303 (see previously, page 217).

It is notable that in this son of 1084, the deviation from the perfect ratio is in favour of the N-type, that is, in the opposite direction to the deviations in the progeny of his sire. It thus appears that if the consistent deviations from the perfect 1:1 ratios which are found in the backcrosses of Sire 1084 are to be regarded as due to something other than chance, then this son must be regarded as lacking this "something". The fact that both these animals, father and son, were shepherded together previous to tugging and were mated in adjacent paddocks at the

same time and to similar ewes appears to preclude the possibility of environmental limitations to the 'get' of 1084. Therefore it may well be that some genetical situation may be responsible for the consistently skewed deviation of the ratios of Sire 1084. Further, the fact that 1238 appears to be completely free from this limiting genotype exhibited by his sire provides evidence that the genetics of the N-type of 1084 are relatively simple when free from limiting factors.

Pedigree of Sire 1238 VI! Plateau:

Sire 1084 VI!	)	
	)	1238 VI!
	)	
Dam E 587 II Valley	)	

Ewe E 587 was born in 1931 from parents of unknown birthcoat grading or array. These animals were in one of Dry's experimental flocks and were both regarded as "harsh". These early flocks have been dealt with before in this section, and it is therefore unnecessary to treat them here again except to note that the material is so meagre that enquiry must rely mainly on the progeny. The progeny of Ewe E 587 are therefore tabulated below.

The progeny of Dam E 587 II are:

1933	To E 131 I Array unknown (harsh)	E 681 ♀ II Valley
1934	To E 611 1/2 II Valley-Ravine	E 867 ♀ I Valley E 866 ♀ V Saddle
1935	To 995 II (high) Valley	1038 ♂ II Valley
1936	To 827 II Valley	1148 ♂ II Valley
1937	To 1084 VI! Plateau	1238 ♂ VI! Plateau

From this it appears unlikely that this ewe carried the N-factor, and therefore it is considered legitimate to hold Sire 1084 responsible for the N-type coat of his son 1238.

SUMMARY

1. Dry's work on the inheritance of the N-type coat is briefly reviewed.
2. It is concluded that the logical explanation of the breeding results of Sire 1016 is a multifactorial type of inheritance.
3. It is concluded that Sire 1084 VI<sup>1</sup> carries the N factor.
4. It is improbable that the dam is responsible for the N factor of 1084.
5. A genetical explanation is probably correct for the consistently skewed ratios of sire 1084.

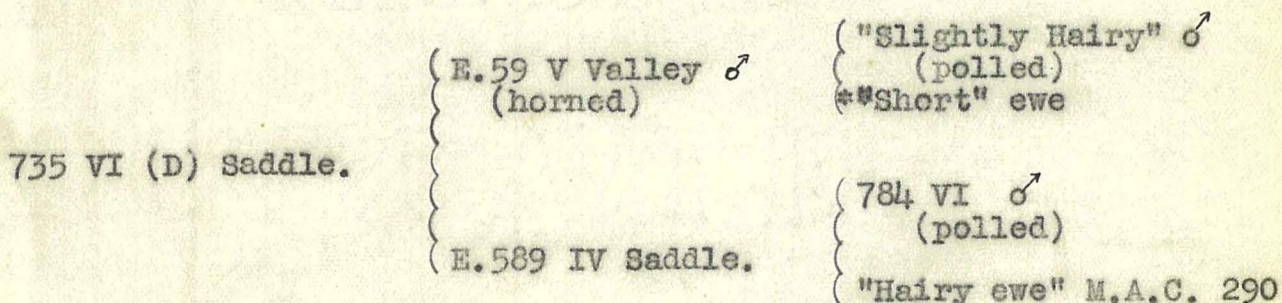
Sire 735 VI (D) Saddle.

From the discussion of the genetics of Sires 1016 and 1084 it is apparent that the mutal Sire of these half-brothers has:

- (1) Produced an N-type, horned ram, (1084) which carried the N factor.
- (2) Produced a Grade V (high) Saddle, horned ram which has when mated to similar animals, produced multifactorial N-type progeny.

Further, it has been found that, "although the evidence is inconclusive it seems unlikely that the dam of 1084 was responsible for the N factor which he carries". Therefore it is possible that sire 735 had the N factor but that this factor failed to come to complete expression. A study of the breeding results of 735 is also necessary as Sire 735 is unrelated to N303, the original N-type animal, and thus the study of sire 735 may throw light on the occurrence and limiting that may occur to the N factor. Further, sheep 735 is sired by Sire E.59 the grandsire of Sire 1059 VI! which animal, due to its remarkable breeding results, has constituted a distinct problem in the study of the inheritance of the N-type.

The pedigree of Sire 735 VI (D) Saddle.



\*Note: Short indicates that this ewe was one of the foundation ewes of the experimental flock and was obtained from Mr. N. Short.

The progeny of Sire 735 VI (D) Saddle.

	VI!	VI	V	IV	III	II	I
Ewes	1	0	4	3	2	2 unknown	
Lambs	1	5	3	1	2	0	0

(from a V ewe)

It is impossible to know whether or not this is a 1 : 1 ratio due to the high grades of the ewes and the small numbers.

There are records for horns for four of these rams; the fifth was castrated.

Two had horns :-

1084 VI! Ex. 164 V Valley  
1016 V Ex. 14 III Saddle.

Two did not have horns :-

1085 V (twin of 1084)  
1072 VI Ex. 541 VI!

This, also, is inconclusive due to the small numbers but it appears likely that 735 was responsible for the horns in his ram lambs. This is significant in view of the fact that linkage occurs between the factor N and the factor H. Further, it has been shown in the previous section on the inheritance of horns that 1016 is probably homozygous and therefore if this animal does not carry the N factor while its half-brother 1084 which appears to have the N and H factors linked, (see previous section page 202) then a crossover must have occurred in the germ cell from which one of these animals arose. This has, however, been discussed previously and, therefore, it is sufficient to note that the evidence from horns for or against Sire 735 having carried the N factor is inconclusive.

A further method of enquiry remains, and that is the study of the arrays of the progeny of Sire 735. These are :-

<u>Dams.</u>	<u>Progeny.</u>
541 VI! Plateau	1072 VI Valley.
20 IV Saddle	1101 VI Valley
589 IV Saddle	1081 IV high. Valley
14 III Saddle	1016 V Saddle
139 V Ravine	1096 III Valley
139 V Ravine	1097 III Valley
264 V Valley	1085 V Valley
164 V Valley	1084 VI! Plateau
181 III Valley	1102 V Valley
Flock ewe ?	1086 VI Valley

From these it is clear that 735 has produced only one real N-type animal (1084) and this animal has been shown to give ratios which are only just significant. Thus unless some limiting factors are postulated it appears unlikely from these experiments that Sire 735 carried the N factor. However, due to the fact that it has been shown that his son 1084 probably carried the N factor which appears not to have come from his dam, it appears necessary to postulate these limiting factors or perhaps some type of factor complex which either acts on the N factor and prevents it from coming to expression or being passed on, or that the N type itself is dependent on some type of complementary complex which may be broken up unless the frequency is high and the genes are few or unless linkage occurs. It is conceivable if this latter suggestion is near the truth that the N-type may still be prevented from coming to expression by separate limiting factors. Such factors could result in Sire 735 being a Grade VI and a definite Saddle Array while carrying the suggested N complex.

A further search of the sons and daughters of Sire 735 adds little, as only one animal, other than 1016 and 1084, was used for breeding. The breeding results of this ewe are :-

Ewe 1086 VI	Valley.	Sire 735/Ex.	Flock ewe.
1938	To 1095 VI	Valley.	1404 ° VI (borders on !)
			1405 ° V Ravine.
1939	To 1046 I	Valley	70 ° VI! Slight (D)

Sire 1046 has been bred for low Halo-hair abundance and is out of ewe 140 I and by Sire 869 I. Thus this ewe may be regarded as an animal which is perhaps similar to her sire. She therefore lends support to the view that Sire 735 may have carried the N factor which was prevented from coming to complete expression in his coat. In regard to the possibility of the complementary factors being present, this ewe neither supports nor disposes of such a possibility.

However, the progeny of Sire 735 other than 1084, 1016 and the ewe 1086, do not constitute evidence for or against the

mode of inheritance and the possibilities of limitation of the N factor. Therefore attention must be directed to the Sire and Dam of this ram.

The Dam of Sire 735 VI (D) Saddle.

E.589 IV Saddle.

Pedigree :

E 589 IV Saddle	{	784 VI Array ? polled.
	{	"Hairy ewe" M.A.C. 290.

This ewe had a polled sire, therefore if she carried the factor for horns she must have obtained it from her dam. Unfortunately her dam was only used once in these experiments. However, in the light of a past discussion (pg. 193) on these early flocks of Dry's the chances are that this ewe, M.A.C. 290, did not carry the H factor. Further, the fact that the sire of 735, E.59, himself horned, obtained three sons with knobs and scurs and one with horns makes it appear probable that Sire 735 obtained his horns from his sire and not from his dam. Also, 735, from breeding results quoted previously (pg. 224), is heterozygous for the factor H and therefore it is unlikely that his dam carried this factor. This is important as the fact that linkage occurs between the factor for horns and the N factor, (see section on the Inheritance of Horns and Dry's unpublished papers), suggests that this ewe did not carry the N factor.

Progeny of E.589 IV.

1933	To E.59 V Valley (horned)	735 ♂ VI Saddle (horned)
1934	To N.303 VI! Plateau (horned)	918 ♀ IV Valley
1935	To 735 VI Saddle (horned)	1080 ♀ VI 1081 ♀ IV high. Valley.
1936	To 852 VI! Plateau (horned)	1150 ♂ VI! Plateau (horned)

These results do not afford evidence of the presence of the N factor in E.589.

Thus if Ram 735 carries the N factor it appears to be unlikely that he obtained it from his dam.

Sire of Ram 735 VI (D) Saddle, horned.

E.59 V Valley horned.

Pedigree :

E.59 V Valley { "Slightly Hairy" ♂  
                  { \*"Short" ewe.

\* "Short" - see page

Sire "Slightly Hairy" is of unknown Halo-hair grading and array. He was one of the original animals of the Massey Agricultural College experimental flock and was a stud Romney, representative of what was regarded as 'slightly hairy' by eye determination. The benzol test was unknown in these early days. He was polled and therefore E.59 must have obtained the Horned gene from his dam. It is clear that it is quite impossible to prove anything by a study of the pedigree of this animal and attention must therefore be confined to his progeny. These also suffer from the disadvantage that this ram was mated largely with ewes of unknown birthcoat.

Summarised the progeny of Sire "Slightly Hairy" are :-  
Mated with ewes higher than Grade III (his only matings with ewes of known grade) :

	VI.	V.	IV.
Progeny	E.195	E.7	E.20
		E.22	E.21
		E.44	

The offspring of these six ewes have been considered and are summarised below :-

E.20	IV	Saddle	Numbers.	Sires.
		Grade II	2	
		Grade IV	1	E.59 V
		Grade VI	1 (735)	E.59 V
		Grade VI!	2	N.303 and his son 852 VI!

E.21 IV	Valley		
	Grade II	1	852 VI!
	Grade III	1	745 IV
	Grade V	1	E.59 V
	Grade VI!	2	N.303 and his son 852 VI!

E.7 V Valley  
No progeny above Grade III

E.22 V	Valley		
	Grade III	1	
	Grade IV	1	E.59 V
	Grade VI!	2	750 VI!

Note: Sire 750 is a son of N.303 / Ex. ewe 541 VI!

E.44			
	Grade III (and below)	3	
	Grade IV	1	669 V
	Grade V	4	E.59 and 669 V

The grade V daughter of E.59 was used for breeding and produced when mated to 1016, one Grade VI! and one Grade VI.

E.195 V	Saddle		
	Grade II		
	Grade V		E.59 V

Summarised these results are :-

- 6 VI! all sired by N.303 or a son of his
- 1 VI Sired by E735, a son of E.59.
- 1 VI (1095) from a daughter of E.59
- 1 VI! and 1 VI by 1016 who was by E.735.

Thus all the many Halo-hair animals trace to N.303 or to E.59.

From the above it cannot be concluded that the Sire of E.59 passed on the suggested factor to any of his progeny other than to E.59. When half-sisters of E.59 were mated to this sire's son and grandsons, which did not obtain the N factor from their dams, N and near N animals were produced. This makes

It appears that this sire, although not carrying the N factor was able to pass on to his progeny some portion which, when added to or concentrated by inbreeding produced the N-type.

It is therefore concluded that the Sire of E.59 did not carry the N-factor and it is thus considered necessary to explore the possibilities of the dam.

Ewe "Short" is an introduced ewe of unknown birthcoat. She had only two lambs during her life in the experimental flock. These were E.59 V and a ewe E.502 III which was sired by "Dense", ram 731 III. This ewe was not used for breeding. There is thus no evidence from either the progeny or the pedigree that E.59 obtained the N-factor from his dam. However, this ewe is definitely unlikely to have been an N-type but it is important to note that she must have carried the factor for horns because the sire of her horned lamb E.59 was polled. The fact that there is a known linkage between the N gene and the gene for horns rather puts this ewe under suspicion if E.59 can be shown to carry the N-factor.

There is thus no evidence from the Sire of Dam of E.59 that suggests that this ram carried the N factor. It is therefore necessary to pay attention to the progeny of Sire E.59.

Progeny of E.59 :-

1932

Mated to Many Halo ewes

VI!	VI	V	IV	III	II	I
1	0	3	3	2	2	)

In addition to these there were two extremely tiny Grade II lambs, dead at birth. These animals may well be regarded as higher Grade animals with some Halo-hairs suppressed by the poor pre-natal development to Super-sickle fibres.

This experiment cannot be regarded as giving a 1:1 ratio and rather provides evidence for a multifactorial situation. As for horns, these do not clarify the position as there were only two ram lambs, one of which died at birth, the other apparently being castrated or disappearing soon after.

A study of the progeny of the higher grade animals is made in an endeavour to ascertain whether they carried the N factor. Thus :-

E.661 ♀	VI!	Saddle / Ex. E.55* V (high)	Saddle.
1934	To N.303 VI!	906 ♀	III Ravine
1935	To 750 VI!	dead ♂	IV
1936	To 669 V	1177 ♀	V high. Valley
1937	To 1016 V	1343 ♂	VI high. Saddle.
		1342 ♂	VI Saddle
1938	To 1016 V	85.5 ♀	VI! Saddle
		86.5 ♀	VI Saddle

\*Note: E.55 was the offspring of parents both of unknown Halo-hair grading. E.661 and E.660 II were the only lambs of E.55.

These results, due in the main to the high grade sires used, are inconclusive and may or may not be a 1:1 ratio. The most reasonable explanation of the VI! progeny is that given in the discussion of Sire 1016, that is, that 85.5 VI! owes its N-type to a multifactorial situation and that E.661 has probably received additional factors from both parents and has passed many of them on to offspring that were able to receive them also from the other parent.

Three N-type grandchildren of E.59 were obtained from this mating. They are :-

E.633 ♀ Valley To 1095 VI Valley 1272 ♂ VI! (D) Plateau.

This from other breeding results of 1095 is regarded as a multifactorial N-type.

E.641 ♀ II Valley to 1084 VI! Plateau 1327 ♂ VI! Plateau.

This N-type is regarded as due to the N-factor which 1084 probably carries. This is supported by the fact that in the following year this mating was repeated and a recessive II animal was obtained. Thus :-

E.641 ♀ II Valley To 1084 VI! 68.5 ♀ II Valley

1937 -

E.647 ♀ V Saddle To 1016 V 1308 ♀ VI! Plateau-Saddle  
1307 ♂ VI Saddle app. Plateau.

This is considered to be a similar mating to that of 85.5 VI! discussed over the page and thus is concluded to be a multifactorial N-type.

It is therefore clear that from the 1932 mating the evidence is in favour of Sire E.59 not carrying the N-factor.

### 1933.

Mated to No-Halo ewes.

VI	V	IV	III	II	I
0	1	1	3	8	2

These figures bear no resemblance to a 1:1 ratio and thus are against the Grade V condition of E.59 having a single factor basis.

The progeny of the animals from this breeding experiment also fails to support the single factor hypothesis. Thus E.685 ♀ II / Ex. 88 I Valley was mated to two N-type rams, namely 852 VI! and son of N.303 VI! and 1084 VI! These matings produced three low grade animals grading I, II and III and one VI (high) by 1084.

Also E 766 ♀ (high) Valley / Ex. 140 I Valley when mated to low grade sires, 995 II and 827 II, produced two Grade I from the latter. Only one of these was mated, a Grade V, and that with sire 1016 V, when it gave one Grade V and one Grade IV, results which are consistent with a multifactorial mode of inheritance.

Thus the detailed results support the view that this experiment provides evidence that E.59 does not carry the N-factor.

Further matings were done in 1933 and E.59 was mated to Medium-Halo ewes. The results of this mating are :-

VI	V	IV*	III	II	I
1	3	4	1	3	0

\*Note: This includes 734 ♂ IV, high or V low.

These do not constitute a 1:1 ratio and are therefore incompatible with the presence of the N factor.

The progeny of these animals resemble closely those

obtained by mating other progeny of E.59 and they thus provide no evidence that this sire carried the N factor. One animal, however, is worthy of particular note as it has been extensively used as a sire. This animal is sheep 1059 VI! Plateau and it was produced by mating ewe 734 IV (high) with 767 I Valley.

Thus with this one exception, there is no evidence that Sire 1059 VI! carried the N factor. This is abundantly clear when the evidence is massed.

Thus :-

VI	V	IV	III	II	I
2	7	8	6	13	1

This in no way resembles a 1:1 ratio. It is therefore considered that the evidence produced leads to the conclusion that E 59 does not carry the N factor.

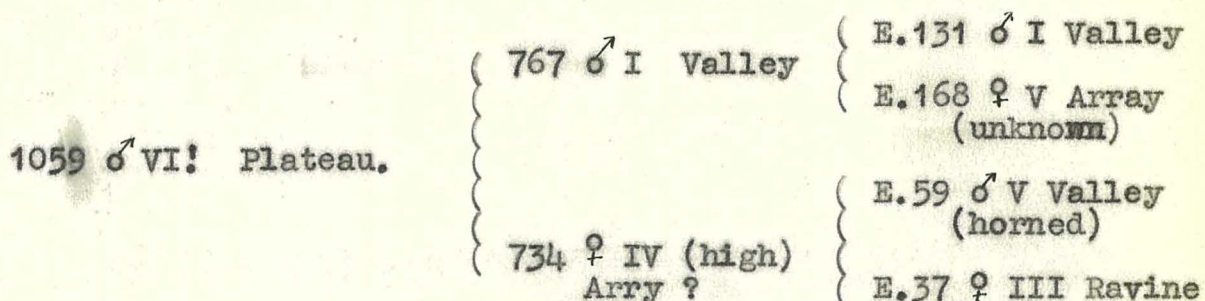
Thus to summarise the conclusions reached in this section :-

1. The bulk of the evidence suggests that Sire 735 does not carry the N factor.
2. The fact that Sire 735 sire 1084, whose breeding results suggest that he carried the N factor, leads to the postulation that Sire 735 V may be a "limited" N-type.
3. Contemplation of the progeny of the grand parents of 735 leads to the conclusion that neither of these animals carry the N factor.
4. E.59 is regarded as having obtained his horned gene from his dam.
5. Evidence from the breeding experiments with E.59 leads to the conclusion that this sire does not carry the N factor.
6. An N-type grandson - Sire 1059 - was produced by mating a medium Halo (Grade IV high) with a No-halo ram.

Sire 1059 VI! Plateau. Horned.

This animal is of interest as it is an N-type grandson of E.59 and is unrelated to the other N-type strains. Further, it has given results in matings which suggest that it has not the ordinary multifactorial genotype for N-type.

## Pedigree of 1059 VI! Plateau. Horned.



From this pedigree it appears that 1059 obtained his horns through his dam from E.59, his horned grandsire and that his N-type coat is due to a multifactorial addition of factors from Grade IV (high) 735, and Grade I Valley 767 who, for such an explanation, must not be regarded as a No-halo animal. It is not known whether a No-Halo animal can actually carry factors for Halo-hairs without showing Halo-hairs in the birthcoat.

Another explanation is that 1059 obtained the N factor from his dam in whom it failed to come to full expression. There is definite evidence that this can occur as is apparent from the backcrosses of N.303 and his sons (pg. 217) where Grade VI animals have been obtained. Further evidence for this has been obtained by backcrossing Grade VI, N.303 animals when typical N-type animals have been produced. However, it is not known whether the N factor can be limited from a VI! for Halo-hair grading to a Grade IV (high). A further disadvantage arising from this suggestion is that it has been shown that E.59 does not carry the N factor and therefore the postulated N factor must come from his Grade III grandam.

Thus neither explanation is satisfactory and both become less so when the results of backcrosses are studied.

These are :-

	VI!	VI	V	IV	III	II	I
1937	0	0	0	0	6	19	2
1938	1	0	0	0	3	6	1
1939	2	1	1	0	8	7	5

This result is particularly illuminating when compared with that obtained from backcrossing Sire 1016, regarded as a definite multifactorial N-type. (see previous section).

VI!	VI	V	IV	III	II	I
1	0	5	1	2	1	0

Thus it is apparent that the concentration of animals in the low grades makes the multifactorial hypothesis untenable.

If the N factor is present then the ratio should be a 1:1 ratio but a 38:1 ratio is obtained. The chances against this being a 1:1 ratio are enormous. Of course, limiting factors similar to those suggested for Sire 1084 could be postulated but this is felt to be unsatisfactory.

The most, reasonable explanation of this animal and one which explains many of the anomalies which have been shown to exist, as well as clarifying the origin of the original N-type sire N.303, has been made by Dr. P.R. McMahon during a discussion on this problem. He suggests that perhaps a dominant complex of two complementary closely linked factors which have no effect singly, is responsible for the N-type. It is difficult with the small numbers possible with sheep to distinguish these closely linked factors when they occur on the one chromosome from a single dominant factor. However, if these genes are carried on different chromosomes it is only when crossovers occur that the N-type of the parent is regained in the offspring.

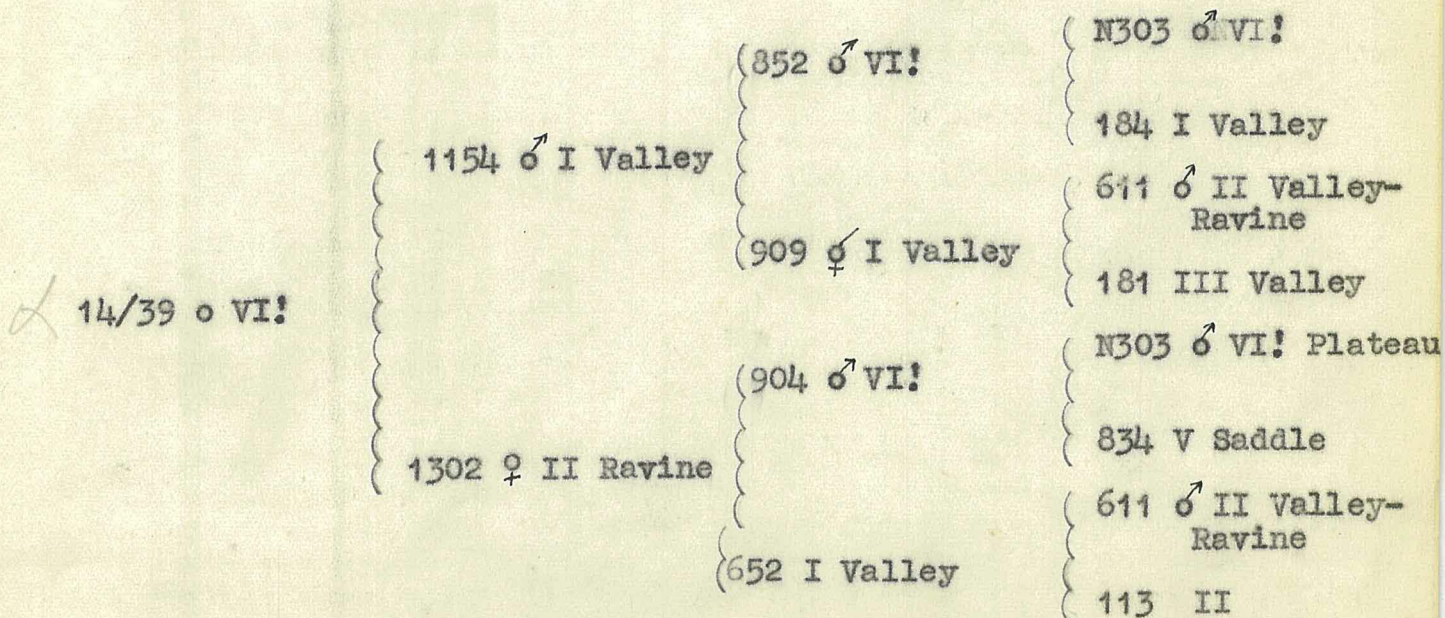
Thus on this theory, Sire 1059 VI! is explained as having the two epistatic <sup>(Lush)</sup> factors which he obtained from both his sire and dam who, due to the fact that each only carried one factor, were not N-type. When 1059 is mated these factors, termed N1 and N2, separate at gametogenesis and the N-type is

lost unless crossing over occurs. On this theory crossing over has occurred twice in sixty-two times giving an N-type sone (one born dead) that should, in breeding experiments, be indistinguishable from a single dominant factor N-type animal due to the fact that this animal, unlike his sire, should carry the N complex on the one chromosome.

The other two N-type progeny of Sire 1059 are out of their own half-sisters (daughters of Sire 1059) and thus they will be probably genetically identical with their sire in so far as the suggested N factors are concerned. That is, they probably receive one complementary factor from their sire, the other from their dam and therefore, although definite N-type animals, they are unlikely to carry the factors on the same chromosome and therefore to "breed true".

Acting on this suggestion breeding experiments were undertaken in 1939 mating together N-type recessives in the hope of obtaining another animal similar to 1059. The chances against this occurring were large as both animals would require to be crossovers assuming that their sires were heterozygous for both N1 and N2. Even if both parents carry one gene each the chances against any particular mating producing an N-type animal are only 1 in 4. However, despite these chances two N-type animals have been produced in matings.

The pedigree of one of these animals is :-



The other animal, sheep 114/39 ♂ VI! (D) slight, has an almost identical pedigree. It is the daughter of sire 1154 and ewe 1293 II J.E. Valley (truncated). This ewe is a paternal half-sister to ewe 1302 (above) whose dam was ewe 912 I Valley.

It is interesting to note that these animals are of our N303 stock - a type of stock which has given satisfactory ratios, apparently free from any limiting factors as postulated for 1084 VI! the outstanding sire of the E.59 family. Further, it is notable that in the massed evidence from N303 stock the ratios are 62 : 59 (see previous section pg. 217), a ratio slightly in favour of the Non-N-type.

When applied to the problems raised by the study of the progeny of E.59 the hypothesis is particularly interesting. Thus Sire 1084 VI! can be explained as having resulted from a cross over in the zygote between the N1 and the N2 genes obtained from both sire and dam respectively. This type of crossover is reported by Goldsmith as having occurred in *Drosophila*. We have, therefore, a relatively simple explanation of the fact that 1084 appears to have the N factor while its sire and dam, as has been shown, are unlikely to have it.

The theory in <sup>no</sup> way affects the conclusion drawn from the breeding results of Sire 1016 and will explain any 1:1 ratios which may be obtained when N-type progeny of Sire 1016 are backcrossed.

It also explains the origin of N303 in a Stud Romney Flock by postulating a similar situation to that suggested above for Sire 1084. This supposition also gains some support from the fact that visiting farmers are seldom surprised by the appearance of the N-type coat and are often quite definite that they have seen similar in their own or neighbours flocks. This is very haphazard evidence but it suggests that a mutation theory, which appears to be an alternative, is not likely to be correct.

Further evidence of the occurrence of the N-type coat is obtained from a backcross mating with a ewe which the late

Mr. D. J. Sidey of Canterbury Agricultural College presented to Dr. Dry. This ewe, a two-tooth, has a great deal of kemp in an extremely gross fleece. When backcrossed to Sire 1046 I Valley an animal of Non-N-type breeding, a Grade VI! N-type lamb was obtained.

The fact that two N-type strains have appeared in the Massey Agricultural College experimental flock in ten years also suggests that a mutation explanation is unsatisfactory. This is also supported by the fact that the N factor is a Dominant and as such could not be carried in a recessive condition for a large number of generations.

With the present evidence, however, Dr. McMahon's explanation must only be regarded as the best so far advanced. It is possible that future breeding experiments may completely disprove it or at least lead to modifications or extensions. However, it appears to be very satisfactory with the present facts and as "the shortest theory that explains all the facts", it is well worthy of further enquiry.

The fact that this theory necessitates the presence of two factors which are only effective when present together and appear to be totally recessive when separate, may be considered to be an argument against the reality of the presence of these genes but it must be remembered that the N-type coat is due to a lack of pre-natal check (22) and is thus a response to a lack of follicular density in the early pre-natal coat. This lack of density may be due to a slow rate of follicular development or a rapid rate of skin expansion, or both. Thus the two genes postulated probably act on developmental rates and as such may have definite effects on the growth of the foetus as a whole even when apart.

It is therefore apparent that a study of the physiological genetics of the N-type coat is of the utmost importance in that it may throw light on many fundamental problems of fleece development and may lead to a distinct step forward in the understanding of the development of the Mammalian coat as a whole.

SUMMARY.

1. The pedigree of Sire 1059 is briefly discussed and it is concluded that there is no reason to believe that either his sire or his dam carried the N factor.
  2. The breeding results of Sire 1059 are given. It is shown that these results cannot be explained on a multifactorial hypothesis.
  3. Dr. P. R. McMahon's suggestion as to the genetics of the N-type is discussed.
  4. Breeding experiments designed to throw some light on the correctness of this suggestion are discussed.
  5. The occurrence of the N-type is briefly discussed and it appears to be too frequent for a mutation theory to be satisfactory.
  6. It is suggested that the N-type may make excellent material for the study of the physiological genetics of the coat of the sheep.
-

SUMMARY AND CONCLUSIONS.  
=====

As summaries are appended at the end of each section it is unnecessary for this section to be a complete reconsideration of the facts and conclusions of this thesis. Rather, it is proposed to briefly summarise the most important features presented. These features will not necessarily be in the order in which they occur in the past sections, neither will they be in order of importance, but their position will be determined by their inter-relationships and these are not necessarily their order in a systematic study.

The history of kemp research is briefly traced and the results and methods of approach to the problem of kemp and the elucidation of the architecture of the fleece as a whole are briefly discussed.

Following the section, Materials and Methods, the fibre types are treated in detail. The order of treatment is the order in which they start to grow. The variations in the macroscopic appearance of fibre types and their relationships to each other are described and discussed, mainly as possible methods of throwing some light on the forces at work in the fleece. Shedding is also discussed with the same objects in view and different types of shedding are described. Evidence is presented to show that shedding is less easily affected than macroscopic features. The possibility that fibres which shed before birth may be followed by successors in the first pelage is considered in relation to what is termed Short Super-sickle A.

The possibility that environment may play an important part in what is termed the Birth check is discussed in the light of the evidence presented. That this points to a gap in our knowledge of the importance of environment on the birth coat is clear, and this question is discussed in the light of the above and also in the light of both pre- and post-natal fibre form.

Tip form is described and discussed for all fibre types. It is considered that tip form is a function of time of

development and medullation. The importance of tip form in the Curly-tip fibres as a possible indication of post-natal potentialities for medullation is discussed.

The importance of Histerotrichs in relation to the development of the fleece and their association with Curly-tip fibres is discussed. It is pointed out that a more complete knowledge of the inheritance of fibres in the post-natal fleece may be important in a study of fleece density.

Following the study of fibre types the Plateau Array is treated in detail. It is recognised that wide variations can occur within the definition of this array and it is therefore regarded as a series. Those features which indicate the extent of the effectiveness of the pre-natal check and those regularly associated with great or small effectiveness are described and discussed in detail. This involves a description of variations in fibre types present, associations between fibre types, freedom of shedding, the relative numbers of Halo-hairs and Super-sickle A fibres in the different types of Plateau Arrays and the occurrence and degree of the Precipicé and Crisis thinning.

A description and discussion of In-parallelism in the Plateau Array is given and an explanation of this phenomenon is considered.

#### Genetics.

Pertinent evidence for the study of the inheritance of horns in the New Zealand Romney is presented and discussed. Variations in the expression of the horned genotype are described and the N-type coat is shown to assist the expression of the factor for horns. Evidence is presented to show that what is termed Hairy Wells may be regarded as the heterozygous expression of the factor for horns in the ewe.

It is shown that the N-type may be inherited in a multi-factorial manner and that a genetical situation is probably responsible for the deviations found in the expected breeding results of some N-type N-factor animals. A suggestion by Dr. P.R. McMahon is briefly discussed and it is shown that it explains all the present facts in a simple manner.

=====



B I B L I O G R A P H Y.

=====

- (1) Barker, S.G. Wool. A Study of the Fibre.  
H.M. Stationery Office. 1929.
- (2) Bowman, E.H. Structure of the Wool Fibre.  
Macmillan & Co. 1908.
- (3) Priestman, Yorkshire Observer. June 1911.
- (4) Barker S.G. A Comparison of Measurements of Diameters  
& King, A.T. of Wool Fibres with the Microbalance and  
the Projecting Microscope, with Applications  
to the Determination of Density and Medulla  
(Kemp) Composition.  
Jrn. Text. Inst., 1926, Vol.17, T68-74.
- (5) McMahon, P.R. Methods for the Estimation of Medullation  
in Wool Samples.  
Jrn. Text. Inst., 1937, Vol.28, T349.
- (6) Duerden J.E. Development of the Merino Wool Fibres.  
& Ritchie S.Afr. Jrn. Sci., 1924, Vol.21.
- (7) Roberts J.A. Kemp in the Fleece of the Welsh Mountain.  
Fraser Jrn. Text. Inst., 1926. Vol.17 T274.
- (8) Duerden, J.E. Kemp Fibres in the Merino.  
Jrn. Text. Inst. 1926. Vol.17.
- (9) Elphick, B.L. The Detection and Estimation of Medullated  
Fibre in New Zealand Romney Fleeces.  
Jrn. Text. Inst., 1932. Vol.23. T367.
- (10) Duerden, J.E. A New Type of Fibre in the Merino.  
& Miss Seale, Jrn. Text. Inst. 1927. Vol.18. T265.
- (11) Duerden, J.E. A Down Pelage in the Ovidae.  
Nature. Nov.12th. 1932. Vol.130, pg.736.
- (12) Dry, F.W. The Pre-natal Check in the Birthcoat of the  
New Zealand Romney Lamb.  
Jrn. Text. Inst. 1933. Vol.24. T161.
- (13) Blyth, J.S.S. Kemp Fibres in the Fleeces of British Breeds  
of Sheep.  
Jrn. Text. Inst. V926. Vol.17. T291.
- (14) Crew, F.A.E. Fibres of 'Intermediate' Character Found in  
& Blyth J.S.S. the Fleece of *Ovis vignei*.  
Ann. Appl. Biol., 1921, Vol.7, 164-169.
- (15) Crew, F.A.E. A Micrological Study of the Fleece of the  
& Blyth J.S.S. Blackface Lamb.  
Jrn. Text. Inst. 1923., Vol.13. T149.
- (16) Dry, F.W. The Coat of the Mouse (*Mus musculus*).  
Jrn. of Genetics, 1926. Vol.16., 287.
- (17) Toldt, (1910-11) Ann. d, naturhist. Hofmuseums,  
Wein, Bd. XXIV.
- (18] de Meijere J.H.C. (1893) Morph.Jahrb. Bd. XXI.  
(1899) Anat.Anz. Bd. XVI.
- (19) Dry, F.W. Hairy Fibres of Romney Sheep.  
New Zealand Jrn. Agr. 1934., Vol. 46.

- (20) Dry, F.W. The Use of Covers on Lambs in Biology Work on Wool. Nature, March 1931. Vol.127, 482.
- (21) Galpin, N. The Occurrence of the Britch-poll Fibre-type Array Gradient in the New Zealand Romney Lamb. Empire Jrn.Exp.Agr. Vol.4. No.14. 1936, pg116
- (22) Galpin, N. Pre-natal Development of the Coat of the New Zealand Romney Lamb. Jrn.Agr.Sc., 1935, Vol.25. pg.344.
- (23) Donald, H.P. (1935) A Preliminary Study of the Variation & McLean, J.W. in the Growth Rate of Lambs in Canterbury. N.Z. Jrn. Sci.& Tech. Vol.17., No.3, pg.497.
- (24) Rudall, K.M. Pulling out Wool Fibres and its Effect on Hairiness. N.Z. Jrn.Agr. Vol. 1934.
- (25), Fraser, K.M. The Rate of Growth of South Australian Merino Fleece. Commonwealth Jrn. Sc. & Indust. Research. Nov. 1931.
- (26) Nichols, J.E. Fibre Growth Phases in a Sample of Australian Merino Wool. Jrn. Text. Inst. 1933 Vol.24 T333/
- (27) Duerden, J.E. Standards of Thickness and Crimps in Merino Grease Wools. Jrn. Text. Inst. Vol.20. 1929. T93.
- (28) Barker, S.G. A Note on the Physical Relationships of & Norris, M.H. Crimp in Wool. Jrn. Text. Inst. 1930. Vol.21.
- (29) Dry, F.W. Fibre Types in the New Zealand Romney Hogget. The Wool Record Vol.38. No.1112 Sept.1930 pg. 602.
- (30) Norris, M.H. Crimp in Wool as a Periodic Function of Time. & Van Rensburg. Jrn. Text. Inst. Vol.21. T481.
- (31) Swart, J.C. A Study of the Group Structure of Merino & Kotze, J.J.J. Fleeces. Jrn.Exp.Agr. Vol.5. 1937.
- (32) Sutton, W.G. Some Studies of Yolk in the New Zealand Romney. Jrn. Text. Inst. Vol.24. T341.
- (33) Roberts, J.A.F. The Cotted Fleece. Jrn. Text. Inst. Vol.17. T171.
- (34) Lockner, The Development of the Blackfaced Fleece. Edinburgh Ph.D. Thesis. 1933.
- (35) Leslie, A. The Frequency of the Distribution of Halo-hairs in Lambs of Poorly and Well Fed Ewes, with Particular Reference to Regularity of Intra-Uterine Lamb Growth and the Feeding of the Dam. Canterbury Agricultural College Bull. Nov.1931
- (36) Dry, F.W. Early Progress of the Romney Lamb and Features in the Development of the Fleece. N.Z. Jrn.Agr.Sc. 1935. Vol.51. Pg.229.

- (37) Malan, A.B. Further Observations on the Body Weight  
& Casson, H.H. and Crown Rump Length of Merino Foetuses.  
Ondersterpoort Jrn. 1936, Vol.7, pg.239.
- (38) Hammond, J. Growth and Development of Mutton Qualities  
in the Sheep. 1932. Pg.7.
- (39) Sidey, D.J. (1933) Canterbury Agricultural College  
Half-Yearly Report. 1933.
- (40) Malan, A.B. The Frequency Distribution of Merino Wool  
Fibre Thickness Measurements.  
Ondersterpoort Jrn. of Vet. Science and  
Animal Industry, Vol.9. No.I, July 1937.
- (41) Dry, F.W. Genetics and Live-stock Production.  
N.Z. Dept. of Sc. and Indust. Research. Bull.  
No. 64. 1938. Page. 52.
- (42) Wood, T.B. A Note on the Inheritance of Horns and Face  
Colour in Sheep.  
Journal of Agricultural Science. Vol.I 1905/06
- (43) Landauer, vonW. Ergebnisse in der Erbanalyse der Dehornung  
von Rind, Schaf und Ziege.  
Zeitschrift für induktive Abstammungs und  
Vererbelungslehre. Band XXXIX 1925.
- (44) Arkell, T.R. A Further Report on the Inheritance of Horn  
Durham, N.H. and Wool covering in Sheep.  
Annual Report of the American Breeders  
Association. Vol. 8. 1912.
- (45) Russell, S.F. Sheep Breeding Experiment on the Inheritance  
of Characters in Sheep.  
Oklahoma Agricultural Experimental Station.  
Bulletin No. 126. 1919.
- (46) Thilo, H.L. Die Zucht des Meleschafes in Neuinkirchen  
1922.
- (47) Goldschmidt, R. Physiological Genetics. Page 176.  
McGraw Hill. 1938.

A P P E N D I X I.

=====

PLATEAU ARRAY.

<u>Sheep.</u>	<u>Pre-Curly tips.</u>	<u>C.T.</u>	<u>Hist.</u>	<u>Total</u>	<u>% C.T.</u>	<u>% Hist.</u>
58.5 VI!	72	404	348	824	49	42
59.5 VI!	30	200	190	420	48	45
78.5 VI!	51	229	203	483	47	42
78.5 VI!	63	305	419	782	39	54
76.5 VI!	118	291	349	758	38	46
77.5 VI!	46	327	374	747	44	50
18.5 VI!	42	280	445	767	37	58
62.5 VI!	46	162	250	458	35.	55
88.5 IV!	74	218	354	646	34	55
29.5 VI!	38	266	224	528	50	42
88.5 VI!	35	169	211	415	41	51
1238 VI!	57	274	380	711	39	53
1402 VI!	71	319	345	735	43	47
1327 VI!	33	250	245	528	47	46
1279 VI!	34	156	186	376	41	49
1280 VI!	61	180	436	677	41	64
1256 VI!	53	176	286	512	34	56
1239 VI!	82	361	560	1004	36	56
1238 VI!	57	274	397	728	38	55
1258 VI!	51	224	429	714	31	61
1329 VI!	79	429	519	1023	42	50
1308 VI!	47	231	230	508	45	45
1068 VI!	36	148	288	472	31	61

Percentage Histerotrichs:

Mean = 51.43 ± 1.31 S.E.

Coefficient of Variation = 12.226

Percentage Curly-tip fibres:

Mean = 40.43 ± 1.16 S.E.

Coefficient of Variation = 13.8.