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Thesis submitted by

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STUDIES OF THE COAT OF THE NEW ZEALAND
ROMNEY LAMB.

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SECTION III.

I. BRITCH-WITHERS FIBRE-TYPE ARRAY GRADIENT.

The present investigation confirmed Dr. Nancy Galpin's result (25) as to the posterior-anterior gradients. A few examples are plotted on graphs 5 and 6, showing the gradual transition from britch to withers. A few exceptions to this rule have been found but for the reason explained in Chapter I no account of these exceptions will be given here.

In the present lot of lambs one exceptional lamb has been examined, having more checked arrays on the rump and back than on the side (Lamb No. 81). This lamb has Ravine on the rump and back and Saddle on the side. This Saddle is very closely associated with Valley and actually it started as a typical Valley having a good many sickle fibres and a few curly tip fibres fine. Medulla has revived only in the middle of the length of the fibre and because of this fact the array has to be deemed less checked than it was at first supposed (see page 86)

Another point worth mentioning is the britch - half britch gradients. It may be remembered that -

(i) these two sampling positions are fairly close together;

(ii) in the majority of my lambs britch positions have Plateau arrays with Saddle arrays (if not more checked arrays) on the half britch;

(iii) the majority of britches have a high grade of halo-hair abundance, being deliberately chosen in order to investigate the significance of many-halo-hair britches in relation to hairiness on the other body regions.

This will be discussed in the next section. Here it will be sufficient to point out that in lambs having many-halo-hair britches and free or fairly free of halo hairs on the half-britch, the most definite progress in fibre type arrays has been encountered. This is understandable in view of the earlier discussions dealing with the centre of gravity of the pre-curly-tip fibre group, where it has been pointed out that the scarcity of halo hairs involves the shifting of the centre of gravity towards sickle fibres. Such a shifting is caused by a more intense pre-natal check and of course this latter determines the array. Hence from the lack of halo hairs it is quite safe to anticipate that on such an area at least Saddle array will be found.

TABLE XVIII

DISTRIBUTION OF ARRAYS.

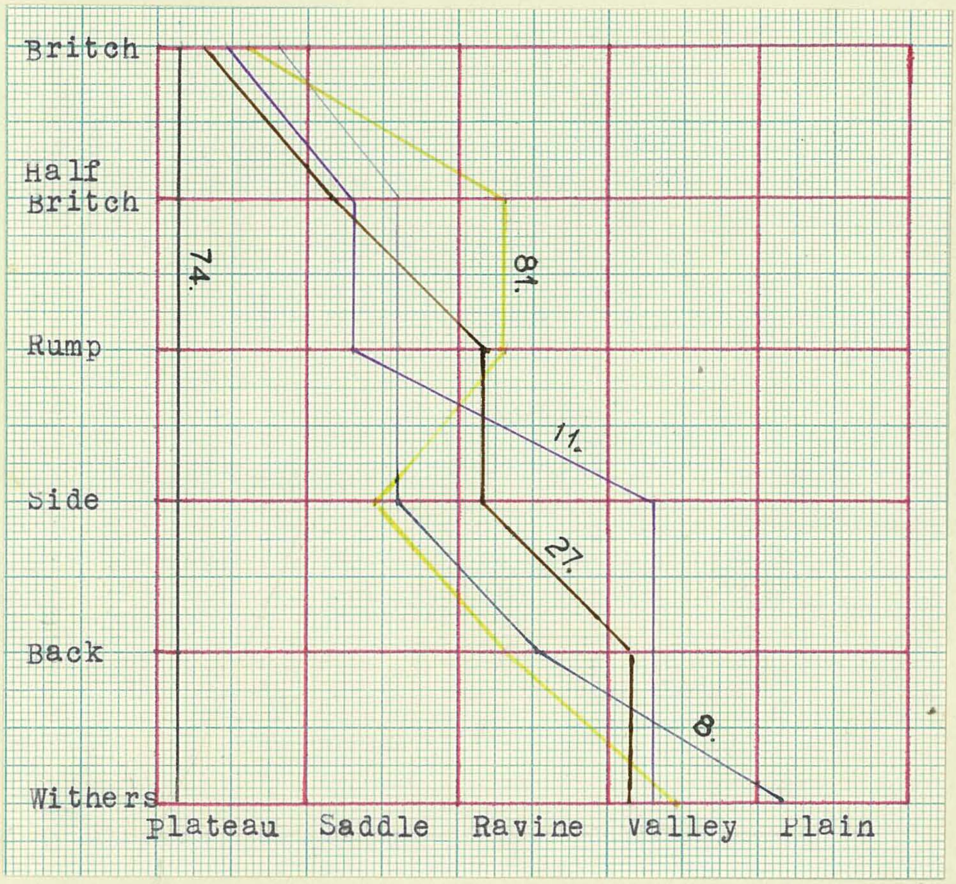
Expressed as the percentage of arrays in different body regions (a) and on the same regions in different lambs (b).

(a)

Region/ Array	Plateau	Saddle	Ravine	Valley	Plain
Withers	6.0	-	-	27.0	80.0
Back	6.0	8.0	10.0	27;0	-
Side	6.0	15.5	15.0	23.0	20.0
Rump	6.0	23.0	35.0	8.0	-
Half-britch	6.0	38.0	35.0	9.0	-
Britch	70.0	15.5	5.0	5.0	-

(b)

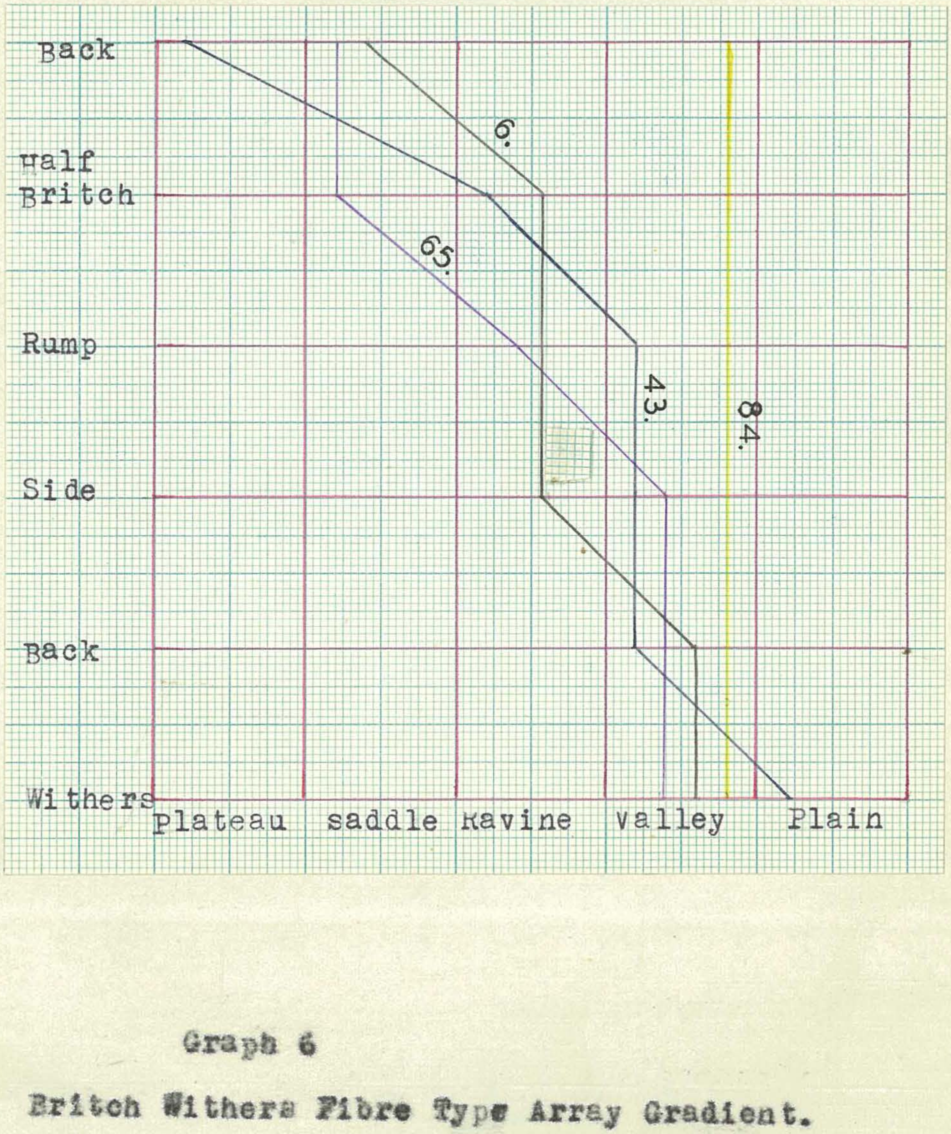
Array/ Region	Withers	Back	Side	Rump	Half Britch	Britch
Plateau	6.0	6.0	6.0	6.7	5.9	70.5
Saddle	-	6.0	11.5	20.0	29.4	11.8
Ravine	-	12.0	17.5	46.6	41.2	5.9
Valley	70.0	70.0	59.0	26.7	23.5	11.8
Plain	24.0	0.0	6.0	-	-	-
all in	-	6.0	-	-	-	-



Graph 5.

Britch-withers Fibre Type Array Gradient.

The separator of points within the region representing any one array is a matter of convenience in graphing. The relative position of points within an array region does not indicate differences in toughness.



Graph 6

Britch Withers Fibre Type Array Gradient.

The separation of points within the region representing any one array is a matter of convenience in graphing; the relative position of points within an array region does not indicate differences in toughness within the particular array.

1. Distribution of the arrays over the Lamb's body.

Tables Nos. XVIII(a) and XVIII(b) as well as graphs 5 and 6 are given in order to illustrate the orderliness of the array distribution found in the lot of lambs studied. These tables are of such an obvious support to the above expressed views that further discussion is not needed.

II. DISTRIBUTION OF HAIRINESS:

The percentage of hairiness has been ascertained by the Fleece Testing Department using the medullometer devised by Dr. P.R. McMahon (35). The results of these are tabulated in Table XIX and graphs 7, 8 and 9.

Prior to the discussion it is felt, that in order to get a better insight into the hairiness situation within different arrays over the body region, the following points must be remembered.

(i) the data given for the hairiness in some arrays (marked x in Table XX) are too scanty on the one hand. On the other the variations within arrays are too large. Hence the discussion will be confined to data which represent a fair number of arrays;

(ii). From the previous discussion it is understood that arrays are linked to each other.

TABLE XIX.

DISTRIBUTION OF HAIRINESS.

Plateau Lamb No.	%	x	Saddle Lamb No.	%	x	Ravine Lamb No.	%	x	Valley Lamb No.	%	x
						BRITCH.					
8	28.3	Hc	6	27.$\overset{4}{3}$	Hc	1	31.9	Hc	35	15.2	Hc
11	36.4	Hc	65	45.5	Hc				84	9.4	Ht
27	35.0	Hb									
43	29.3	Hc									
44	30.7	Hc									
46	31.6	Hc									
48	63.0	Hc									
74	93.0	Hc									
75	24.6	Hc									
76	37.0	Hc									
81	49.8	Hc									
82	49.2	Hc									
M= 42.3			M= 36.4			M = 31.9			M = 12.3		
						HALF - BRITCH.					
74	104.0	Hc	8	27.1	H$\overset{b}{\text{b}}$	6	15.5	Hb	1	9.3	Ht
			11	34.2	Hc	43	11.5	Hb	35.	15.9	Hb
			27	31.4	Hc	46	19.4	Hb	44	15.7	Hb
			48	47.0	Hc	75	21.8	Hb	84	10.9	Hb
			65	36.0	Hc	76	42.0	Hc			
						81	41.6	Hc			
						82	34.5	Hc			
			M=	35.1		M = 26.6			M = 12.9		

(con.)

TABLE XIX (con.)

Plateau			Saddle			Ravine			Valley			Plain		
Lamb No.	%	x	Lamb No.	%	x	Lamb No.	%	x	Lamb No.	%	x	Lamb No.	%	x
						RUMP								
74	109.0	Hc	8	13.5	Hb	6	9.3	Ht	1	10.9	Hb			
			11	20.6	Hb	27	23.5	Hb	43	10.4	Ht			
			48	40.0	Hc	46	19.0	Hb	75	16.5	Hb			
						65	41.5	Hc	84	12.8	Hb			
						76	25.6	Hb						
						81	15.9	Ht						
						82	24.5	Hc						
M=109.0			M= 24.8			M= 22.7			M= 12.7					
						SIDE								
74	100.0	Hc	8	17. 8	Ht	6	7.4	Hb	1	10.7	Hb	44	3.1	T
			81	28.5	Hb	27	17.2	Hb	11	9.7	Hb			
						82	9.4	Hb	35	8.9	Hb			
									43	7.0	Ht			
									46	9.5	Ht			
									48	29.3	Hb			
									65	11.7	Hb			
									75	4.2	Ht			
									76	15.0	Hc			
									84	8.2	Ht			
			M= 23.1			M= 11.3			M=11.4					

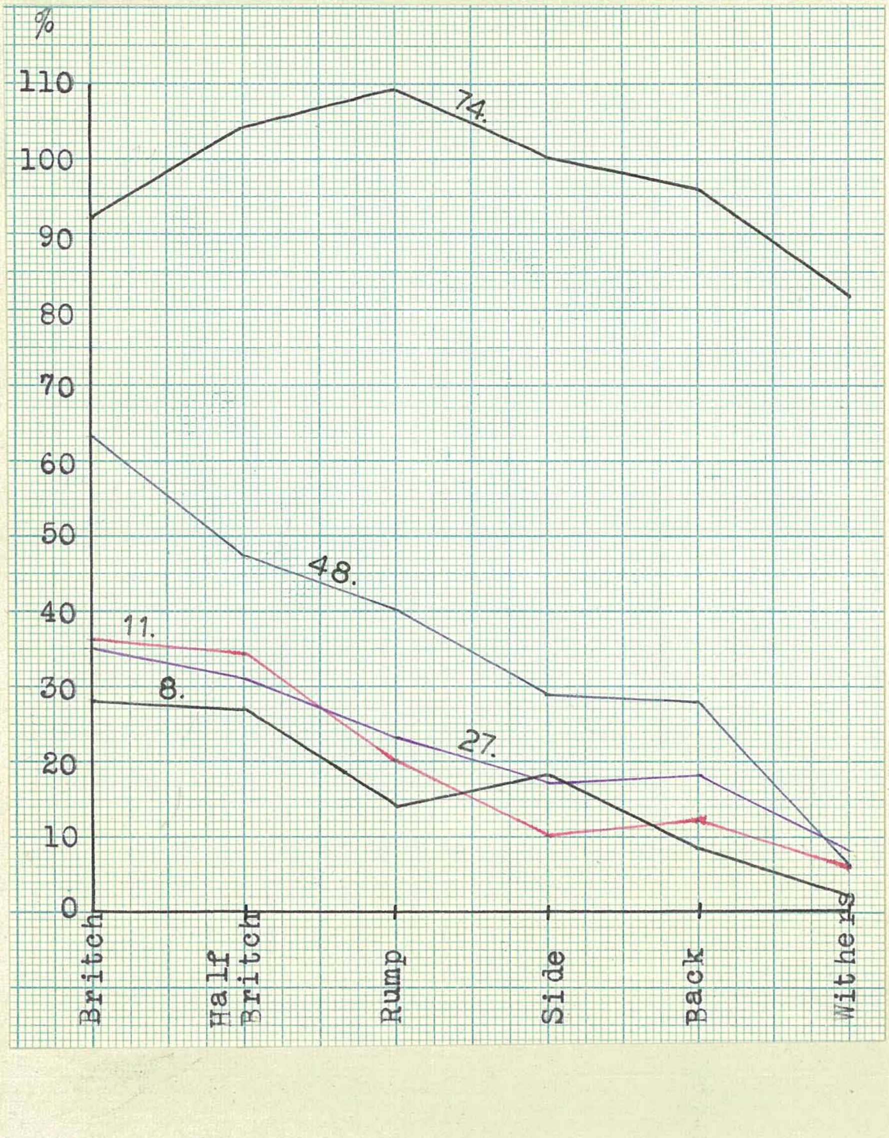
(con.)

TABLE XIX (con.)

Plateau			Saddle			Ravine			Valley			Plain		
Lamb No.	%	x	Lamb No	%	x	Lamb No	%	x	Lamb No	%	x	Lamb No	%	x
BACK														
74	96.0	Hc	82	16.4	Ht	8	8.1	Ht	1	4.4	Ht			
						81	9.8	Hb	6	5.0	Ht			
									11	12.4	Ht			
									27	18.1	Ht			
									35	9.8	Hb			
									43	6.8	Ht			
									44	4.6	Ht			
									48	27.7	Hb			
									65	19.7	Hb			
									75	10.3	Hb			
									76	26.7	Hc			
									84	6.8	Ht			
						M=	8.9		M =	12.7				
WITHERS.														
74	82.5	Hc							6	2.0	T	1	2.0	T
									11	6.0	Ht	8	2.0	T
									27	8.0	Ht	43	2.0	T
									35	2.0	T	44	2.0	T
									46	7.1	T			
									48	5.9	Ht			
									65	3.7	Ht			
									75	3.1	Ht			
									76	6.8	Hb			
									81	2.0	T			
									82	2.0	T			
									84	2.7	Ht			
									M =	4.3		M=	2.0	

x Legend:

Hc - hairy throughout, equal throughout
Hb = " " less at butt
Ht = hairy tip
T - Trace



Graph 7

Percentages of Hairiness:

Lamb No. 74 with Plateau on all regions; other lambs with Plateau on Britch and Saddle on half-britch.

Graph 8

Percentages of Hairiness:
All lambs with Plateau on Britch and Ravine on Halfbritch

Graph 9

Percentages of Hairiness:

Lamb No.	Britch	Halfbritch.
65	Saddle	Saddle
6	Saddle	Ravine
1	Saddle	Ravine
84	Valley on all the regions.	

TABLE XX

Region/ Array	Plateau	Saddle	Ravine	Valley	Plain.
Britch	42.3	36.4*	31.9*	12.3	-
Halfbritch		35.1	26.6	12.9	
Rump		24.8	22.7	12.7	
Side		23.1 *	11.3 *	11.4	
Back		16.4 *	8.9	12.7	
				4.3	2.0

* = one or two samples only.

Under the name of one array, say Plateau, are grouped a series of arrays; the left wing of such a series may be thought of as linked up with a hypothetical array still "tougher" than Plateau, whereas the right wing is linked up with tough Saddle (bordering on Plateau). In an evolutionary sense the arrays are nothing but gradual steps, intimately connected with each other in linear order, steps which mark the path of the evolution process leading from a more primitive coat to a more improved one; hence the "overlapping" previously discussed which occurred in these arrays is only to be expected in hairiness.

(iii) The "head" of an array, that is, pre-curly-tip fibres and checked curly-tip fibres, plays a decisive role in the determination of the arrays as well as in the presence and abundance of kemp. There are, however, still other factors which do not play any role whatsoever in the determination of either array or kemp, but they play a decisive role in hairiness abundance. These factors are:

the precipice,
crisis thinning
base (or inborn) hairiness
abundance of histerotrichs (etc.)

We called tentatively the forces responsible for some of the above phenomena "tail check" and this will be discussed in due course. Thus it is apparent from the discussion of hairiness, a discussion based on the arrays, which for their part, are determined only by their "head", we can expect sometimes to get less hairiness in more primitive arrays or more hairiness in less primitive ones.

(iv) The distribution of hairiness in the sample is of great importance. This is denoted in Table XIX (third column) by symbols borrowed from F.T.D.. The explanation of these symbols is to be found at the end of the Table.

1. Hairiness in the same arrays on different body regions.

(a) Plateau arrays.

The most primitive array found in the New Zealand Romney is the Plateau, and therefore it was not surprising to find in these arrays the highest percentage of hairines. In this lot under present study, all the Plateau arrays except those of one animal, were found on the britch region. The percentage of hairiness ranges from 24.6 per cent to 93.0 per cent, the mean being 42.3 per cent. All these samples were "hairy throughout"; only one was "less hairy at the butt end".

As to the other body regions, only one lamb was included in my material with Plateau anywhere but on the britch. This lamb (No.74) is N-type, having extraordinarily chalky fibres with hairiness percentages oscillating in the vicinity of 100 per cent. In spite of the lack of other data there is no reason to suppose that the percentage of hairiness in the Plateau arrays on other body regions may be significantly lower.

(b) Saddle Arrays;

The Means of hairiness in Saddle arrays on the britch and half britch regions are fairly close to that of Plateau; the others tend to be lower. Whether this tendency is a real one or due to the scarcity of data it is impossible to say. As to the distribution of the hairiness down the staple it is interesting to notice that "Hc" (Hairy throughout) are diminishing and "Hb" (less at butt) or even "Ht" (Hairy tip only) are increasing.

(c) Ravine Arrays

The means in these arrays are a bit lower than for Saddle arrays. The trend is maintained. Again an appreciable decrease of "Hc" and a great increase of "Hb".

(d) Valley Arrays

The means of hairiness in Valley arrays show the most significant decrease and the most stability over the body regions, except for the withers region where a marked drop occurred (Back - 12.7 per cent, withers 4.3 per cent). The deviations plus and minus from the mean are smaller.

Table XXI shows the distribution of hairiness down the stapleP

TABLE XXI.

Region	Britch	Half Britch	Rump	Side	Back	Withers	Total
Hc	1	-	-	1	1	-	3
Hb	-	3	3	5	4	1	16
Ht	1	1	1	4	7	7	21
T	-	-	-	-	-	4	4
TOTAL:	2	4	4	10	12	12	44

Out of 44 Valley arrays only 3 arrays were "Hc", this being less than 7 per cent of all Valley arrays analysed. The distribution of hairiness down and along the array is of very great practical importance. In the present tabulation we actually watch the gradual decreasing of "Hc" from Plateau to Saddle, from Saddle to Ravine and from Ravine to Valley. We expect, too, that we will reach a stage in Valley or in Plain arrays where only a trace of hairiness is detectable. This assumption is very correct. Thus we could advocate: Select for Plain arrays in order to get rid of hairiness. We are, however, very far from such a suggestion. There are a couple of reasons why it is considered that such a suggestion is not to be put forward. First: Plain arrays are found usually on the withers region, that is the most improved region of the fleece and it seems very difficult to raise the standard in other parts of the fleece of the New Zealand Romnay up to Plain arrays; secondly, Plain arrays are inclined to have the count much higher than the standard count for Romney breed, hence selection for Plain arrays involves a simultaneous selection for higher count and the latter is undesirable in the Romney breed.

The data found in the present study suggest that Valley arrays and particularly weak or truncated Valley arrays are the very arrays selection should be based upon. It may be remembered that the hairiness which is confined to the region up to the crisis level, after which it disappears, is rather harmless and tolerable. This is especially for Valley arrays which show a low percentage of hairiness. Therefore only such Valley arrays which are "Hc" are undesirable, all the others are desirable. The former comprises only 7 per cent of the total Valley arrays analysed. It may be interesting to discuss these three arrays. The first one, found on the britch region of Lamb No.35 is a tough Valley array, approaching Ravine array, having only 3 per cent of checked curly tip fibres and 33 per cent of peak curly tip fibres.

The latter are more or less chalky throughout, with a small portion fine after the crisis level. Peak curly tip fibres are the actual fibres responsible for the hairiness sustained down the staple although this array is not heavily medulated (15.2 per cent of hairiness).

The second one, found on the side of Lamb No. 76 is again "tough" Valley, having only 29 per cent of fine sickle fibres and 11.6 of checked Curly tip fibres. The same applies to the third Valley found on the back on the same lamb. This array is approaching Saddle, having a well developed pre-curly-tip fibre group, with only 30 per cent of fine sickle fibres in it and 7.2 per cent of checked curly tip fibres. These figures are well below the mean for Valley arrays (see page 87), The percentage of hairiness being 15 per cent and 26.7 per cent respectively.

Thus it is plain that the above Valley arrays are border-line ones, and they are not truncated Valley arrays.

2. Hairiness in different arrays on the different body regions.

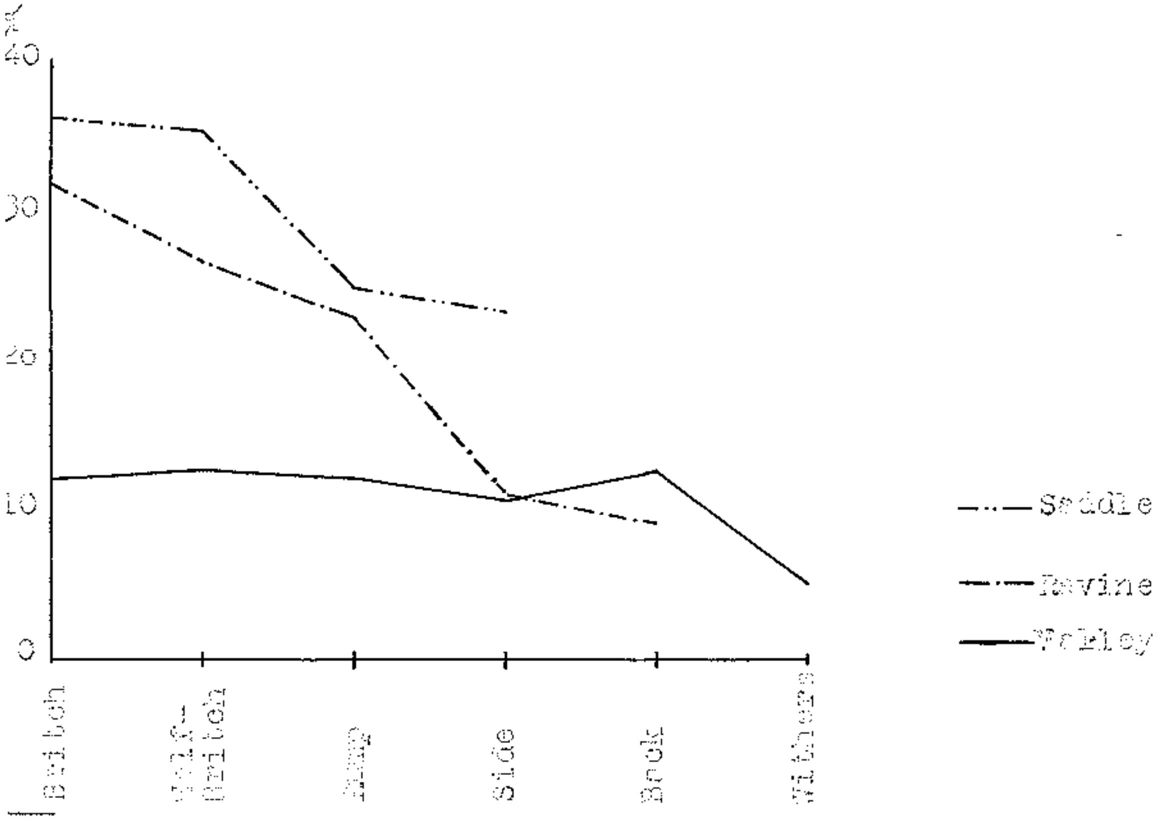
The data tabulated in Table XX and graphs 7, 8, 9, 10, and 11 suggest a slight inclination to decrease the percentage of hairiness in the following order:

Britch, halfbritch, rump, side, back, withers. There are, however, some individual variations. In the majority of cases the britch region, having as a rule the least depressed array over the lamb's body, has also the highest percentage of hairiness, whereas the withers region, having the most depressed arrays, has the lowest percentage of hairiness. As to the former, it may be mentioned that a few exceptional cases were found. They are: Lamb No. 74, N-type (graph 7) having the percentage of hairiness higher on the half-britch than on the britch and highest of all, on the rump. Lamb No. 76, Plateau on britch and Ravine on the halfbritch (graph 8) the latter is a little more hairy than the former and finally Lamb No. 84 with Valley arrays all over the body (graph 9) having the same tendency as lamb No. 74.

As to the other regions, a few exceptions are to be seen on the graphs and therefore they need no further discussion, except one point which raises a question of considerable practical interest, namely, the significance of high abundance of halohairs on the britch, with far fewer halo hairs on the half britch and on the rest of the main areas of the body. The answer to the above question is to be found in graphs 7, 8, 9 and 11 showing the percentage of hairiness over the body regions. Graph 7 shows Plateau on the britch and Saddle on half britches

Graph 10

Percentages of Hairiness in Plateau on Britches.



Graph 11

Means of Percentage of Hairiness in different arrays on different regions of the body.

(Lambs Nos. 8,11,27,48). Graph 8 shows again Plateau on the britches but Ravine on Half-britches (Lambs Nos. 75, 43, 46, 76, 81, 82). In the graph 9 Lamb No. 65 with Saddle-saddle; No. 6 Saddle-ravine; No. 1 Ravine-ravine, and No. 8~~5~~4 - Valley-Valley on britches and half britches respectively. All the above graphs show that usually half-britches are less hairy than britches but the difference between these two regions are less marked than between the other extremes, namely - withers-back. The diminishing of hairiness from the britch regions towards half britch regions takes place in slow and rather gradual fashion, hence in the course of selection against hairiness the britch region is of great significance.

Plateau or "tough" Saddle arrays (e.g. No. 65) on the britch regions involve:

(i) arrays on half britch regions more or less associated with Plateau arrays rather than with Plain arrays;

(ii) high percentage of hairiness on the half britch. This is for Saddle arrays higher then 26 per cent and for Ravine higher than 11 per cent. As it has been said the hairiness is gradually diminishing from britch to withers, hence if the starting point is high we cannot expect any marked diminution of hairiness on the hind portion of the fleece.

Since the hairiness is correlated with arrays (graph 11) it is suggested that the ideal plan would be to base selection against hairiness on truncated Valley or Ravine on the britch.

Thus we arrive at the same conception as Thomasset (47) who suggested that selection against hairiness be based on the tail. Thomasset's suggestion cannot be discussed here because the hairiness of the tails, which, though graded for halo-hairs, were docked, has been left out of account in the present study. The britch was chosen because the hairiness of that region itself is of substantial practical importance. When we bear in mind that the correlation between britch halo grade and tail halo grade is high r = + .78 (Dr. Dry's personal communication) the result of this present investigation suggests that it would be worth while studying the significance, for the hairiness of the rest of the fleece, of halo-hair abundance and distribution on the tail.

It is well to remember that wool as such is a subject of different interactions, not only of genetic origin but also of environmental (McMahon - unpublished). Therefore all suggestions which come as a result of an investigation of a given problem must be carefully examined against the background from which the problem was picked out and after such a final test we can believe that such a practical suggestion will not mislead a practical breeder. Certainly further investigation is needed to test the suggestion that in order to get rid of hairiness no matter whether kemp hairiness or not, selection must be based upon truncated Valley and that the crucial position should be the britch. All the same, from inquiries made in F.T.D. it seems to me likely that truncated Valley arrays have little chance of the revival of hairiness in subsequent fleeces.

III. Forces responsible for the diminution of Hairiness:

In the preceding chapters the "head" check was discussed. It was pointed out that this check causes the head of the array to be fine. Mention has already been made that there are other forces which cause the end or tail of the curly-tip fibres to be fine. To this action the term "tail check" is conveniently applied, for contrary to the head check "tail check" starts to work at the end of the curly tip series and its expansion is directed towards the middle of an array. In Plain arrays where both the checks reach their climax, they cause all peak Curly tip fibres to be fine and thus these two checks come together. The "tail" check probably exercises its influence on the percentage of histerotrichs for when the chalkiness is maintained well along the array the percentage of histerotrichs is higher.

It is proposed to discuss now the "tail" check in its primary form, known as a "precipice", and other forces responsible for happenings after "crisis thinning". The base, or inborn chalkiness upon which all these forces are at work, must be left out of the present discussion because we know practically nothing about it.

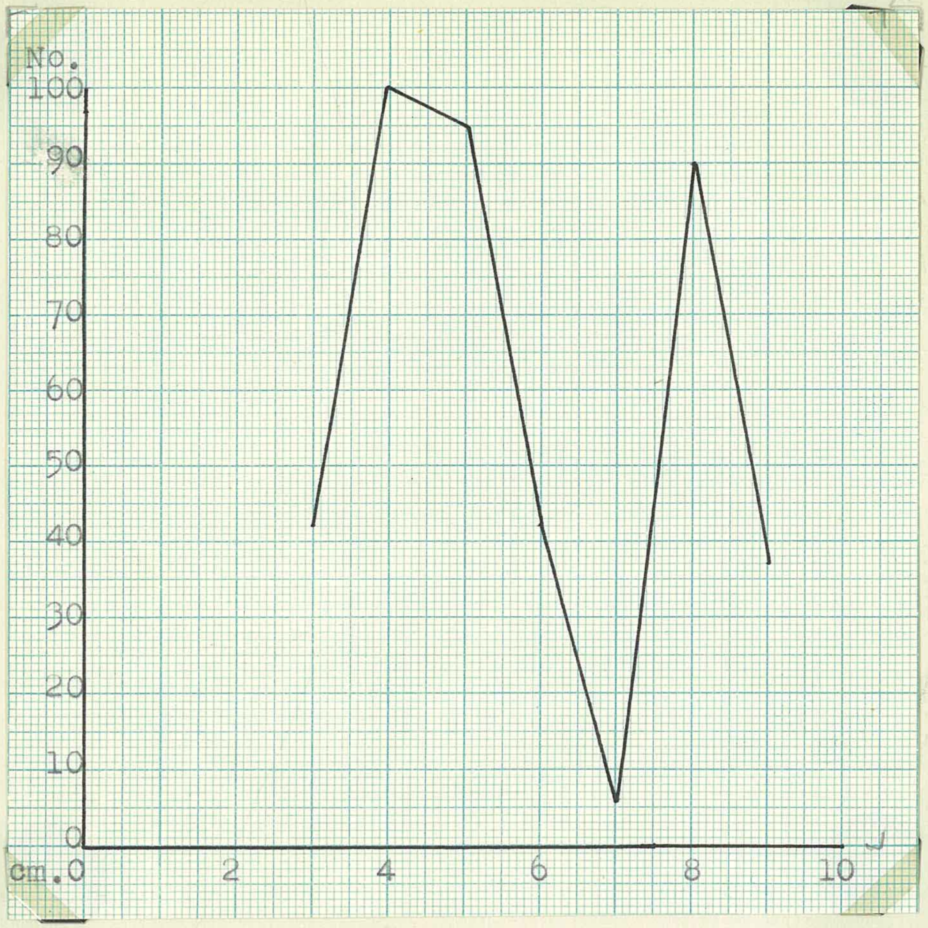
1. The Precipice

Galpin (unpublished paper) defines it as follows:

> "Precipice is the term given to the sudden change along the array from the coarse to the fine curly-tip fibres without intermediate fibres".

The above definition is correct only for some Plateau arrays.

A precipice in its purest form can be seen in Plateau arrays. Graphs 3 and 12 show such a precipice in the length of the fibres. The trough between the two peaks is very deep. Just the same may be shown in the diameter of the fibres. The



Graph 12

Lamb No. 124 (First sample) Plateau on the side. Note the precipice in the length of fibres.

cm.	3	4	5	6	7	8	9
Halo hair						16	7
S.S.A					2	13	
S.S.A'						1	
S.S.B.					2		
H.T.C.T.					1	60	30
C.T.	42	100	95	42			
Total:	42	100	95	42	5	90	37

latter is more important and therefore the discussion will be focussed on the changes in the fibre diameter.

The most striking and illuminating examples are provided by Lamb No. 74. As it has been mentioned many times, this N-type lamb has very coarse and primitive wool and therefore the differences in the length as well as diameter are easily detectable. Thus there has been found on its britch region a very sharp precipice both in the length and diameter of the curly-tip series but what is extremely interesting is that

(i) this precipice occurred at the very beginning of the curly-tip series and thus it has sharply divided two fibre types from each other, and

(ii) the post-precipice fibres were not actually fine at all and were hairy. The pre-precipice fibres, i.e. H.T.C.T. fibres, were so extremely chalky and thick that the post-precipice fibres, i.e. curly tip fibres, looked as if they were fine.

The precipice found on the half-britch region is of great importance too. The beginning has retreated a little. (This retreating - that is moving towards the right in the array) is apparent only.) It is better to regard at this stage of discussion, the pre-precipice region as unmovable and stable - see page 182. The post-precipice curly-tip fibres here again are not fine, those on the left wing are longer and coarser, those on the right wing are shorter and finer. Looking from the left to the right wing we can see the gradual transition in both length and diameter up to the extreme right wing where the curly-tip fibres are really fine. The precipice found on the side region is the most abrupt. The beginning has seemingly retreated still further, i.e. has moved more to the right and only a few post precipice - curly tip fibres, namely the first fibres - are hairy, others are fine or nearly fine. It seems that the side region has the precipice with the greatest drop. The same to a lesser extent applies to the withers region, whereas on the rump region the precipice is much more shallow than even on the britch and finally the precipice on the back region is so flat that it is very hard to recognise it as a precipice and it is much better to speak of a gradual transition in both diameter and length.

Thus to sum up; we can state that -

(i) in six regions studied the precipices found behaved differently. The most powerful precipice was on the side. The least or practically none on the back region. Other regions placed in order from strongest to weakest are:

withers
half britch
britch, and
rump.

As to the latter, it may be added that it was more akin with the back region than with the half-britch.

(ii) Post precipice curly-tip fibres need not be fine, as it was postulated by Galpin. They can be medullated. In this particular case the pre-precipice fibres were so chalky that the post-precipice fibres looked in comparison rather fine.

(iii) The post precipice curly-tip fibres may show diversity in their diameter and length. This being the case, the first lot of fibres is longest and coarsest, whereas the last lot is shortest and finest. All intermediates occur.

These three points are of primary importance in the understanding of the work of the precipice. It must be emphasised once more that these conclusions are drawn from unmistakable facts and all the precipices, except on the back, were distinctly and acutely recognisable owing to the fact that all the precipice fibres were extremely chalky. Now, the following question arises: we know already that when the precipice is "weak" only the last fibres are quite fine, and the "stronger" the precipice the more fibres become fine until the stage is reached where all the post- precipice fibres are fine. Now what has happened to the pre-precipice fibres, in other words, does the upland to the left of this precipice undergo any changes which will, in turn, bring about the deterioration of this region? It must be admitted that for a long time it has been thought that the upland was the Mountain and the lower Mahomet, and it was hard to imagine that the mountain would come to Mahomet. Such a question was of interest since the majority of precipices, or, strictly speaking,precipices in Galpin's sense of this word, were found in less checked arrays, like Plateau or Saddle, but none of them in Valley or Plain arrays, and naturally the question arises - what happens to the precipice?

The main features of post-precipice fibres did not undergo many great changes, the influence of the force responsible for the/precipice extended towards the middle of the array, bringing about firstly the diminution of hairiness and finally causing all fibres at the foot of the precipice to be fine. Similarly the force of the "head" check extending too towards the middle of an array has caused the fibres to be finer and finer, and thus as will be explained in the evolution section, a stage was reached where the differences between the top and foot of this precipice were levelled. The precipice is a geological term, therefore it may be permitted to say simply that the top was eroded. Thus the top was not the mountain, only Mahomet. Of course, in the last case a precipice as such may be hardly called a precipice, because there may be a gradual (not sudden as postulated by Galpin) transition from fairly chalky pre-precipice fibres to fairly chalky post-precipice fibres. Here it may be added that Sutherland's conclusions are not dissimilar.

The precipice as understood in this broad meaning of the word is a rather common feature of fibre-type arrays. In some arrays, e.g. arrays with a considerable number of hairy-tip-curly-tip fibres, all curly tip fibreslie at the foot of the precipice. In others, however, only a part of curly-tip fibres. Further, this precipice is in some arrays very abrupt, this is the common case in Plateau arrays, but in more checked arrays it is to be found too, and then again all post- peak - curly tip fibres are fine. Finally, the precipice is normally both in the length and the diameter of fibres, but there has been found in a number of cases a precipice in the diameter only or in the length of fibres only.

2. Crisis thinning x

As it has already been stated "crisis thinning" usually occurs at the age of about 2 months (Dry, 13) but this is not a rule and great variations exist. Hence, in benzol test data the symbols Ht (hairy tip only) and Hb (Hairy, but less at the butt end.)

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x The term "crisis thinning" as used in published papers means reduction in area of cross section and cessation of medullation at the age of about two months. This is the meaning ~~in which~~ the term carries in this thesis, in whatever persistent fibres the thinning may take place. It should however, be pointed out that Dry is apt to use the term in a more special sense. He usually applies it only to birthcoat fibres whether pre-curly-tip fibres or the earliest starting curly-tip fibres, of types which have a chance to shed as birthcoat kemps, but which frequently become fine, often very suddenly about the same time as fibres of the same types stop growing to be shed soon afterwards.

Since the diminution of hairiness down the staple is mainly due to crisis thinning, it is plain that in "Ht" samples, the "crisis thinning" takes place earlier than in "Hb" samples. Such a crisis thinning is described as very similar to the catogen phase of shed fibres (Sutherland,46) but the Telogen does not ensure and a fibre does not shed. Another suggestion that crisis thinning may be due to the influence of the environment, is discussed by Sutherland (46). He concludes that "crisis thinning" (in Dry's sense) is not due to environment. Sometimes "crisis thinning" is not a sudden, but gradual change from chalkiness to fineness. Sometimes such a gradual change takes place very late (after four months) and of course in our present ~~material~~ staples was confined to the very butt end. This latter is not regarded in the present discussion as "crisis thinning".

For the sake of simplicity as well as for reasons explained later, it is thought advantageous to describe the "crisis thinning" in the same kind of terms which describe the result of the pre-natal check in the pre-curly tip fibre group. If we say "crisis thinning" takes place in super sickle A' fashion, this means that the crisis thinning is confined to a very short portion of the fibre length, not longer than the corresponding region in the pre-natal region of super sickle A' fibres, while (e.g.) "fine sickle fashion" means that the fibre is fine after the "crisis thinning".

Thus, crisis thinning taking place in super sickle A' fashion is confined to a relatively small number of fibres. In the curly-tip fibre group the first fibres which at the same time are the most chalky fibres may have such a crisis thinning. Crisis thinning taking place in super sickle B fashion is more common. The fine region, that is the region after "crisis thinning" and before the revival of chalkiness varies a good deal in length. Here again the shorter fine region is to be found in the left wing of the curly-tip fibre group, whereas the right wing is furnished with fibres having this fine portion very much longer and very often without revival of the medullation. As to the revival of medullation, it must be added that the medulla after the "crisis thinning" may be or may not be, as thick as before the crisis thining. In fact, all gradations exist. The same applies to the fashion in which medulla revives. It may revive suddenly or gradually. If reduced medullation revives it does so usually in a gradual fashion.

The most common fashion in which "crisis thinning" takes place is the "fine sickle fashion" with no revival of hairiness. This may be encountered in all arrays without any exceptions, but broadly speaking is more common in more checked arrays. Here again the situation plays perhaps a greater part than the array. Usually the last curly-tip fibres have the fine sickle-fashion crisis thinning, and what is of great interest, there has never been found an array having a super sickle A' fashion of "crisis thinning " on the right wing, with fine sickle fashion"crisis thinning" on the left wing of the curly-tip fibre types. Just as one cannot imagine fine sickle fibres first and later super sickle A' fibres in the pre-curly-tip group.

The above discussion makes probable the conclusions that there is a parallel between the "head chedk" and the check which causes the expansion of crisis thinning". In other words, history repeats itself.

The analogy is so close and suggestive that it is thought sufficient to lay stress upon only a few common characteristics:

(i) the above described facts are almost identical with the events in the pre-curly-tip fibre group, namely, there are in the latter group, e.g. halo hairs or super sickle A fibres, which do not show any thinning of the medullation. Further, thereare super sickle A' fibres showing exactly the same kind of thinning as the crisis thinning. As to these super sickle A' fibres it may be as well to remember that the small number of super sickle A' fibres found on all arrays corresponds with the small number of super sickle A'-like "crisis thinning".

(ii) It may be mentioned for the sake of curiousity rather that some traits characteristic for halo-hairs are found in some curly tip fibres, chalky throughout. We may recall that some halo-hairs have the distal region finer than other regions. Such a gradual fineness of halo-hairs does not disqualify a halo hair from belonging to the halo-hair fibre type, and in turn, the same phenomenon found in the post-natal region of some chalky fibres should not be regarded as "crisis thinning".

(iii) In the pre-curly-tip fibre group, the fibres are arranged in order so that always sickle fibres furnish the extreme right wing. Again, exactly the same order holds true for crisis thinning. Finally -

(iv) In the best checked arrays, like truncated Valley or Plain, the pre-curly-tip fibre group consists of only one fibre type, namely fine sickle fibres. Similarly in well advanced crisis thinning, all fibres below crisis thinning are fine, because "crisis thinning" takes place in "fine sickle fashion".

No attempt is made to speculate upon the forces responsible for this phenomenon. The crisis thinning is probably not to be regarded as the result of the "tail check". In Dr. Dry's laboratory there are some speculations leading towards connecting the crisis thinning with the precipice, although the other view connecting crisis thinning with "head check" is not without foundation. It may be hoped that further study upon this line will reveal the forces responsible.

From the point of view of hairiness "crisis thinning" is of very great importance. As it has already been pointed out there are three sides from which the chalkiness in an array is attacked, namely from the head of an array, from the tail of curly tip fibre type series and from the crisis level. The first two attacke are performed by means of "Head" and "tail" check, respectively. These two forces are of very primary importance, they play a main part in the evolution of the fleece, and they are able to weed out the chalkiness. The fineness caused by crisis thinning is perhaps not of primary importance from the evolution point of view, but it is very important in the diminution of hairiness in these regions of the fibre length in which either the previously mentioned checks are powerless or when they do not yet extend to these fibres. An example for the first case is chalky sickle fibres. For the second, peak curly-tip fibres. In such cases, crisis thinning often comes and helps to keep the inborn chalkiness down. However, such a help may be capricious and dangerous, for when a follicle once produces a chalky fibre it is plausible to think that it can later on come back to the production of chalkiness. It seems that a follicle which does not produce a chalky fibre early has less chance to produce chalkiness in its later career. Although it must be remembered that checked curly tip fibres were found in which a slight chalkiness occurred in the proximal part of the fibre length, the latter being of very rare occurrence may be regarded as an exception.

Thus to sum up, selection against hairiness should be based on truncated Valley arrays on the britch regions for:

(i) truncated arrays cannot have kemp hairiness;

(ii) the hairy fibres in truncated Valley are confined to a relatively small number of peak curly tip fibres; the latter when having "crisis thinning" are fine after it;

(iii) the britch as the least improved region of the fleece is the most suitable region for selecting against hairiness, although the rump region may get the upper hand in the percentage of hairiness. The differences, however, are of no significance.

SECTION IV

I. N-TYPE - FROM THE STANDPOINT OF EVOLUTION

1. Introduction

In dealing with evolution in the fleece of the New Zealand Romney breed, it is thought necessary to consider first of all the material upon which the present study is based. As was pointed out in the first chapter, Dry's experimental stock furnishes the best material for such a study because it comprises sheep on which the wool ranges in uninterupted series from very coarse and mixed wool to very fine and even wool. Thus some N-type sheep may be linked up with the Blackface breed of sheep or even with the Cakiel, whereas some Non-N-type lambs, having truncated Valley or Plain arrays are in this like merinos (25,46). The present study, however, is confined to the evolution of the fleece within the New Zealand Romney breed and therefore it is not attempted to draw any general conclusions from facts presented now, although those facts and the knowledge of other breeds of sheep strongly suggest that the same changes have taken place in the evolution of the fleece of other domestic breeds of sheep. The data from the point of view of the evolution of other breeds of sheep and especially of the birthcoat of wild sheep is so sketchy that it is not possible to say how wide is the significance of the ideas that are to be presented.

Of course, if could be objected that my approach to the evolution problem is based on the study of a well improved breed of sheep. Such an attitude would be completely wrong; apart from the fact that all experimental science is based on induction (and especially genetics) it may be taken for granted that nobody could question the right of a historian to write a study of the Napoleonic epoch without particular knowledge of the epoch of Alexander the Great.

2. N-Type - as example of Atavism.

Although Dry's flock is still under investigation and its genetic make-up is still largely unknown, yet Dry, McMahon and Sutherland in a recent publication (17) discussed the mendelian situation in these animals:

> "In several N-type animals born in various experimental matings, it is concluded from their ancestry and/or breeding performance that their genetic basis is multifactoral, but in most N-type lambs born at the College the genetic basis is mainfestly relatively simple",

and further:

> "We are able to suggest more than one somewhat elaborate explanation of our list of facts. Two linked complimentary factors for N-type are favoured by one of us, while a dominigene is the pivot of another hypothesis."

From the above statement we can conclude that genetically there are two kinds of N-type. The most interesting for our present discussion is the first, namely, the multi-factorial N-type.

Now the question arises of the way in which all the changes were brought about.

At this stage of our knowledge there are two ways in which it is possible to explain these phenomena, namely (a) reverse mutation (b) recombination.

Although some reverse mutations do occur,(36) they are confined to fairly simple cases and occur very seldom indeed.

Data in hand suggests that recombination is the phenomenon which brings about the atavistic appearance of the coat of N-type animals. There is some evidence to be found in literature which deals with similar cases. Thus in every textbook mentions are to be found concerning atavism in domestic animals, the best known is :

the red calves in the white and black cattle. The latter case is identical with that reported by Dry (17) that on New Zealand sheep farms such N-type lambs dropped up from time to time.

The above cited cases will not be discussed here, chiefly on account of the lack of data for genetic consideration.

Stockard (45) in his very fascinating study on the atavistic reappearance of digits in mammals proved conclusively the presence of a factorial basis for characters lost in evolution. For more than one reason his experiment is of interest to all those who are interested in evolutionary problems. Firstly, because it was concerned with osteology and all the authorities in this discipline regard bones as being the material that is most resistent to variation. Secondly, he proved the wrongness of Osborn's statement:

> "The evolution of anatomical organs is never reversible".

Finally it has a direct bearing upon our study of the evolution in the fleece of the Romney breed.

It is hoped to deal with the problem of the evolutionary ofigin of N-type lambs in a separate paper, for the present purpose it will be sufficient to explain briefly that Stockard by means of combining different generations and taking account only of the toe- quality achieved in a gradual way the atavistic reappearance of extra toes; Thus:

> "Through these experiments the usual four-front and three-hind-toed condition of the guinea-pig has been brought back to a five front and four hind toe arrangement which is similar to the arrangement now found normally in the dog".

The method employed by Stockard is very simple He mated similar with similar and in this way achieved his results. Thus he denotes by "N'"an animal showing a trace of extra toe, "P" as poor, "F" as fair and "G" as good. In this order "P" class is better than "N'" class, and"F" class is better than "P" class, whereas "G" class comprises normally developed extra toes. His statistical results are of primary importance. Now, however, it will be enough to cite only his summarised data:

Thus, mating similar to similar he achieved

N' x N' = 5% of extra toed animals

P x P = 65% of extra toed animals
but in this class 22% of animals
show for the first time "F" (fair)
condition.

F x F = 95% of extra toed animals
Here for the first time the good
toes (G class) appear

G x G = 100% of extra toed animals:
This class comprises -
85% of G-class condition
9% of F-class condition
6% of P-class condition.

The main points stressed by Stockard having a direct bearing upon our present discussion are:

1. "Certainly no one will assume that all individuals of a race carry the factors for polydactyly in their germ cells;"

2. "On the other hand, the reappearance of normally missing digits in guinea pigs is not only a different but possibly an opposite phenomenon from polydactyly, a return to previous foot conditions, a typical atavism. The reappearance of a toe should probably not be thought of as resulting from a new mutation, but rather it oocurs on account of a peculiar bringing together or com-

"bination of old factors in certain individuals".

3. "The expression of extra toes seems to depend upon multiple factors".

4. "When atavistic return of digits occurs in these mammals, the digits reappear in reverse order from that in which they disappeared."

In the N-type animals, it is much easier to prove that the reappearance of the primitive coat is due to recombination. All the writers agree that Kemp is nothing but a remnant of the outer coat of wild sheep. It will perhaps be enough here to quote Barker (3)

> "Even in pure Merino flocks a sheep will very occasionally occur with a coat that is quite full of kemp. This is a good example of what is popularly termed 'reversion', a purely hereditary phenomenon".

It will be well to remember that one of Dr. Dry's aims was to study the kemp situation by selecting for kemp. His grading system is based upon the abundance of halo-hairs, that is the largest birthcoat kemps and N-type

Fig. 31

Lamb No. 74(N-type) 6 months old, forequarter

Fig. 32

Lamb no. 74 (N-type) 6 months old, hind quarter.

are always Grade VI! We will remember the conclusions reached in preceding chapters, namely, that each array has its peculiar centre of gravity in the pre-curly tip group and animals with Grade VI! must have Plateau array, hence the Plateau array is closely dependent on and correlated with this highest grading. Thus the selection for kemp brings about not only the greater percentage of kemp but also a change towards more primitive in all other properties of the coat.

Now a few examples will illustrate the way in which such an atavism in the birthcoat is brought about:

(1).

```
  E54 V.V )
          ) - 735.VI S)
  589 IV S)           ) -1016 V.S.)
              14.III.S)           )
             E 54 V.V.)           ) - 1342 VI S   )
             E 55 V.S?) - 661 VI S)               )
                                                  )
  E 59 V V)                                       )   - 74 VI! P
          )- 735 VI S )                           )
  589 IV S)           ) - 1016 V S)               )
              14 III S)           )               )
                                  )  - 1328 VI V/S)
             E 54 V. V)           )               )
                      ) -731 V R  )
             36 III V )
```

P = Plateau; S = Saddle; R = Ravine; V = Valley

(other examples are discussed by Sutherland (46).)

(see also figures 31, 32,34 and 39)

(2) In the 1939 offspring is an experiment designed to investigate the inheritance of Saddle array by mating Saddle x Saddle, five lambs out of eleven have Plateau on all the regions examined. In other words, 45 per cent of the offspring of Saddle x Saddle mating were N-type lambs!

Here it will be worth while to mention other facts which strengthen our interpretation. Sutherland (46) described the reappearance of horns in N-type animals whereas Clarke in his unpublished paper describing N-type animals from the standpoint of meat quality, found that -

> the head and neck are heavier in N-type and the special processes of the thoracic vertebrae are higher than in Non-N-type animals.

From the above cited facts it is quite logical to presume -

(i) that the recombination of genes with rather low frequency is responsible for bringing about the atavistic characteristics of the coat of the N-type Romney sheep;

(ii) This was achieved by means of inbreeding and selection;

(iii) the expression of N-type coat seems to depend upon multiple factors;

(iv) the building up of N-type occurs in reverse order from that in which it evolved, and therefore the Plateau array~~s~~ is regarded not only the most primitive but also the oldest array, and the Plain the most improved and the youngest in the sense of phylogeny;

(iv) The Plateau array is not to be regarded as an array which is to be found on the coat of wild sheep. Plateau array may be found on some mixed wool sheep, as, for instance, Blackface or Polish Mountain sheep (cakiel). In other words N-type animals cannot be looked upon as throw-backs in their fleece to their ancestors, but they can be regarded as reverting to a fleece-type lower on the ladder of the evolution of the fleece.

SECTION V.

I. EVOLUTION OF THE FLEECE OF THE NEW ZEALAND ROMNEY BREED.

1. Introduction.

The work hitherto done [x] on the problem of the evolution in the sheep's fleece has divided students of this problem into two distinct groups. The first one, represented chiefly by Duerden, believes that wool evolved only from the fine inner coat, the second one, led probably by Prawochenski and his school in Poland believes that the fleece of domestic sheep originated from both inner and outer coat.

Thus Duerden (20), for instance, arrived at the conception that (20, page 467) -

> "In the course of evolution, the long coarse fibres have become the true kemp of the sheep and the fine under fibres have become wool; separate follicles then give either kemp or wool, not kemp at one period and wool at another".

This view of Duerden's has been influential and helpful in directing thought on the evolution of the fleece,

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[x] Due to the war condition it is quite impossible to collect all the literature on the subject, and therefore the history of the work in evolution of the fleece must be treated in a very sketchy manner.

but towards the close of his life Duerden himself found that the outer and inner coats of the Merino were not so distinct as had been supposed. Wildman (49) reports how Duerden had learnt that in the Merino fine fibres could grow in follicles which had shed birthcoat kemps.

Returning to Duerden's conception - we do not know how much he modified it before his death - we realise that if Kemp is to be regarded as the only remnant of the outer coat, an explanation has to be found for coarse fibres or mixed wool sheep such as Scotch Blackface. Hence Barker (3,p. 264) arrived at the idea somewhat fantastic, as it seems to me, but logical enough on Duerden's view, which is expressed in the following statement:

> "If a structure or organ is lost during the course of evolution, it is usually found that another organ becomes modified to perform the functions of that which has been lost. In the sheep there is a tendency, after the outer coat has been lost for the inner coat to become coarse and so take on some of its functions. This secondary modification may go so far that some of the inner coat fibres become almost as coarse as kemp, e.g. the long straight hairs of the Scotch Blackface".

On the other hand Prawochenski (40, p.29) states: "The thick and stiff outer coat fibres of wild sheep become gradually thinner and begin to lose their medulla. The less the race is primitive, the more it has fibres of transitional character which are in different stages of more or less advanced diminution of the medulla and primary chalkiness. Finally, only a remnant of the outer coat is left which may be found even in the best improved specimen. The reverse is to be watched in the inner coat fibres which in the course of evolution become longer and thicker than the down in wild sheep".

Kaczkowski, onee Professor Prawochenski's assistant, has studied all the different Polish breeds of sheep and arrived at the same conclusion as Prawochenski did. None of the above cited writers was able to prove this hypothesis conclusively. This was mainly due to the lack of suitable material as well as the lack of knowledge of Dry's comparative wool anatomy. It may be added that those workers who have had the opportunity to work on coarse woolled breeds of sheep could not agree with Duerden's view. Thus Lockner (34) passes a remark which is in accordance with Prawochenski's statement. Similarly in Dr. Dry's laboratory no one was in favour of Duerden's view.

Perhaps it will be worth while to mention a letter published by Cossar Ewart (24) In 'Nature' in 1927. He writes as follows:

> "........From this short account of the investigations on hand it follows that a study of the coat of sheep during foetal life lends no support to the view hitherto held by Bowman and others, that wool is hair from which pith or medulla has been bred out, but shows that wool is a distinct and primitive type of fibre different alike from fur and hair".

From this it might appear that Ewart missed the point, for the problem at stake is whether the fleece evolved from the inner coat or from both outer and inner coat and as far as I know no one questioned that wool, or at least a part of it (histerotrichs) is "a distinct and primitive type of fibre".

2. Evolution in the Pre-Curly-tip Group.

From the preceding chapters it is understood that there are three primary, oldest fibre types from which all other fibres have evolved. The primary fibre types are:

halo-hairs in the pre-curly-tip group.
hairy-tip-curly-tip fibres in curly-tip group
and in the last group, histerotrichs.

Halo-hairs and hairy-tip-curly-tip fibres belong undoubtedl to the outer coat, whereas histerotrichs comprise the inner coat. In some N-type lambs these two coats are distinctly separated from each other.

As to the histerotrichs, it may be of great interest to quote Duerden: (21) -

> "The outer kempy coat is already well developed over the body of the new-born Persian lamb, while the inner woolly coat is represented by only a few short fibres, restricted to certain areas".

This statement is in full accordance with the manner in which histerotrichs develop and therefore histerotrichs may be regarded as inner coat fibres.

Dry (13) and Galpin (26) proved that halo-hairs are the oldest or first fibres to pierce the surface of the lamb's skin. Dry, Sutherland and myself were able to show the intimate relationship between all the constituents of the pre-curly-tip group. Thus there is no need to dwell on this point any longer. It may be well just to mention shortly that the fibre types of the first group comprise a gradual transition from halo-hairs to sickle fibres, hence halo-hairs are connected with super sickle A fibres, super sickle A fibres with super sickle A' fibres, super sickle A' fibres with super sickle B and the latter with sickle fibres. The resemblance in the tip shape is so suggestive that one could suspect that these fibres evolved from common stock. (fibres with non-typical tip will be discussed later on). This common stock is halo-hairs and from halo-hairs all the other consti-

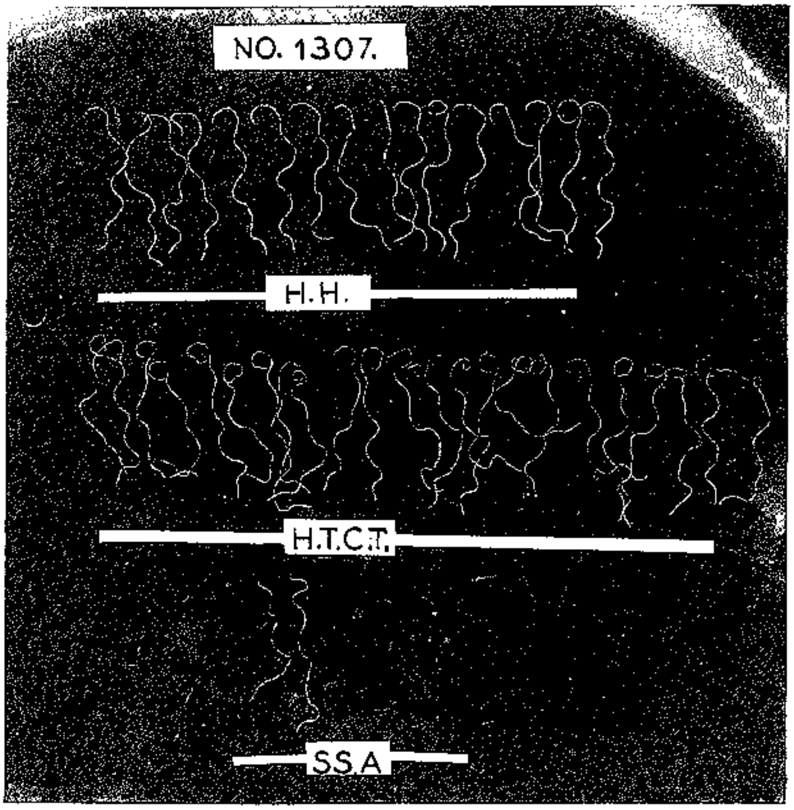


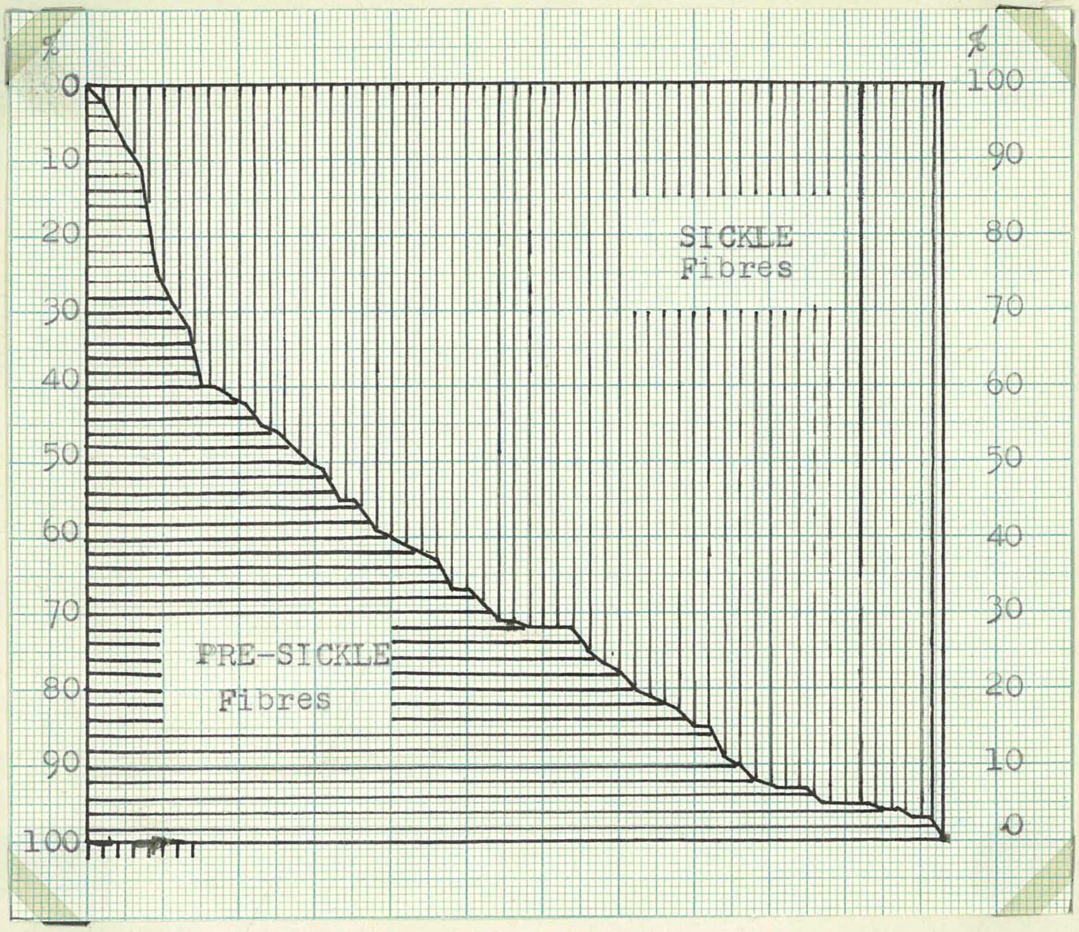
Fig. 33

Lamb No. 1307 - Plateau on the britch.

ents of the first group evolved. The above statement will be better understood when we remember Plateau array on the animals Nos. 1307 and 48. As to the first example, see fig.33 all the pre-curly-tip fibres, simply enough, are halo-hairs and the odd super sickles are not typical and came from a different stock. Thus this array shows no trace of other fibres than halo hairs. Plateau on Lamb No. 48 shows one step further. Here halo-hairs comprise only 77.8 per cent of the pre-curly-tip group and a new fibre type, namely super sickle A (22.2%) makes its appearance. A further step may be seen in Plateau array on Lamb No. 74, having halo hairs 51.4%
super sickle A 30.7%
Super sickle A'17.9%

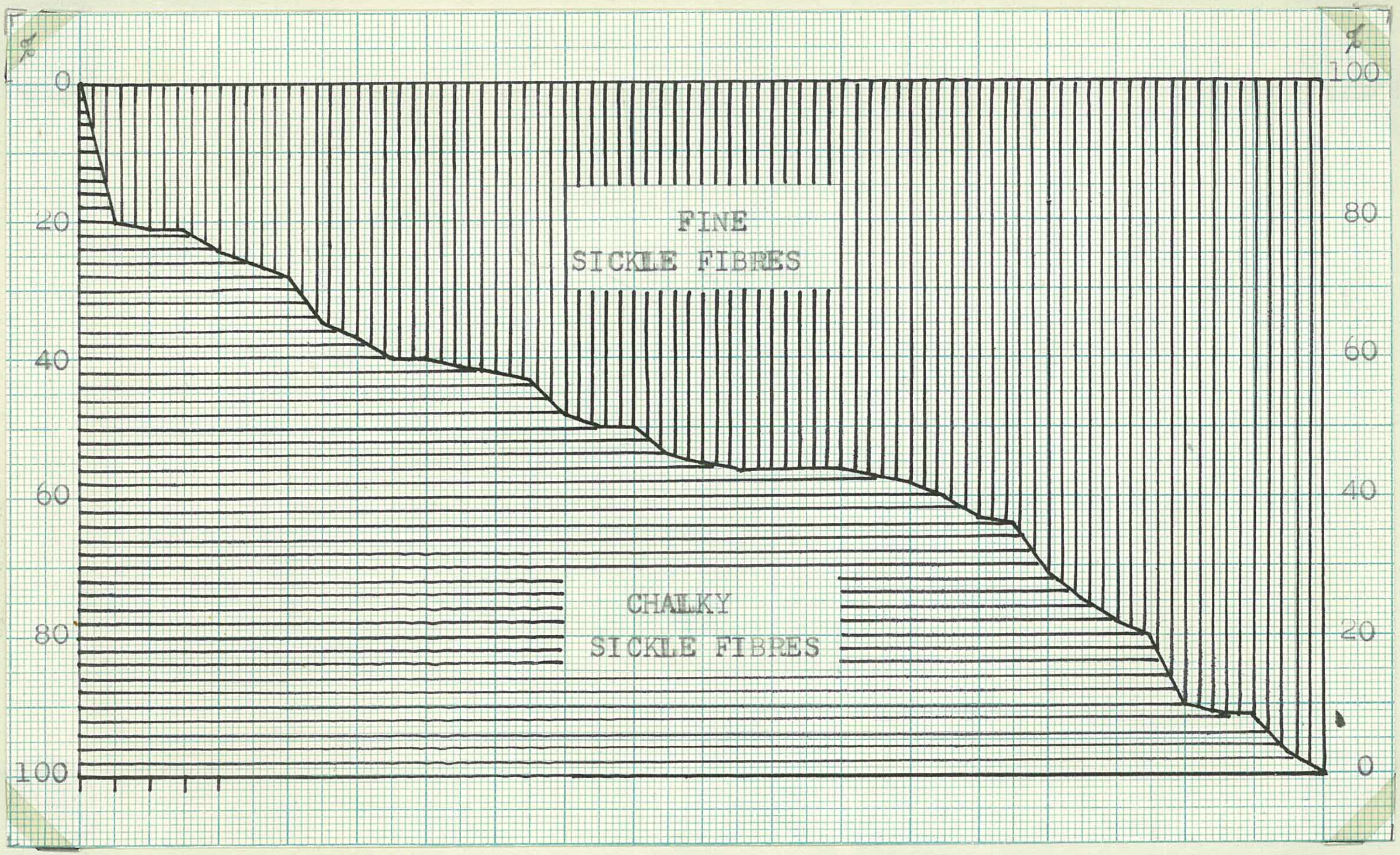
This example shows not only a new fibre type but a slow tendency in diminution of halo-hairs. Finally the Plateau array on Lamb No. 75 shows the birth of super sickle B fibres:
halo hairs 24.4%
super sickleA63.4%
super sickle A' 9.8%
super sickle B 2.4%

Just in the same way we may show the origin of all other fibre types. The most important fibres of this group, namely sickle fibres, differ from super sickle B fibres in the length of the neck, and of course no one could doubt that fine sickle fibres had originated from chalky sickle fibres. The actual data for this discussion is collected in the appendix. Thus we can assume



Graph 13

Evolution of sickle fibres from pre-sickle fibres.



Graph 14

Evolution of fine sickle fibres from chalky sickle fibres.

that all the fibres comprising the pre-curly-tip group are potential halo-hairs which could not reach their full expression because of the preventing power of the "head check".

It must be remembered that Plateau array has practically no sickle fibres whereas the pre-curly-tip group of Plain array in my material consists of 100 per cent of sickle fibres, and these sickle fibres are all fine. Graph 13 and 14 show the evolution of sickle fibres and of fine sickle fibres respectively. As it has already been said, each array has its own peculiar centre of gravity in pre-curly-tip fibre group. This centre of gravity in Plateau arrays is within halo-hairs, and super sickle A fibres, and it is gradually shifted until it reaches fine sickle fibres in Plain array. The table below illustrates this shifting. (Table XXII)

It must be recalled that the percentage of the pre-curly-tip group does not show any significant changes from one array to another, the means of these fibres, expressed as percentages of total fibres are:

in Plateau array	8.59%
in Saddle array	8.72%
in Ravine array	8.29%
in Valley array	7.54%

There are, however, cases when the percentage of pre-curly tip group is very low. Such cases will be discussed later on.

TABLE XXII.

MEANS OF FIBRE TYPES EXPRESSED AS THE PERCENTAGE OF TOTAL PRE-CURLY-TIP FIBRE GROUP.

	Plateau	Saddle	Ravine	Valley	Plain
Baby halo hairs	1.37				
halo hairs	30.30	0.20	0.9	0.16	-
super sickle A	41.50	4.00	1.9	0.52	-
super sickle A'	11.06	8.30	4.0	1.16	-
super sickle B	15.00	26.50	14.4	13.04	-
sickle fibre	0.77	61.00	78.8	85.12	100.0
sickle fibre - chalky	100.0	100.0	57.9	10.58	0.00
sickle fibre - fine	0.00	0.00	42.1	89.42	100.00

Thus to sum up it may be stated:

The constituents of the pre-curly-tip group evolved from halo hairs, that is from fibres belonging to the outer coat.

3. Evolution in the Curly tip Group

From the preceding discussion and especially from the discussion on the hairy tip curly tip fibres we have gained a clear picture of the significance of these fibres. Perhaps here it is necessary to emphasise once more that hairy tip curly tip fibres are not younger in phylogeny than in other constituents of the outer coat and that they probably pierce the surface of the lamb's skin at very much the same time as halo hairs or super sickles.

To prove the above assumption only a few points need be recalled.

(i) Plateau array on lamb No. 1307 shows a great abundance of halo hairs and hairy-tip-curly-tip fibres and a very negligible per centage of super sickle fibres, hence such an array proves that from the phylogeny standpoint halo-hairs and hairy-tip-curly-tip fibres are the oldest fibres of the outer-coat and all the others, especially super sickle and sickle fibres, are younger.

(ii) In the preceding chapter we watched the origin of super sickle fibres in arrays in which the hairy-tip-curly-tip fibres were plentiful. It would not be possible to watch the origin of both halo-hairs and hairy-tip-curly-tip fibres for they are the first and aboriginal fibres of the outer coat.

(iii) With regard to the last point, Galpin's study (26) on embryology of the fleece is in full accordance with the statement made.

(iv) Lamb No. 74 VI! has one array in which nearly all hairy-tip-curly-tip fibres have an identical thinning in the neck region, as the super sickle A' fibres. It may be recalled that it has not been postulated for super sickle A' fibres to pierce the surface of the skin later than, say, super sickle A, only super sickle A' fibres happened to be more subjected to the pre-natal check and therefore it is understood that:

(v) The hairy-tip-curly-tip fibres, as data tabulated in Table IX show, are as long as at least some of the halo-hair fibres.

There is no need to stress the fact that within the curly-tip fibre group, hairy-tip-curly-tip fibres are phylogenetically older than the curly-tip group, the latter being evolved from the former. In Plateau and near-Plateau it is possible to see such evolution in status nascendi. Perhaps the most striking example was furnished again by lamb No. 74. As we know the most primitive coat is to be found on the britch region whereas the most advanced is on the withers. Thus we should expect to get:

(i) Less hairy-tip-curly-tip fibres on the withers than on the britch;

(ii) more pre-precipice curly-tip fibres on the withers;

Hairy-tip-curly-tip fibres per 100 curly-tip fibres.

Britch	Half Britch	Rump	Side	Back	Withers
70.4	62.7	61.6	37.8	58.1	25.5

What has happened to the lost hairy-tip-curly-tip fibres? If our assumption is correct, we should find them, as they become pre-precipice curly tip fibres. Again the table below supports the correctness of the above assumption.

	Curly-tip			
	Pre-precipice		Post-precipice.	
Britch	No	%	No.	%
Britch	0	0	125	100
Half britch	6	4	174	96.0
Rump	0	0	130	100
Side	30	14.0	195	86.0
Back	No precipice			
Withers	70	34	135	66

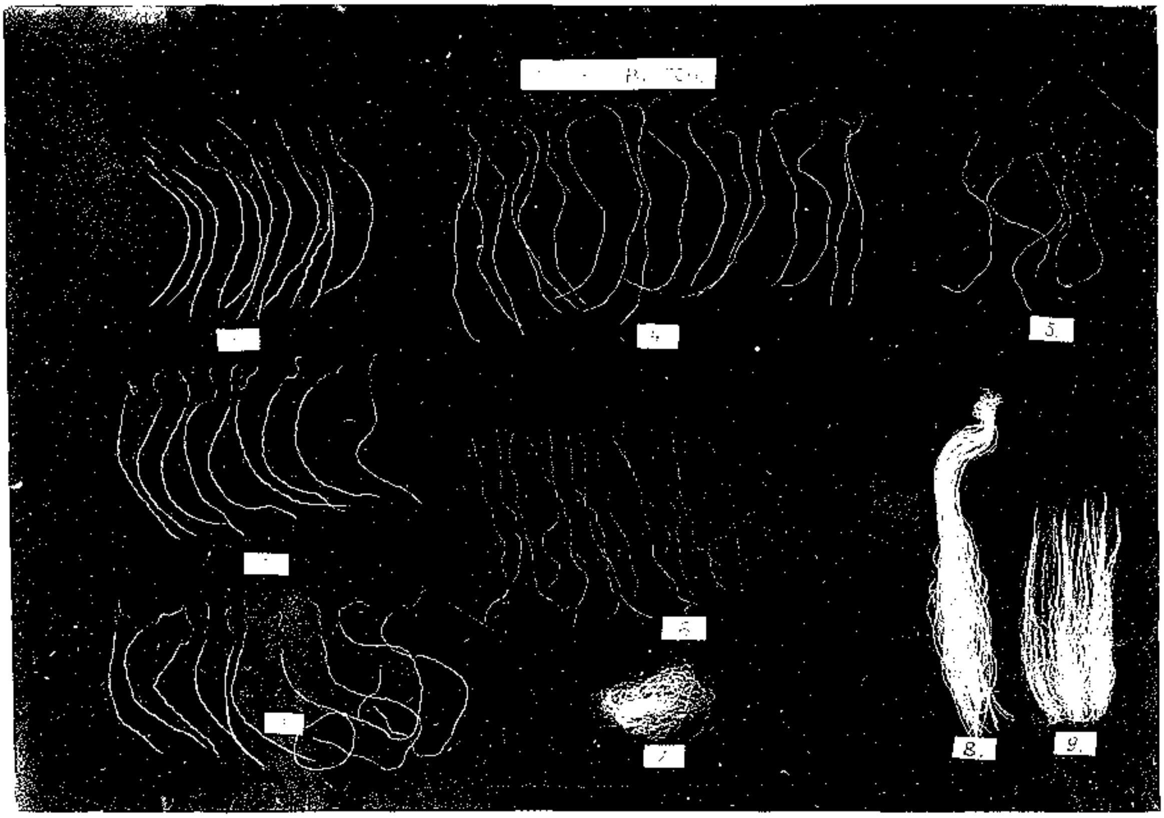
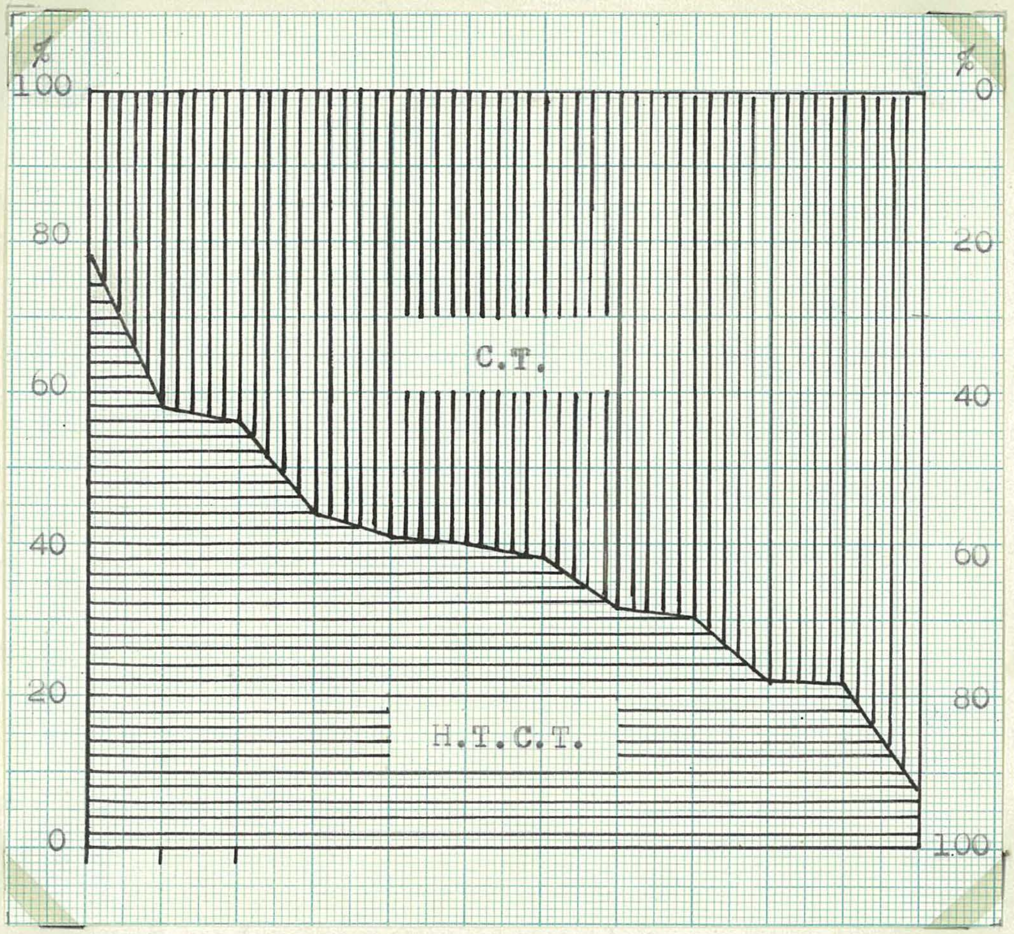


Fig.34

Lamb No.74(N-type) Plateau on the half britch:

1. Halo-hairs,(shed): 2. S.S.A. (shed)
3. S.S.A' (Shed and cut) 4. H.T.C.T. (cut)
5. Pre-precipice C.T. fibres (cut) -
   note that these fibres differ only in one respect from H.T.C.T. fibres, namely the tip of the former is fine.
6. Post-precipice C.T. fibres (cut) -
   note the sudden drop in diameter when we pass along the C.T. series from pre-precipice to post precipice fibres; Gradual transition in post-precipice curly-tip fibres, from mildly chalky to quite fine C.T. fibres.
7. Heterotrichs;
8. Outer coat consisting of fibres pictured under 1,2,3,4 and 5.
9. Inner coat plus post-precipice curly-tip fibres (7 plus 6). Note the differences in the length and diameter.



Graph 15

Evolution of C.T. fibres from H.T.C.T. fibres in Plateau

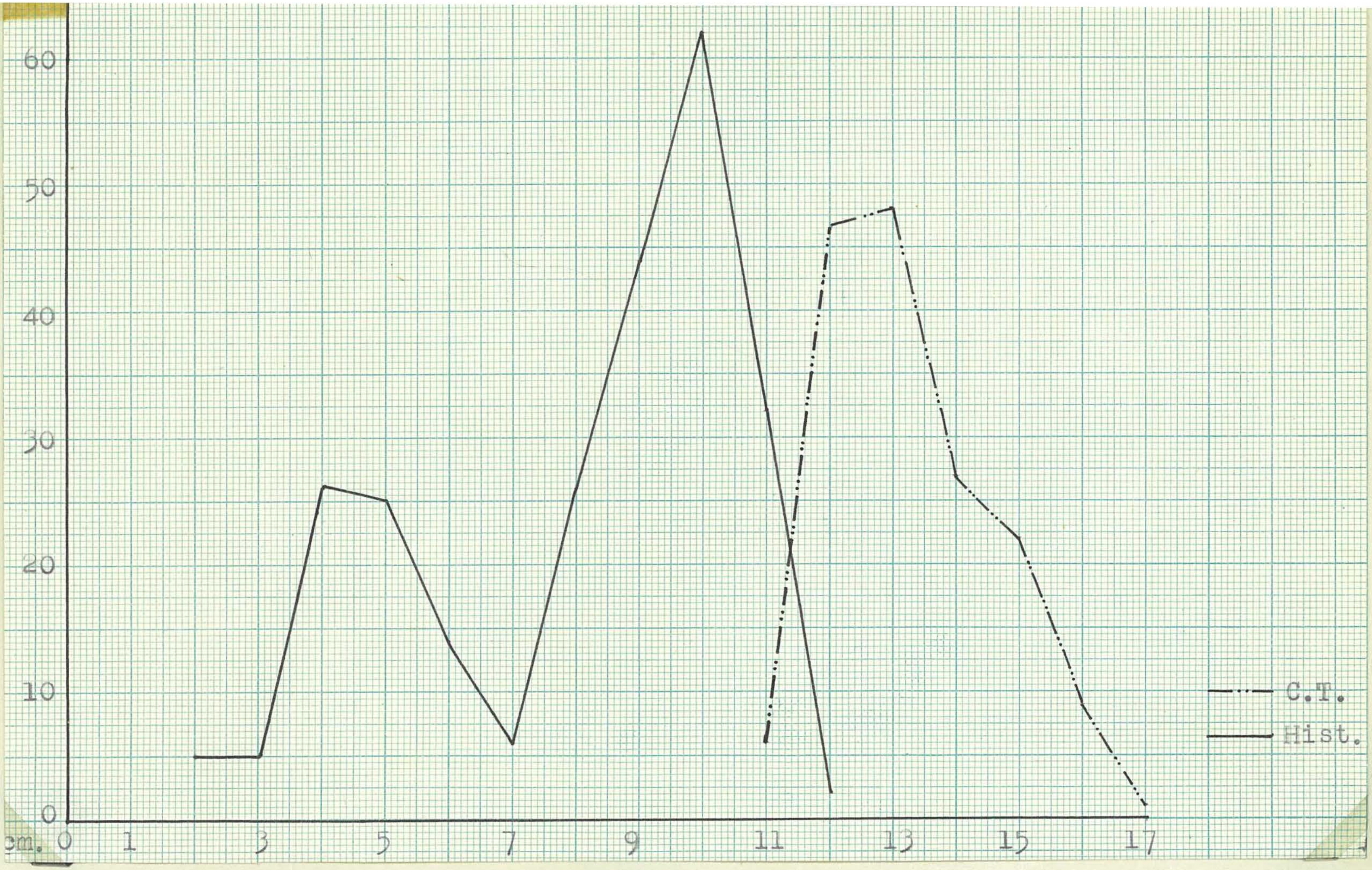
The most outstanding feature of Plateau arrays found on lamb No. 74 is the unmistakable clearness of all the changes which are caused in the course of the evolution in the fleece, and thus the pre-precipice curly-tip fibres (see fig.34) differ only in one respect from the hairy-tip-curly-tip fibres, namely the tip of the former is fine. Of course, a few intermediates occur showing the way in which this gradual change was brought about. The post-natal structure of all these fibres is exactly the same. Table XXIII and Graph 15 showing the evolution in Curly-tip group allows us to get a better insight into the phenomenon.

Of course, in more depressed arrays, the hairy-tip-curly-tip fibres disappear as the halo-hairs do. However, sometimes a hairy-tip-curly-tip fibre may crop up in very fine arrays as it has already been shown in Section I. The same equally applies to halo-hairs, which are found in fine arrays like Valley.

TABLE XXIII

Evolution in Curly-tip fibre Group in the Plateau Arrays.

Lamb No.	% of Hairy Tip-curly-tip	% of Curly tip	Total.
46	77.6	22.4	100
48	58.0	42.0	100
27	56.3	43.7	100
8	43.7	56.3	100
74	41.3	58.7	100
82	40.0	60.0	100
11	37.7	62.3	100
75	31.4	68.6	100
76	30.2	69.8	100
81	22.2	77.8	100
44	22.0	78.0	100
43	7.9	92.1	100



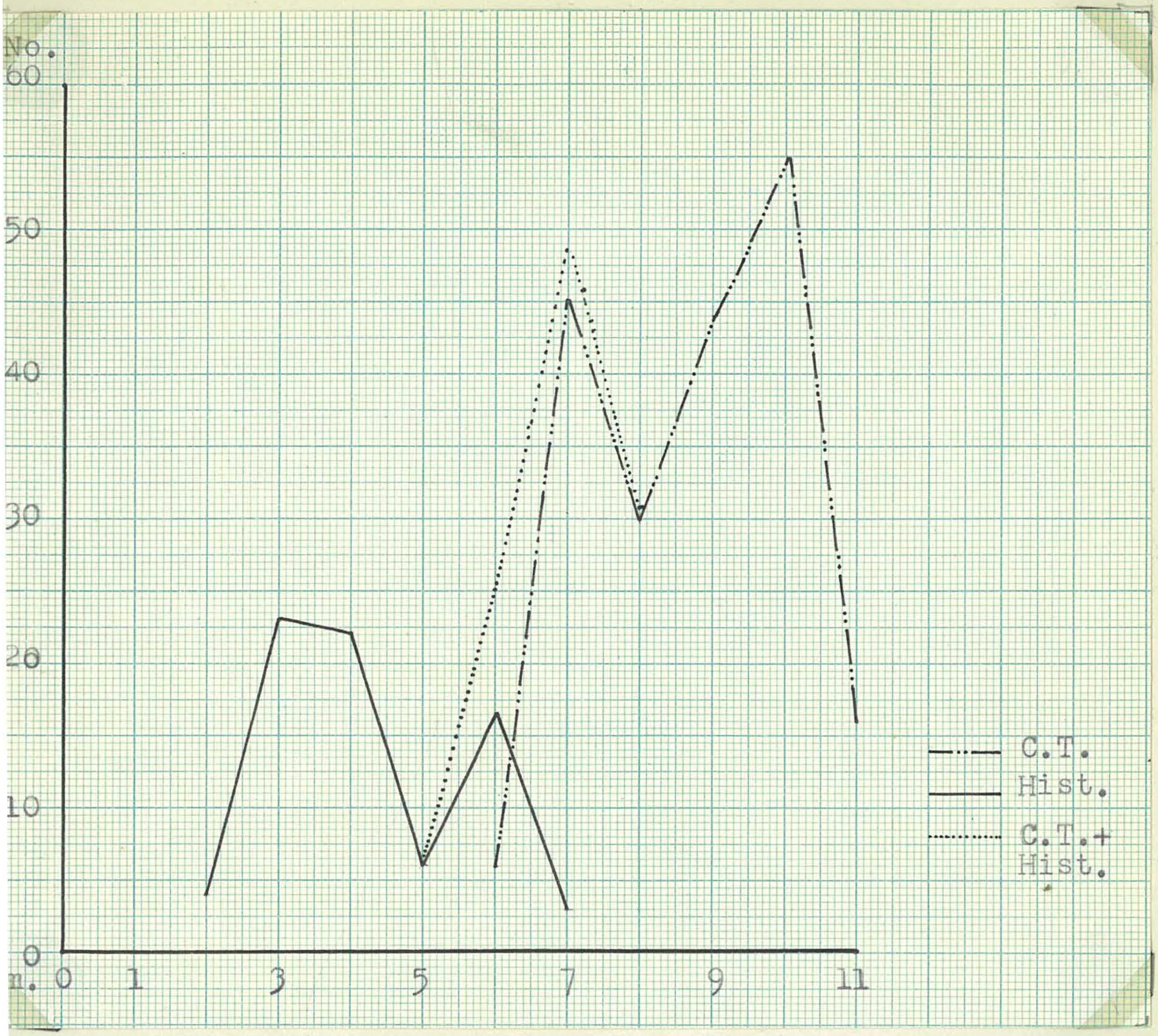
Graph 16
Length of Histerotrichs and curly tip fibres - Lamb No. 46 (173 days old) Ravine on Rump. Note the two peaked curve for histerotrichs and single curve for curly tip fibres; the second peak (longer fibres) is longer than the first; some overlapping between histerotrichs and late curly tip fibres.

4. Evolution in Histerotrichs.

In dealing with histerotrich abundance it has been shown that the highest percentage of histerotrich fibres are found in Plateau and the lowest in Plain, other arrays furnishing intermediate figures. Thus the question arises "What has happened to histerotrichs?" Have they been lost in the course of evolution? The data in hand suggest that histerotrichs in the course of evolution have become curly-tip fibres. There are the following reasons for regarding the late curly-tip fibres as transferred histerotrichs:

(i) We may take it that the density of an improved fleece is not lower than that of a primitive one in spite of the fact that an improved fleece has much fewer histerotrich fibres;

(ii)Arrays having the "tail" of the curly tip fibre series fine have usually less histerotrichs than those chalky as far as the first histerotrichs (see appendix). True enough we can deem the precipice responsible for the fine curly-tip fibres, but a glance at graphs of the length of fibres will reveal a very interesting set of affairs.



Graph 17

Length of Histerotrichs and Curly tip Fibres.

Lamb No. 84 (148 days old, Valley on half britch) Note a very remarkable diminution of the second peak of histerotrich length; two peaked curve for curly tip fibres; much closer overlapping between histerotrichs and late curly tip fibres. The dotted line suggests the way in which the first histerotrichs became late curly tip fibres.

Graph 3 illustrates the arrangement of fibre types in Plateau array on the britch of lamb No. 74. There is reason to believe that this lamb furnishes the best example of the atavistic reappearance of the primitive fleece. This graph shows (59.5% of histerotrichs) -

(a) The way in which histerotrichs grow - note that the second peak (longer histerotrichs) is a very little lower than the first one;

(b) The precipice in curly-tip group;

(c) Some overlapping between the first histerotrichs and last curly-tip fibres.

Graph 16 (51.8% of histerotrichs) shows that the second peak of histerotrich fibres may be even higher than the first one and the overlapping between histerotrichs and curly-tip fibres is still negligible.

Now graph 17 (24% of histerotrichs) shows a very remarkable diminution at the second peak of histerotrich length and much closer overlapping between

Graph 18

Length of histerotrichs and curly tip fibres: Lamb No. 43(174 days old) Plateau on britch. Note the height of the first peak and the diminution of the second peak of histerotrichs length; very close overlapping between the first wave of histerotrichs and fine curly tip fibres.

histerotrich and curly tip fibres.

The graphs above cited suggest the way in which such changes were performed. It follows, then, that the precipice is not entirely responsible for fine curly tip fibres, but probably the first wave of histerotrichs has accelerated its development and become in the course of the evolution, a part of the curly-tip series.

It has already been pointed out that the "Tail" check must be regarded as being phylogenetically older than the "head" check, and, furthermore, the "tail" check is not correlated very closely with the "head" check; hence some less depressed arrays may have lower per centages of histerotrichs, whereas some more depressed have higher (see graph 18). However, if one remembers that the classification of a given array depends entirely on the "head"check , such a discrepancy will be readily understood.

5. Relationship between fibre-type Groups.

In the preceding chapters the evolution of typical fibre types was discussed. Mention was made that there are some fibres which have non-typical tips and only by virtue of the neck thinning, a phenomenon entirely dependent on the pre-natal check, were assigned to the pre-curly-tip fibre group. There are still others which fill the gap between groups of fibre types, in that they are intermediate fibres linking the pre-curly-tip group with the curly-tip group and the curly-tip group with histerotrichs.

With regard to the first type of intermediate, it has been postulated that such fibres are derived from hairy tip curly tip fibres because the tip, the structure of the post-natal region and shedding are very similar to those of the hairy-tip-curly-tip Group and they are always to be found on the right wing of their fibre types. Thus it is logical to assume that in some arrays the pre-natal check extends into the hairy-tip-curly-tip-fibre type and causes the neck thinning. Probably the curly-tip fibre group is more apt to be influenced by the pre-natal check than halo-hairs. Such a hypothesis explains satisfactorily one of "Dry's "in parallel" concepts - a concept employed by Sutherland to explain the occurrence in Plateau arrays of a few sickle fibres apparently unrelated to other fibre types. These sickle fibres in Plateau which have non-typical sickle ends had been derived from hairy-tip-curly-tip fibres and hence the discontinuity in pre-curly-tip fibre group. An example of such a Plateau array is given by Sutherland (46).

Sheep:	Halo hairs	Super sickle A	Super sickle A'	Super sickle B	Sickles	Curly tip	Histerotrichs.
18.5	31	8	0	2	1	280	445.

If the intermediate fibres are a nuisance in the classification of an array, they are of outstanding importance from the standpoint of evolution. They furnish the very link between the fibre types and thus show the gradual transition from less to more advanced fibre types. Such "intermediates" are found everywhere. The "intermediates" within groups were discussed earlier. Now mention must be made of those which link up two different groups of fibre types.

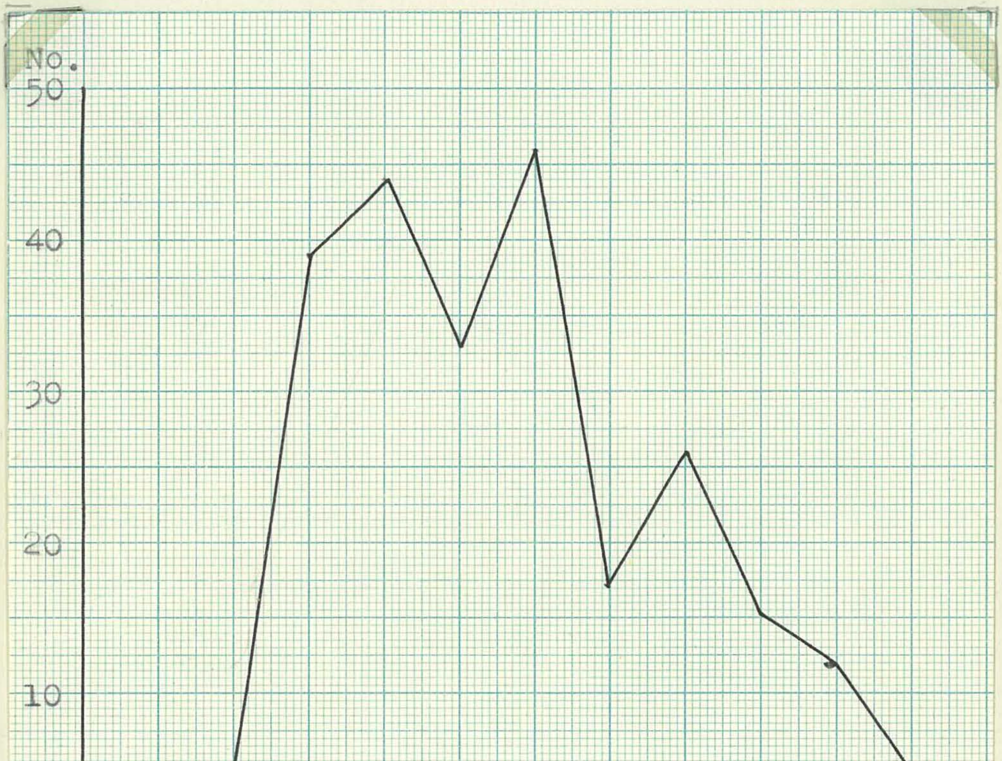
The "intermediates" between sickle fibres and curly tip fibres show that there is a stage in the evolution process at which fibres may become either sickle fibres or curly tip fibres. If the late sickle fibres did not succeed in piercing the skin surface before the prenatal check had reached its threshold, obviously they will be prevented from becoming sickle ended, and as it has already been mentioned, curly-tip characterisation may be imposed on what would otherwise have been a sickle fibre. Of course, a potential sickle fibre which failed to produce a sickle end cannot be classified as a sickle fibre, only a curly-tip-fibre; besides it has all the other characteristics of curly-tip fibres. One seeing all the steps of the above described process, in these intermediate fibres, must undoubtedly arrive at the conclusion that hasbeen reached.

Again, the above hypothesis explains the great variations in sickle fibre abundance. Here it will perhaps be enough to point out that in very well improved fleeces plain arrays were found by Sutherland and myself showing very few sickle fibres, the latter being the only representative of the pre-curly-tip fibre group. At the same time such arrays show besides very few histerotrichs. Such a stage must be regarded as the last step of evolution tending to even the diameter and the length of fibres by means of increasing the number of curly-tip fibres to the hypothetical level of 100% of total fibres.

The "intermediates" between curly-tip fibres and histerotrichs furnish the best examples of the direction of histerotrich evolution. Here the intermediate fibres are so plentiful that in some arrays it is very difficult to classify them properly. It is a well-known fact that Plateau array has its pre-natal region much longer than Plain array and hence one may believe that the differences in the time of piercing the skin surface by different fibre types are more marked. The other extreme is to be found in Plain array - the remaining arrays furnished all intermediate steps. In such an array the bulk of fibres pierce the skin in a rather short period of time, that is, initiation of the growth of the first fibres is retarded and that of the last (histerotrichs) accelerated. It follows then that in our material under investigation we have come across arrays in which we were able to watch the evolutionary process in _status nascendi_; hence the intermediate fibres.

6. Evolutionary tendency and the Density of the Fleece.

One question which arrests our interest is whether such an evolutionary tendency to confine the bulk of fibres to the curly tip series may proceed to completion so that curly tip fibres become the only surviving type.



Graph 19

Length of histerotrichs;

Lamb No. 27 (179 days old), Ravine on side. Note the first peak which is actually the peak of the second wave, is split into two teeth.

Sutherland's data (46) based on the arrays of Wensleydales does indeed suggest that an evolution may proceed precisely to that ultimate goal, since some Wensleydales have as much as 95 per cent of curly tip fibres[x] This question is of great practical importance because it is connected with the density of the fleece. That data in hand are in favour of the idea that the evolutionary process tends to even the start and finish of fibre growth and in Wensleydales this process has nearly reached its goal, but there is probably a secondary process which distinctly has nothing to do with the evolution as such, a process which gives rise to new histerotrich follicles to be laid down and in this way the fleece density may be increased. This conclusion is drawn from graphs 4 and 19 (No. 27 - half britch and side). As may be noticed the first peak, which actually is the peak of the second wave, is split into two teeth. Such a peak may suggest

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[x] The outcome of the elaborate phylogenetic history which we have been reviewing as best we may - like a paleontologist making the best of a broken series - would then be that curly tip fibres became the only surviving type. All the same curly tip fibres would then be the living representatives of the types which had vanished. Thus we are reminded of the soundness of a contention pressed by Ruddal, namely, follicles do not possess specificity but that a follicle is the produce of whatever fibre type is the resultant of the forces acting in, on, or through that follicle. All the same, the endowment settled upon a follicle in its early days may produce permanent effects.

that new follicles are laid down, follicles which probably owe their existence to some secondary process. Whether or not this idea be right, the importance of comparative studies of histerotrich development is emphasised.

In examining the graphs plotting length frequencies of histerotrichs, it is well to bear in mind what is known about the development of these fibres, which was studied by Dry in a preliminary manner some years ago. From various dissections he concluded histerotrichs beginning to develop later than those of what may be called my "first wave" are grown in follicles produced as buds from original histerotrich follicles which themselves - like those of all fibres preceding them in the array - are developed from downgrowths of the Malpighian layer of the skin. Often Dry found two histerotrichs in the compound follicle, but occasionally, and that in Non-Plateau, at the age of some four months, he found three histerotrichs in the compound follicle. The follicles of other fibre types, he thought, do not give rise to daughter follicles. He is not certain that later histerotrichs never develop in follicles which are the direct product of the Malpighian layer of the epidermis, but he thinks it probable that at least the normal mode of development is by budding, from a follicle already established.

Two points suggested by my graphs are to be stressed. The first is that sometimes the second wave of the histerotrichs is larger than the first wave. The histerotrichs of the second wave are more numerous. Assuming that later histerotrichs are always developed in daughter follicles, it is then probable that sometimes those daughter follicles develop as buds from follicles growing smaller curly-tip fibres. If this indeed prove true it would fit my conception of the evolutionary trend of the "promotion" of histerotrichs to become curly-tip fibres.

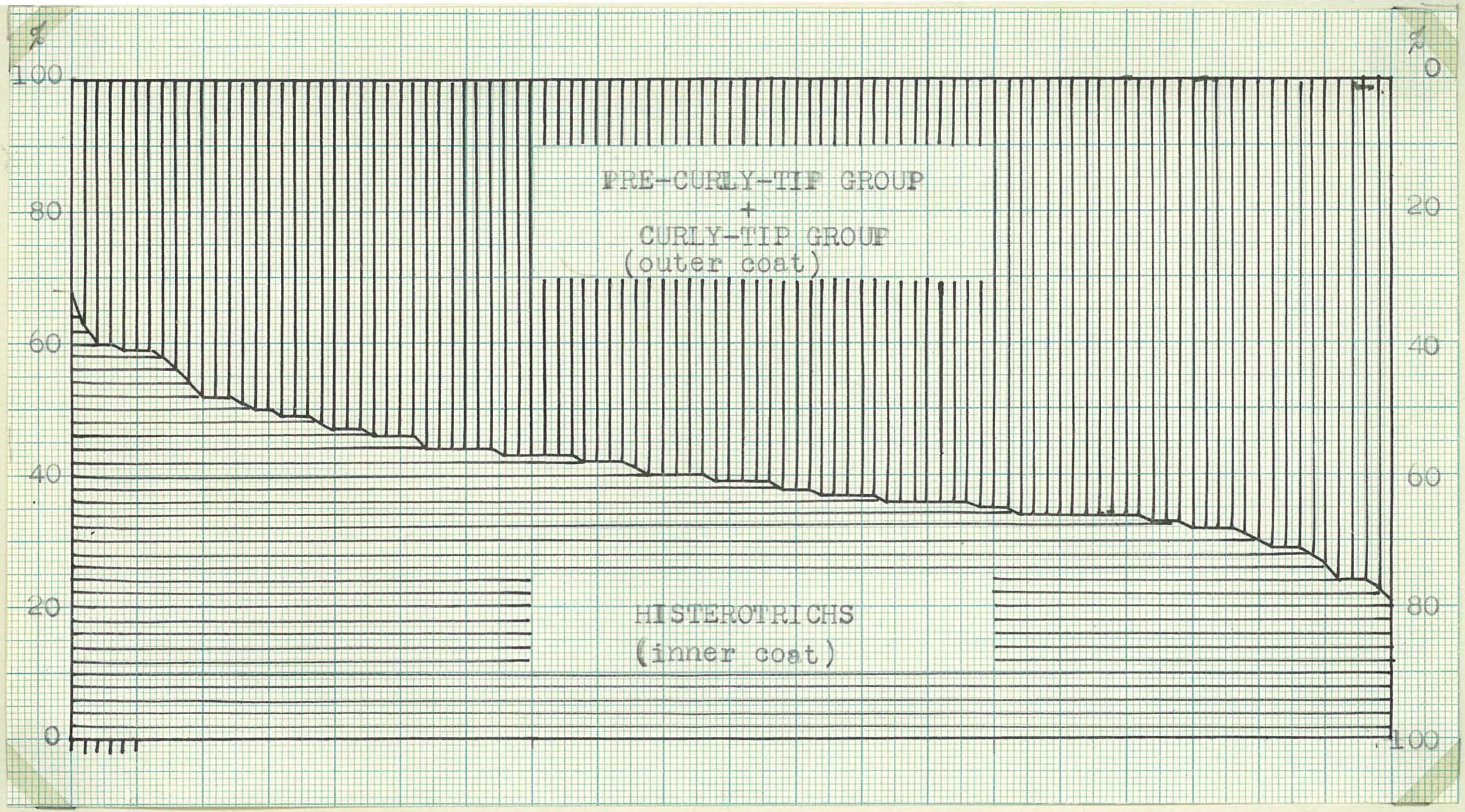
The second point bears on what I am inclined to regard as a sècondary process in evolution. Although histerotrichs are very abundant in Plateau Array, my measurements of length reveal only two waves. I am asked to emphasise this point for the reason that it is not known how many histerotfichs grow in a compound follicle in Plateau Array. Sutherland, and also Dry, made a preliminary exploration, but they tell me the matter proved less easy to decide - probably because of the great density of the fibres - than was anticipated, with the result that the question was left unsettled. My graphs suggest that in Plateau array it may well turn out that only two histerotrichs grow in the compound follicle.. Therefore, it may prove significant that my hint of a divided second wave, i.e. the existence of a third wave - and Dry's three-fibre compound follicles, are recorded from non-Plateau. My suggestion consequently is that the third wave may be a secondary phenomenon, adding to density in secondary fashion, tending to restore the abundance of histerotrichs reduced to what I look upon as the main evolutionary trend.

In these ideas there is some speculation, but I am asked to put forward these ideas as a basis for further work on histerotrichs (and on the whole problem of evolution), for it is known weal in this laboratory that the much needed study of histerotrichs willhhave to be of a patient kind.

II. FORCES AT WORK RESPONSIBLE FOR THE EVOLUTION OF THE ROMNEY FLEECE.

From the evolution point of view, Dry's fibre type arrays are nothing but gradual steps in evolution.

As it has already been pointed out a name given to an array really covers a series of arrays, having one common characteristic. This characteristic, is, for example, for Plateau arrays the lack of sickle fibres, and for saddle the lack of fine sickle fibres, but within an array are great quantitative differences, hence the term "toughness" is employed. Toughness of an array is an indicator of the progress achieved in the course of evolution. Thus all the Plateau arrays may be arranged in linear order according to their toughness. The first will be linked up with an array which may be found on some primitive breed of sheep, the last with the first array of the Saddle series, etc. until we will find some array which may be more checked than even Plain. Again, in the Plateau series we can watch the slow process of evolution from halo-hairs through super sickle fibres to sickle fibes and in the Saddle series we see the further diminution of more primitive fibre types and gradual increase of sickle fibres; In Ravine and Valley we watch the further changes within sickle fibres with gradual increase of fine sickle fibres until finally all the pre-curly-tip fibre group consists of one type, namely, fine sickle fibres. Even the latter tends to shift into curly-tip fibres. Just the same changes were under-



Graph 20

Evolution in Histerotrichs:

Note the decrease in the percentage of histerotrichs (inner coat) from 68% to 21% and simultaneous increase of pre-histerotrich fibres (outer coat) from 32% to 79%.

gone by hairy-tip-curly-tip fibres, which gradually become curly tip fibres, then later checked curly tip and fine curly tip fibres and finally all peak curly tip fibres become fine too. A part of the collection of fine curly tip fibres was derived from histeretrichs. The latter, in the course of evolution, have decreased in number and some/have been shifted to the curly tip fibre group (see graph 20). It must however, be remembered that so far we have not succeeded in Plateau arrays in showing that at this primitive stage all the Curly tip fibres were derived from hairy tip curly tip fibres, for the highest percentage of hairy tip curly tip fibres found up to the present is about 80 per cent of the whole curly tip group.

The graphs which illustrate either the representative type of fibre or the fibre type group, show most typical and progressive curves for evolution process. The shape of these curves was not foreseen. They have proved unexpectedly arresting and their significance is an obvious one.

The forces at work responsible for the evolution of the fleece have already been discussed. The "head check" causes all the pre-curly-tip fibres and a part of the curly-tip fibres to be fine and the "tail check" is responsible for the fineness of the remaining curly-tip fibres. It is not known what part is played in evolution by the "crisis thinning" which in the majority of arrays is very pronounced. It is very doubtful whether the crisis thinning depends on other forces than those hitherto mentioned. However, these two checks are sufficient to explain the evolution. We will remember that in some Valley arrays the chalkiness is confined only to peak Curly tip fibres and in the course of further evolution even this chalkiness is depressed by these two checks, as Plain arrays show.

Finally it may be worth mentioning that post-precipice fibres are derived from chalky curly tip fibres. Lamb No. 74 again may furnish a clear proof. The percentage of curly tip fibres, calculated on total fibres, on the side and back regions is 35.7% and 35.2% respectively, and yet the side region has a very profound precipice, whereas all the curly tip fibres on the back region are chalky throughout.

Thus to sum up the present study has proved conclusively

(i) that the hypothesis associated with the name of Duerden and others about the evolution of the fleece is not tenable.

(ii) the fleece of improved sheep comprises both inner and outer coat;

(iii) the separation of kemp hairiness from non-kemp hairiness has no phylogenetical justification, both of them are derived from the outer coat.

(iv) the same follicle can give either kemp or wool, that is, a kemp in one period and wool in another.

III. SOME GENETICAL CONSIDERATION UPON THE FORCES AT WORK BRINGING ABOUT THE EVOLUTION OF THE FLEECE.

1. Causes of Evolution:

Some geneticists seem to overlook the fact that the domestic animals as we know them today have undergone many evolutionary changes. Even these geneticists who take for granted that evolution brought about these changes still fail to see that in the majority of cases mutation is the real phenomenon which causes these changes. Thus Hagedoorn (29) writes "In the evolution of our domestic animal breeds from wild ancestors, mutation has probably played only a very small part. The main cause of variability is certainly cross ~~br~~ breeding", and "the chief source of variability is undoubtedly cross-breeding, the recombination of the genes in respect to which crossed breeds differ". To believe in such a theory it is necessary to assume firstly that wild ancestors had all the genes present in today's existing breeds and yet there is little sign of segregation of genes in living wild forms, or of atavism in crosses between different domesticated forms. Of course, known facts are in obvious contradiction with such an assumption. One might be tempted tooask whether by crossing Ovis vignei with all other wild sheep we can "recombine" genes responsible for the Karakul birthcoat.

The leading geneticists, however, had agreed already that a mutation is the real and important event which gives the material for selection. Thus Huxley (31) states "Evolution is joint product of mutation and natural selection". He refers to the evolution of species, rather than domestic animals, but there is no reason to believe that evolution in the latter is brought about in a different manner. Morgan (38) for example, states

> "....... a great number of mutant types furnished mankind with the material for artificial breeding. Not only do fantastic types of animals and plants produce varieties...... but there are numberless characters of domestic animals and plants depending on gene mutation, that have great economic value. Their discovery and maintenance is in itself an evolutionary process; andeven if plant and animal breeding often makes use of characteristics that, without human protection, would perish, it is nevertheless a real evolution that is taking place".

2. The Kind of Mutation.

Generally by mutation we are inclined to understand a change in the germ-cell which brings about sudden and abrupt inherited change in some of the characteristics of living beings. Such changes are easily detectable and visible, they occur rather at random and are often disastrous. There are, however, other mutations which bring about changes which are neither sudden and abrupt nor easily detectable and visible, hence they are more often than not overlooked. It seems, however, that not only have these mutations been overlooked but also the paper in which Baur first described them in 1924. However, this might seem to be the natural way of "evolution" of science that attention is paid first to things which are easily visible. Of course this is most natural. Most certainly a fish in water was discovered before the plankton. When Cuvier promulgated his theory of cataclysms of living and lifeless beings he was seeing only the fish. However, his successor, Charles Lyell (50) was already in a position to see the plankton too, and rejecting Cuvier's theory of catastrophes put forward his own, explaining most geological phenomena as the result of slight and slow changes, similar to those still taking place. It is thought that "Leyll's work had a lasting effect upon Darwin" (quoted from Rádl; 41). Again, De Vries who conceived the mutation theory was in no better position than Cuvier. De Vries' theory as we understand it today involves the same fundamental idea as Cuvier's and similarly the credit of challenging De Vries' theory may be given to Baur as it was given in geology to Lyell.

One may feel that Baur's papers are of much greater importance in explaining that mutations are the motive force in evolutionary processes, that it is considered better to let the author speak for himself. It may, however, be added that the discussion will be confined to those factors which have a direct bearing upon the present investigation.

Thus Baur (5) discussing the frequency of mutations states (p. 111)

> "However, if one is accustomed to use his eyes for a period of years it can be shown that the conspicuous mutations occur only in extreme cases that at least as often as that or probably far more often than that little inconspicuous 'small' mutations take place, which are not pathological but are types which are perfectly well able to survive".

Thus Baur divides mutations into two groups: big mutations of De Vries, and "small" mutations. The latter are very difficult to detect. Thus he writes (p. 112).

> "A second cause for my serious underestimating of the frequency of mutation, a thing which is still today done by the majority of biologists is that the mutants are not all so conspicuous as to make their recognition possible, even in cases of a homozygous mutant individual. According to my experience the great majority of mutants show

> transgressive variation with the original. That can be best explained by an example. Out of the offspring of a typical green-leaved plant one may be heterozygous for a recessive chlorophyll factor; but this cannot be detected. In its offspring segregation takes place, and 25% are of the new type having the colour of its leaves a bit darker. Even this segregation will not be recognised in the majority of cases. Darker and lighter green plants may occur in the same bed, due to the variation of nutrition (unequal distribution of nitrogen in the soil). However, if you proceed to continue this experiment into the second generation it can be shown that some of the offspring, that is, all those which descended from an F_3 plant with the new homozygous darkening factor, show in the whole bed a darker green than the other beds, it is only now that you pay attention to the new mutation. So only in the F_3 you recognise a new mutant which actually occurred as a homozygous individual in F_1. And the majority of all mutations, as far as my experience goes are mutations of this kind".

Further Baur describes the types of small mutations

(p.113) -

> "The small mutations which can be picked up in this way are of diverse types. They cause small differences in the colouring of the leaves, the blossoms, in the relative length of anther and the kind of hairiness, the size of the seed, etc. in one word, they are a tremendous multitude".

Then he mentioned how he arrived at those conclusions:

> "It would go too far if I should attempt to describe how I arrived at those conclusions. I like to mention that since 1904 I made many experiments with the species Antirrhimum, I cultivated on the average some 30,000 individuals a year. I examined them, so, at least for this one species I justifiably draw my conclusions".

Stating (7, page 145) that the percentage of mutations in Antirrhimum is about 10 per cent and even the latter is too low according to his results from the last year's investigations, he dwells upon the role of gene mutation in evolution (page 145)

> "The statement that mutations and above all small mutations are so extraordinarily frequent is principally important for our entire attitude toward the question of evolution. Up to the present we have greatly overestimated the constancy of pure lines, thanks to the influence of the experiments of Johansen. I do not want, however, to speak unfavourably of the methods and conclusions of Johannsen. The sharp distinction between hereditary and non-hereditary variation, the destruction of the vague idea which is known under the term'inheritance of acquired characters'. Furthermore the whole critical analysis of the variations is due almost entirely to Johannsen, and on this analysis the whole building of the up to date science of heredity was erected. But even here, his followers were more Johannsen than Johannsen himself. Johannsen drew no conclusions from his experiments with barley and beans as to how frequent or how rare the mutations were,

> "but bye and bye the idea became predominant that mutations and above all factor mutations are always something quite unusual and rare, and that only monstrosities were the result. The result of this utterly false estimation of the frequency and the effect of factor mutations was either a complete 'ignorabimus' on the question of evolution or an evolution based on natural selection of combinations as Lotsy and Heribert Nilssen believed:

> "However, my experiments with Antirrhimum prove conclusively that in this species factor mutations and above all 'small' mutations (kleine mutationen) are extraordinarily frequent. These 'small(mutations embrace all possible morphological and physiological properties; they do not generally cause any changes which could be described as monstrous or pathological, they are changes which remain quite within a norm and do not diminish its viability. They even sometimes increase them".

Finally he sums up the definition of "small" mutations (p. 146):

> "Before our very eyes occur perpetually in big numbers, small differences conditioned by factor mutations, in the majority of cases they are so tiny that they can be seen only if special methods for experiment have been found. They include all the properties of the plant".

Slizynski (44) tackles these small and invisible changes from a somewhat different angle. He studied cytologically as well as genetically spontaneous and induced lethals in Drosophila mel. These lethal changes were not connected with any visible changes of the traits. During this study it was revealed, what already Painter and Mackensen had pointed out, namely, that the genetic map shows that the genes are more or less equally distributed through the chromosome, whereas the cytological map of the chromosome shows a different distribution, that is, in one region of the chromosome there were found more loci per unit length than in another. Slizynski explains this phenomenon as follows;

> "The best explanation of this phenomenon (unequal distribution of genes in a chromosome) is the theory of morphogenetical potential. This term defines the amplitude of gene expression or its power of creation of a trait, peculiar to its different allelomorphs. Genes having high morpho-genetical potential, when changed by mutation bring about a very distinct change in pre-existing characteristics. Here belong almost all genes known in Drosophila, up to the present."

In other words, these genes, when undergoing mutational change bring about 'big' mutations of De Vries. This is understood in the light of his further explanation:

> "It is well known that not all the genes can easily mutate. In some regions of a chromosome mutation concern only 'strong' traits, that is, a change of such a trait is easily detectable and hence these genes have a high potential".....

> "Forces which bring about mutations no matter whether spontaneous or induced encounter 'resistant genes' in some region of a chromosome, and in others genes with low potential, that is genes which do mutate, but these

> "mutations are invisible. Thanks to the latter process we get 'white' places on the genetic map of a chromosome, places which are seemingly not filled up with genes".

Now we can recognise genes having low potential as genes which mutate in Baur's fashion. Slizynski describes the role played by those two types of genes in the domestic animals and thus an attempt is made to connect the result of theoretical genetics with data furnished by practical animal breeding -

> "Genes having low morphogenetical potential, that is, genes which mutate without any detectable changes of the preexisting characteristics, play probably a greater role in the processes of evolution as well as in the processes leading to adaptation of the organism to a given and strictly defined condition of 'milieu' than hitherto found and described 'laboratory genes' with very high potential. The latter have definite evolutionary value only in the case of sudden and cataclysmic changes in the physical and biological conditions of the environment. There are many examples in genetical literature to support this view".

Finally Slizynski mentions the "kleine Mutationen" (Baur's original definition of 'small' mutations) and defines them as "genes of low morphogenetical potential". Thus Slizynski distinguished, as Baur, Hammond and probably

Goodale did, two kinds of mutations and furnished cytological evidence of the existence of changes in the chromosomes of Drosophila with invisible effects.

3. Role of Mutation and Selection in Evolution.

There is no reason to believe that Johannsen's pure line theory is to be challenged. What is to be challenged is the attitude of some geneticists to the question of the kind and frequency of mutation. It might seem that to this category of geneticists belongs Goodale (28). His experiment on the mouse selected for larger spots of white hairs on their foreheads compelled him to state "close contact with the mouse material produces an impression that something of the nature of a creative process is taking place under one's manipulation of selection and mating, not a mere rearrangement of pre-existing genes." Yet he discusses all possible ways furnished by the present knowledge of genetics and fails to present a satisfactory explanation of the result of his experiment. However, he is obliged to state :

> "These changes may by some be called 'mutations', but if this is done, the term 'mutation' has been transferred by successive changes in meaning from the elementary species of De Vries which at one bound developed striking differences, often in several characters at once, to the small fluctuating variations of Darwin in the sense in which Darwin used the word "fluctuating", i.e. small inherited variations, not in the sense of transitory environmental variations which is in current use in biological circles".

Goodale himself, apparently being not familiar with Baur's work hesitates to arrive at such "new"conclusions that actually these small inherited variations are the "small" mutations (although his whole experiment suggests Baur's theory of small mutations). This may be seen from his two statements:

> "Since our present knowledge of mutations indicates that they are too infrequent and too erratic to furnish a suitable explanation of the success of selection....."

and

> "most mutations, by reason of their nature, do not supply the kind of change necessary for the progressive adaptation of a form to its surroundings or for the progressive advance in structure".

Finally, stating that "it is immaterial whether that which is developed by selection was hidden in the germ cells .... or whether it is a new creation", Goodale writes "Darwin's view that selection has power to advance the creation of new inheritance finds support in this experiment,..."

Perhaps there is no need to emphasise that other geneticists are perfectly clear as to the role of mutation and selection ineevolution. Just let me quote Morgan who writes (37) "Selection ceases to produce any further effects after these genes have been sorted out and the material has become homozygous for them".... "Evolution, however, means prdducing new things, not more of what already exists".... "It follows, that if new characters transcending the extremes of the original population arise, this must come about through a change in one or more of the genes themselves. At present we have discovered only one way in which such a change takes place - by a mutation in a gene". (See also Serebrowski's paper (43).

Now it will be of arresting interest to view the conclusions that Baur arrived at. Thus he states (7, p. 146) "The 'small mutations evidently play a very important role in evolution" (5, p.115) "Differences of species in the group of Antirrhinastrum at least, are the summation of very small mutation steps"......"I for my part do not see the smallest difficulty - generally speaking - in tracing back the whole process of the creation of species, as it can be watched today in the group of Antirrhinum to the effect of natural selection, on selected individuals with small mutations. It is not necessary to mention that the whole display of combinations is here also of the very greatest importance. A mutation which in itself possesses no selection value may get selection value when in combination with some other mutation. I do not underestimate therefore the importance of combination for the mechanism of evolution. I go today so far as to say that I interpret the biological meaning of bisexual reproduction to be that more progess is made possible through the selection of combination of mutant genes. But in the last analysis it is the mutation process which actually creates new material." ...

" With the statement that there is sufficient material available for selection, we clafify, of course, only a small part of the problem of evolution. But the statement that evolution is at all possible by the way of natural selection, seems to me to be of principle importance. The selection theory is attacked today from all sides, particularly by investigators who know more philosophy than biology, or, if they are biologists, have very little experimental experience. It is repeatedly argued that natural selection cannot work because the theoretically necessary material for selection does not exist in sufficient multitude of variations. This argument is false. When one applies correct methods in searching for the hereditary differences one finds them".

It might take us too far afield to sum up Baur's conclusions. As far as our present discussion is concerned the following chief points of Baur's conclusions must be stressed:

> "(a)....we arrive at least as far as differentiation at subspecies is concerned, purely at Darwin's selection theory with the supplement that the original selective material is mainly given by these 'small' mutations.
>
> "(b)....of course, the selection of special combinations must play a big part. I by no means underestimate the great importance of the combinations but in any case - in the final analysis it is the mutation which gives the original material for selection.
>
> "(c)....in the case of artifical selection it is the conspicuous big mutations which are very important. The usually very conspisuous differences in races of Antirrhimum majus are not summations of small mutations but are due to factor mutations that are rare but very productive. The reason for it is that artificial selection works with a very much less fine sieve than natural selection, that is that man finds and pays attention generally only to the conspicuous mutants and these are mutants which in the majority of cases are annihilated in the course of natural selection".

The significance of selection will be discussed briefly in the next chapter. Now it is necessary to discuss point (c) of Baur's statement. It is felt that Baur made the same mistake for which he reproaches other biologists. His last statement is illogical and is in contradiction to his previous statements. Apart from the fact that he explains the evolution of species by means of small mutation and natural selection, a conclusion arrived at by means of artificial selection, he states that

> "man pays attention to the conspicuous mutant"

and that

> "artificial selection works with a very much less fine sieve than the natural selection".

Of course, this statement is false. Artificial selection usually can reach a higher level than natural as the latter selects animals or plants from the standpoint of their fitness and the former usually leaves out of account an animal as such and pays attention only to the particular trait it is selecting for. Of course, if Baur had been more familiar with domestic animals he could not have arrived at such a ridiculous conclusion. However, Baur's last statement cannot impair the validity of his main conclusions, but must be taken as a weak point in his generalisation.

With regard to the role of 'small' mutations, in the evolution of domestic animals it will be of great interest to quote Hammond's views. He apparently has not been familiar with the work done by Baur. Hammond did not use the term 'small' mutations in describing these changes which count in the evolutionary processes of domestic animals; yet he, as Baur and Goodale did, laid stress on the small inherited changes which are of the very greatest importance in the evolution of live-stock. Thus Hammond writes (30):

> "The large mutations that occur in our live stock are nearly all of the recessive type, and for the most part consist of defects and abnormalities or fancy points (such as colour and horns), which are of little commercial importance. They usaally segregate out in simple ratios, and it is an easy matter to breed for them by using Mendelian methods. On the other hand, almost all commercial qualities are 'blending' in inheritance; there is no dominance, and in my opinion they have been produced by quite different methods, that is by the accumulation of small variations, which are continually appearing and may be stimulated by environment........
>
> "Thus I see the real evolution of commercial qualities, built up by small variations, constantly being added to according to the environment of the animal, and the formation of varieties, freaks and fancy points produced by the mutation of genes already formed by other processes......
>
> "The evolution in the skeleton (of the horse) has followed a definite and uniform course of changes. This evolution has not been broken

> "by a number of sharp changes, such as mutation affecting different parts of the body independently; for example, no shortened limb bones, such as those which occur in the Daehshund dog..... and behave as mendeliah recessives, come in the series. These things are mutations that may easily be picked out by man and bred to form fancy strains, but they play no real part either in natural evolution or in the development of the body in commercial meat production. These mutations do not as a rule form intermediates when bred to the normal type; whereas when two different "developed" types are crossed, all gradiations between them may be obtained. In the horse the different types of conformation are maggnifications (light horse) or extentions (heavy horses) of the gradual changes which have taken place during the course of evolution."

In short, Hammond, probably quite independently from Baur came to the same conclusions as the latter. Hammond distinguishes very sharply indeed two kinds of mutations, that is, big and small, and attributes to the latter a very great part in evolution not only in live stock but also in natural evolution. There is no need to discuss Hammond's explanation of the forces stimulating the origin of mutation. The point we were looking for is that 'small' mutations were recognised by Baur in the plant and by Slizynski, Goodale and particularly by Hammond in the animal realm.

4. Selection and its Part in Evolution.

It is thought necessary to devote a few remarks to the question of the selection which plays such an important role in evolution. Again these remarks must be strictly confined to those problems which concern our present discussion. Huxley (31) notes that species may originate in several different ways and this origin "may be either gradual or abrupt...... The divergent origin of new forms after isolation appears always to be gradual..." Morgan (37) states "Evolution once begun in a given direction is in a favourable position to go on in the same direction rather than in another". Goodale (28) is under the impression that "Darwin's view that selection has power to advance the creation of new inheritance finds support in these experiments and may eventally regain its former standing as a factor in organic evolution." Baur, it may be remembered (p.245) arrived at the same conclusion, whereas Hammond's opinion is that environment and especially nutrition play a stimulating role in progressive evolution;

In the light of the above cited opinions and in the light of the present investigation, one is inclined to think that if a set of genes is apt to mutate the selection goes in somewhat "snowball" fashion. The snow is furnished by mutation and selection furnishes the direction and perhaps the speed too. If the balance between genes is upset and the power of the selection maintained, it is easier for the evolution to go in the direction insisted upon by selection. This being pure mechanistic speculation must be regarded as such. The point which needs to be stressed is that evolution by means of "small" mutations and selection is a real phenomenon.

In this discussion, one more remark is to be offered. In the course of evolution a stage is reached in which evolution cannot go any further; evolution in the sheep's fleece for instance can hardly go above the Plain arrays. The medullation in Plain arrays is already "bred out" and the variations in plus and minus from the mean are very small indeed. But in Plateau arrays the percentage of hairiness is very high and ranges asTable XIX shows, from 24 per cent to 109 per cent. In other arrays the variability in the percentage of hairiness is gradually diminished until in the Plain arrays the variability reached almost 0. The high coefficient of variation indicates a multifactorial base of inheritance, the latter in our example is obvious from the evolution standpoint too.

But we know that Plain arrays are determined by probably no fewer genes than Plateau. Hence the low coefficient of variation in Plain arrays may lead to underestimation of the number of genes involved in the determination of fineness of wool. This is only one example. Of course all other properties of the array, e.g. the number of fibres in a given fibre type, the diameter, the shedding situation, etc. in short, all the traits in wool show the same properties, hence the low coefficient of variation does not mean necessarily that the number of genes involved must be also very low, and therefore a statistical treatment of genetic data must be treated with great caution.

5. Role of "Small" Mutations and Selection in the Evolution of the Fleece.

From the above discussion it is obvious that "small" mutations furnished the material for evolution. It must be, however, remembered that the fleece as an entity has undergone many evolutionary changes. In the present study attention was paid only to the most primary evolutionary changes, leaving practically out of account such important properties of the wool as rate of growth, density, character, etc. Even in the description of the evolution it was necessary to confine the discussion only to the forces responsible for the changes from Plateau to Plain arrays, leaving out of account the base or inborn coarseness upon which the checks act. This fact, however, does not obscure the picture of evolution in the fleece.

The 'small' mutations could not have been detected without the foundation work of Dr. Dry. Without the knowledge of comparative wool anatomy, such little changes which count in the evolution process were overlooked. Now, however, in the light of the facts hitherto described it is felt unnecessary to point out all the facts which are in favour of regarding the evolution in the fleece as a joint product of "small" mutations and selection. The data and graphs presented here are sufficient proof. For the sake of example, let us discuss the occurrence of "small" mutations in the Pre-curly-tip fibre group. One of the first small mutations had caused some of the halo-hairs to become super sickle A fibres, then other small mutations caused some of the super sickle A fibres to become super sickle A', that is, this mutation has caused the tiny region of the neck to be fine, later probably more than one small mutation caused super sickle A' to become super sickle B and still other mutations cause super sickle fibres to become sickle fibres. Chalky sickle fibres by means of further small mutations have gradually lost their hairiness until sickle fibres become fine throughout. These are qualitative changes only, but quantitative changes occurred too, changing the balance of the pre-curly-tip fibre group as has already been described. Such gradual changes may be noticed in all the other properties of the arrays. One may evolve faster as for instance fine sickle fibres or hairy-tip-curly-tip fibres (graphs 14 and 15); another more slowly, (histerotrichs - graph 20), but all of them show typical evolutionary trends. From unknown times (Barker, 2) "Man has selected sheep for fine wool, hence the frequency of mutation is in our consideration not of primary interest. Even if the frequency were very low it would not matter. Of course, the frequency of mutation even in the same species or race may differ greatly, hence the same methods applied to the same species or race give different results.

At the present stage of the knowledge of genetics, it is thought better to confine the discussion of the evolution of the fleece to the few points stressed above.

SECTION VI

I. THE CHARACTER OF LAMB's WOOL.

1. Introduction.

In this part of the thesis a preliminary account is being presented of investigations on the character of the lamb's wool. As far as our knowledge goes, no such investigation has hitherto been carried out, and therefore it was necessary to find out an easy and simple method for comparison of different staples and to judge the different properties of the wool ad oculos. Such investigations may be of interest first because they may reveal some relationship between the physical properties of wool at an early stage of the lamb's life, and the fleece of adult sheep; secondly they give some idea of the amount of variation in the wool character between the same body region of different lambs and between different body regions on the same lambs. Thirdly, some correlation may be shown between different wool characters. Finally they may furnish interesting data as to the origin of some wool characters.

It is felt necessary to point out that only 17 lambs, which furnished the chief material for the whole present study, were examined and therefore all conclusions drawn must be treated with great reserve.

The actual examination of staples was done by Mr . E.A. Clarke with assistance from Mr. J.A. Sutherland and Mr. R. Weber, to whom I wish to express my indebtedness.

2. Fineness

The length of the lamb's stape consists of a wavy region and a crimped region. The fineness of wool was ascertained only in the crimped region. The crimped region is as a rule finer than the wavy region. This is due to the "crisis thining". The fineness was ascertained by means of a grading scale consisting of seven grades. Grade I was the finest, Grade 7 the coarsest.

TABLE XXIV.

FINENESS OF WOOL IN DIFFERENT REGIONS OF THE BODY.

Region/ Grade	1	2	3	4	5	6	7	Total	Sum up 1-3	 4-7
Withers	9	6	1	-	-	-	-	16	16	-
Back	8	6	2	~~1~~	-	-	-	16	16	-
Side	4	9	2	-	-	-	-	15	15	-
Rump	2	3	5	4	-	-	~~1~~	15	10	5
Half Britch	-	3 -	5	4	4	-	-	16	8	8
Britch	-	-	2	2	6	3	3	16	2	14
Total:	23	27	17	10	10	3	3	94	67	27

TABLE XXI

FINENESS OF WOOL IN DIFFERENT ARRAYS.

Array/ Grade	1	2	3	4	5	6	7	Total	Sum up 1-3	 4-7
Plain	3	1	-	-	-	-	-	4	4	-
Valley	14	20	8	2	2	-	1	47	42	5
Raiine	3	4	6	5	-	1	-	19	13	6
Saddle	2	2	2	1	5	-	-	12	6	6
Plateau	-	-	1	2	3	5	6	17	1	16
Total	22	27	17	10	10	6	7	99	66	33

(a) Relationship between Fineness of Wool and Body Region.

The above tables show the relationship between the fineness of wool on different body regions and in different arrays. The results of this investigation may be summed up as follows:

Withers: as a rule are as fine or finer than Back and side regions, but there are a few exceptions; it may happen that back or side is finer than withers.

Back: is as fine, or less fine than withers but in four cases out of 17 back was finer (1 grade difference) than both withers and side.

Side: is stronger than withers and back; only in 3 cases out of 17 was side finer than both withers and back.

Rump: is still coarser than side region; only in 1 case out of 16, rump was as fine as withers and finer than back and side, and in one case rump was as fine as both withers and back but finer than side; rump is finer than half britch; However, out of 16, rump was in four cases coarser than the half-britch, and in only one case stronger than britch and in 3 cases rump was as fine as both half-britch and britch;

Half-Britch is still coarser than rump with the exceptions just enumerated. Only one case was found where half-britch was finer than britch (No.74) and 3 cases when half-britch was as coarse as britch;

Britch is the coarsest region of all the regions examined (with the exceptions mentioned above).

Thus we can say with regard to the fineness of wool in crimped regions that there is a transitional gradiation from withers, back, side, rump, half-britch to britch with the exceptions enumerated above.

(b) Relationship between fineness of wool and fibre type array.

Table XXV shows that the finest array is Plain, then go Valley, Ravine, Saddle and Plateau. The Valley arrays are concentrated within the first group of fineness (grades 1 to 3) but some valley arrays may be as strong as Plateau arrays. Within Ravine arrays the great majority belong to the first group of fineness, but Saddle arrays, as it was expected, are rather on the border line. All gradients exist. The Plateau arrays belong definitely to the coarsest group. There is, however, one interesting point, namely some Plateau arrays may be finer in the crimped region than, e.g. Valley arrays, and some Valley arrays and other less depressed than Valley arrays may be coarser than Plateau arrays. However, we may say that as a rule the more depressed the array, the finer the wool.

It is, however, very hard to say whether there is a correlation between the kind of array and the fineness (count) of the wool. This is due to the fact that all the staples examined are from as many as six regions of the body and it is quite impossible to eliminate the error which may be due to the differences within arrays on different body regions. So on the material in hand, it is impossible to correlate these traits, yet it is quite logical to assume that such a correlation exists. It may be added also that Sutherland (46) has come to the same conclusion.

A very interesting example of the differences in the fineness of the wool within arrays on different parts of the body is furnished by Lamb No. 74 VI! We remember that all the six regions have Plateau arrays and the fineness of wool is confined to grades 6 and 7, that is to the coarsest extreme of the grading scale. This example furnishes the evidence that the chief factor causing the wool to be fine depends on the array rather than on the part of the body. The last statement is easily understood in the light of the discussion in preceding parts of this thesis.

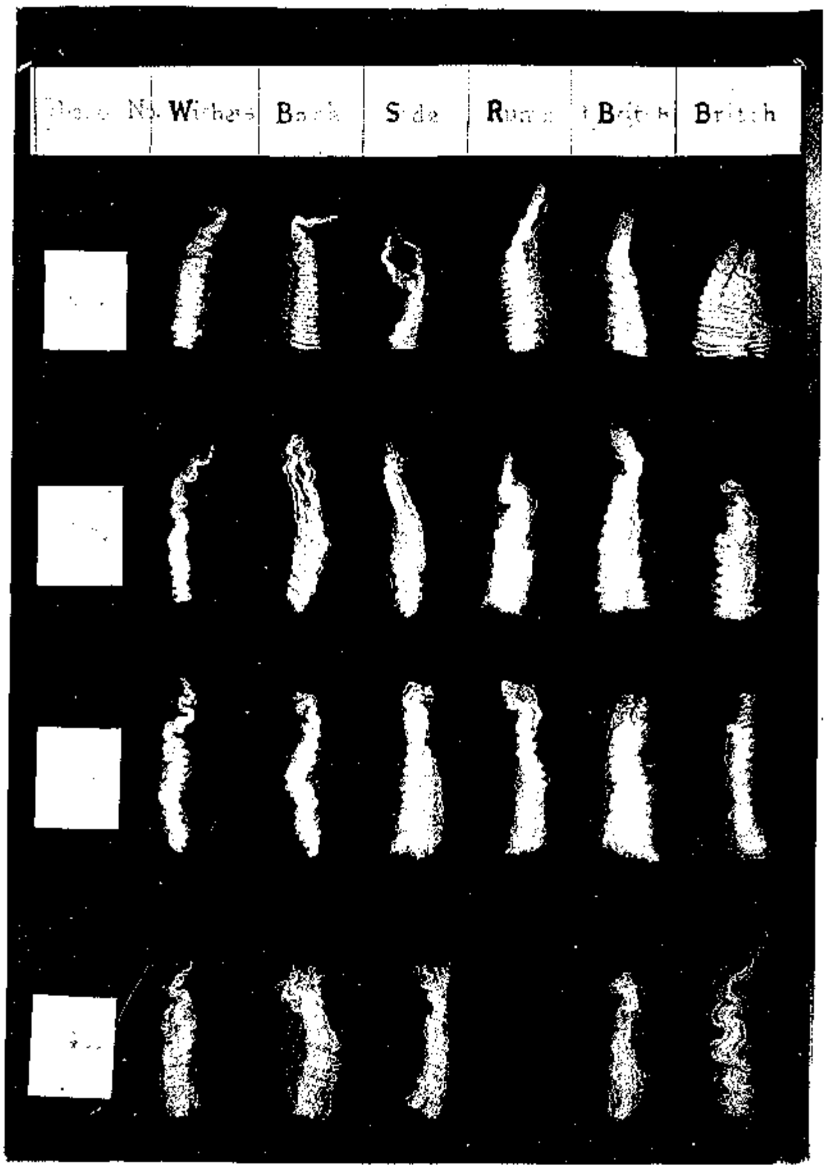


Fig.35

Lamb No.	Withers	Back	Side	Rump	Half-britch	Britch.
84	V	V	V	V	V	V
35	V	V	V	V	V	V
1	Pn	V	V	V	V	R
44	Pn	V	Pn		V	P

Pn = Plain;   V = Valley;   R = Ravine
S = Saddle   A = All in   P = Plateau

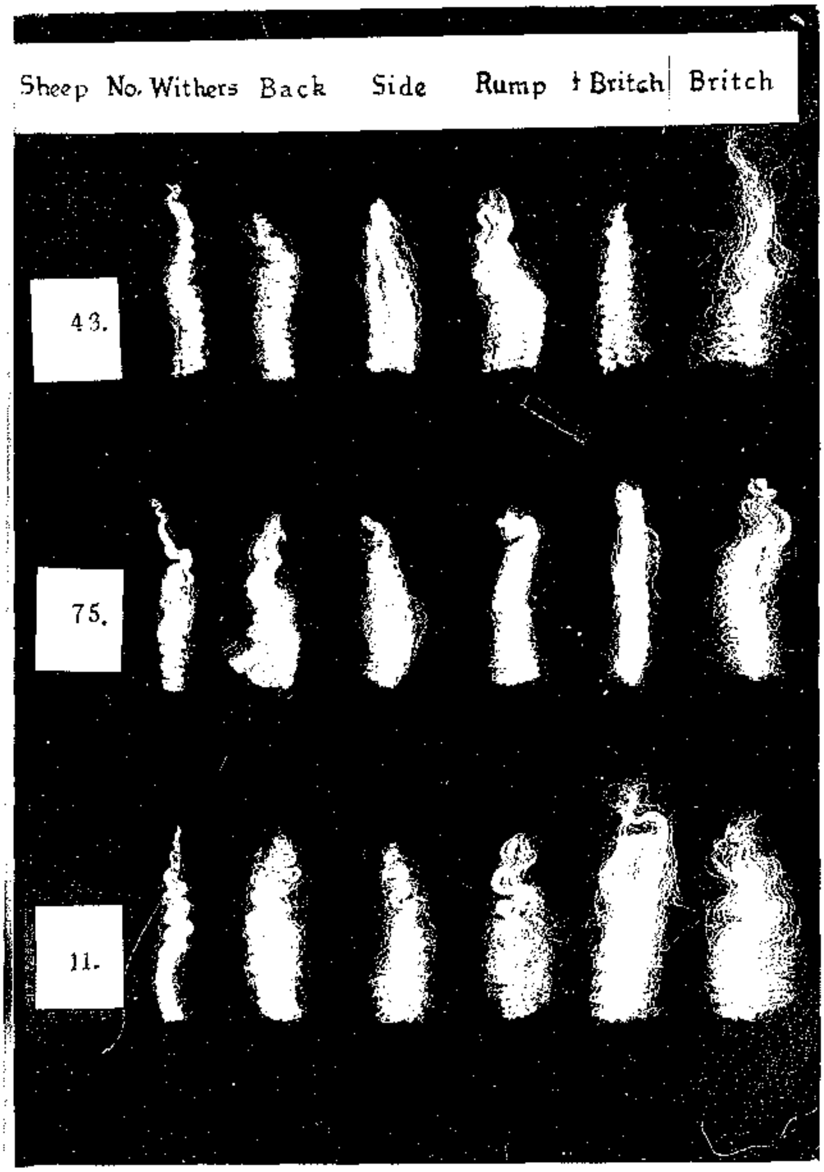


Fig. 36

Lamb No.	Withers	Back	Side	Rump	Half-britch	Britch
33	Pn	V	V	V	R	P
75	V	V	V	V	H	P
11	V	V	V	S	S	P

Pn = Plain; V = Valley; R = Ravine

S = Saddle; P = Plateau

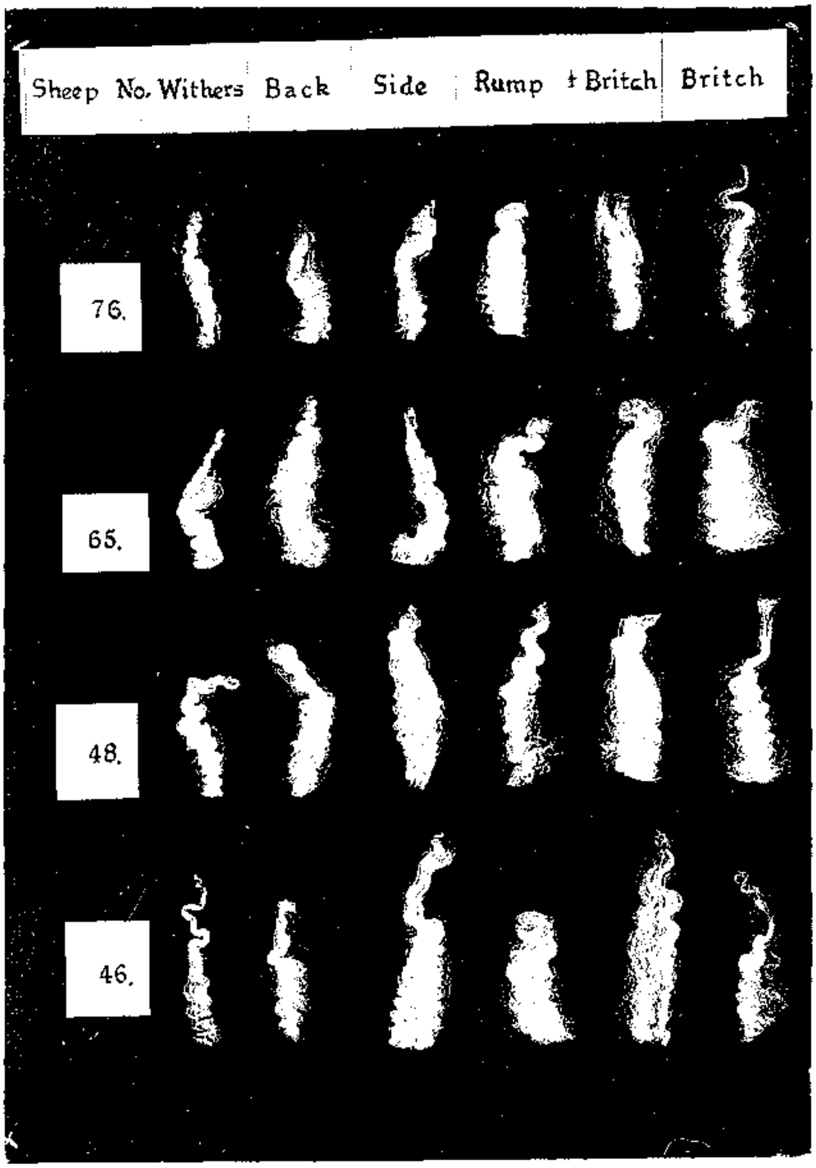


Fig. 37

Lamb No.	Withers	Back	Side	Rump	Half-britch	Britch
75	V	V	V	R	R	P
65	V	V	V	R	S	S
48	V	V	V	S	S	P
46	V	A	V	R	R	P

Pn= Plain; V = Valley; R = Ravine;
S = Saddle; A = All in P = Plateau

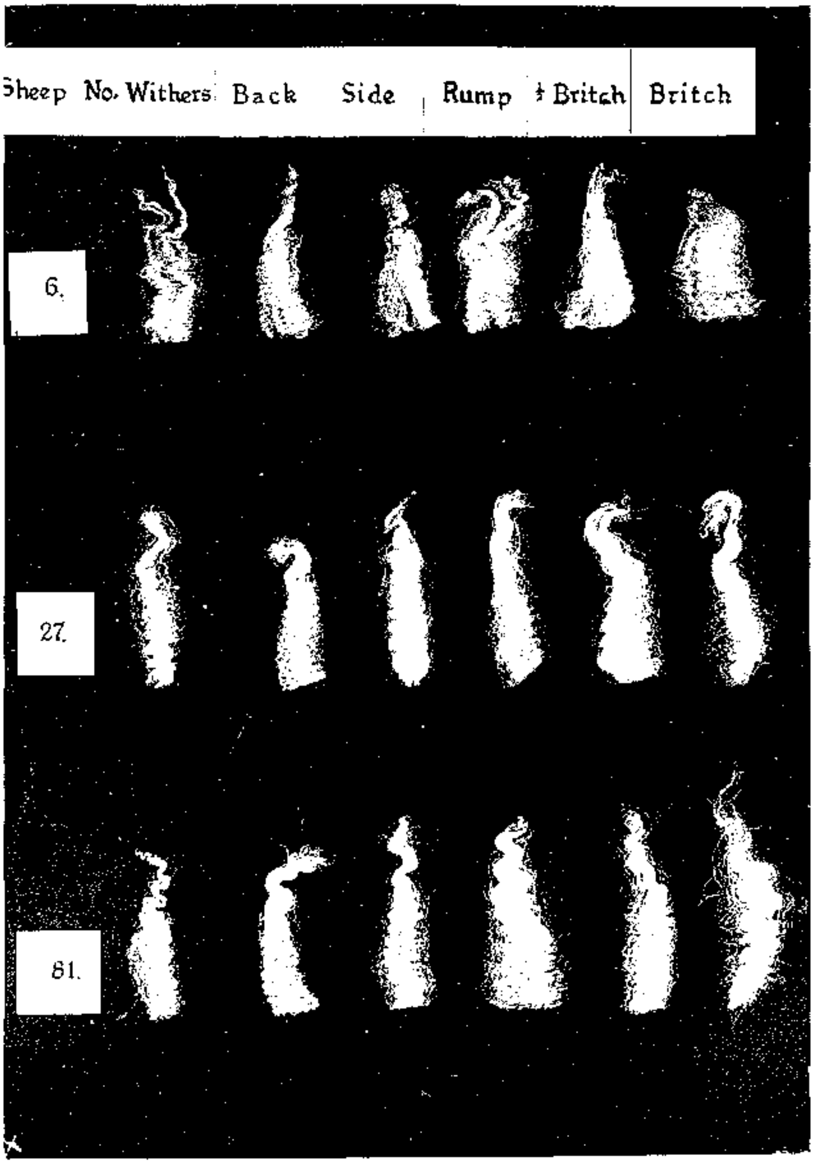


Fig. 36

Lamb No.	Withers	Back	Side	Rump	HalfBritch	Britch
6	V	V	R	R	R	S
27	V	V	R	R	S	P
81	V	R	S	R	R	P

Pn= Plain ; V = Valley; R = Ravine

S = Saddle ; = Plateau

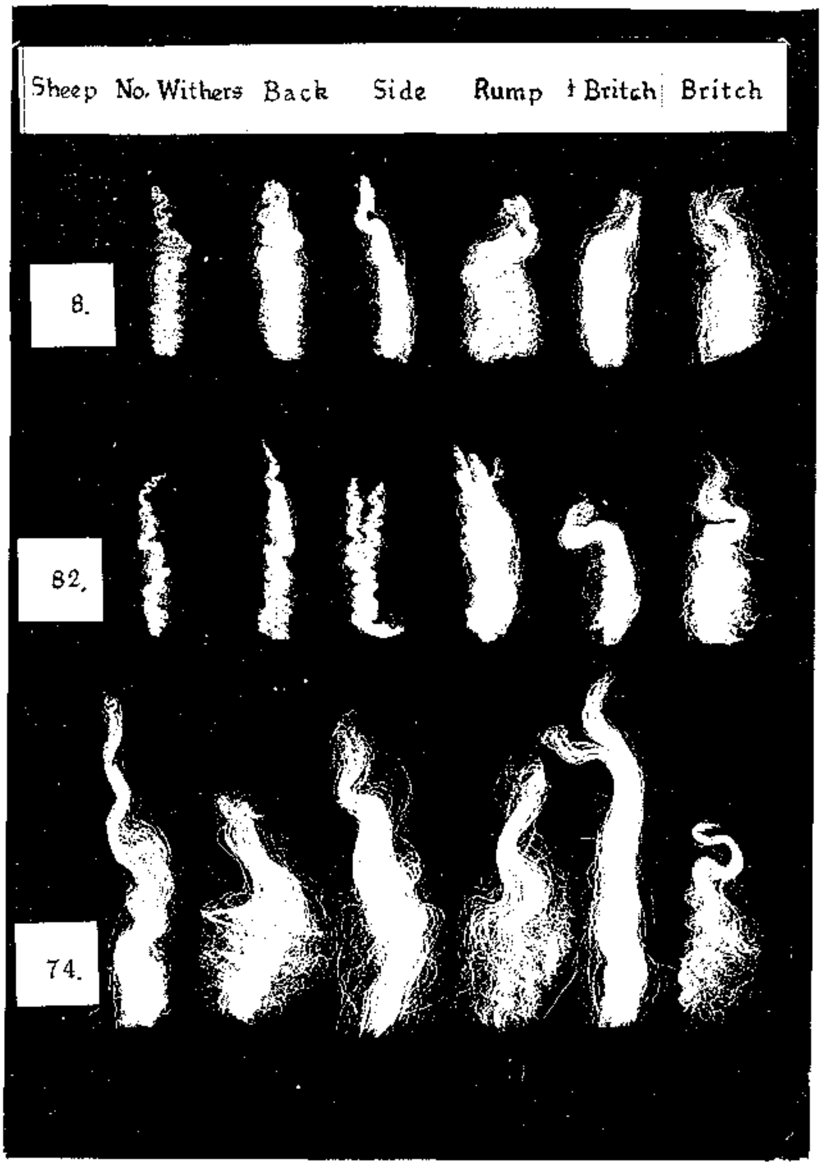


Fig. 39

Lamb No.	Withers,	Back	Side	Rump	HalfBritch	Britch.
8	Pl	R	S	S	S	P
82	V	S	R	R	R	[illegible]
74	P	P	P	P	P	[illegible]

Pl = Plain V = Valley R = Ridge

S = Saddle P = Plateau

3. Wave:

As it has already been pointed out, the length of a staple consists of two regions - the first (distal) one is wavy, the second one (proximal) may or may not be crimped. As to the former, the length and character of waves were ascertained (see also plates, 35, 36, 37, 38 and 39).

TABLE XXVI.

THE LENGTH OF THE WAVE REGION ALONG THE STAPLE

	Length	Withers		Back		Side		Rump		Half Britch		Britch	
Group I	3/3 ^{x}	2				3		-		1		1	
	2/3^{++}	-		1		-		-		-		-	
	2/3^{+}	2	12		11		7	2	13		8	1	9
	2/3	6		3				4		3		4	
	1/3^{++}	2		7		4		7		3		3	
Group II	1/3^{+}	4		4		2		1		5		4	
	1/3	5	5	2	6	7	9	1	3	3	10	2	7
	1/3-	-		-		-		1		2		1	

x 3/3 = right to the cut butt
1/3- = less than 1/3 of the length of the staple

The length in order from longest.

1	Rump	2	Withers	3	Back
4	Britch	5	Side	6	Half britch

TABLE XXVII

THE CHARACTER OF THE WAVES.

	Charac-ter	Withers		Back		Side		Rump		Half Britch		Britch	
Group I	Excel.	1		1		-		-		2		-	
	Very good	3	9	5	99	-	3	2	6	2	3	-	4
	Good	5		3		3		4		1		4	
Group II	Medium	6		1		5		4		4		2	
	Poor	2		3		5	13	2	10	5	14	4	12
	Bad	-	8	4	8	2	13	4	10	2	14	6	12
	Very bad	-		-		1		-		3		-	

The character in order from best:

1	Withers	2.	Back	3	Rump
4	Side	5	Britch	6	Half britch.

As it can be seen from Table XXVI the longest wave region is to be found on the rump, withers and back and the shortest on britch, side and half-britch respectivelyy There are, however, some individual variations.

There is no correlation between the length of wavy region and character of waves.

Table XXVI as well as pictures shows that the better waves are to be found on the withers, back and rump regions, respecitvely and the worse on the side, britch and half-britch respectively. There are, however, some individual variations.

4. The Crimp:

The length of the crimped region may be computed from the data given for the length of the wavy region of the staples.

The following characters were ascertained:

(a) the regularity of the crimp along the length of the staple;

(b) the depth (amplitude) of the curves;

(c) the wave length (frequency) of the curves;

(d) general character ot the crimp.

The data are shown in the Tables below.

TABLE XXVIII

REGULARITY OF THE CRIMP

		Withers		Back		Side		Rump		Half Britch		Britch	
Group I	Excel-lent	1		-		-		-		1		-	
	Very good	1	7	4	6	1	3	4	7	8	12	3	11
	Good	5		2		2		3		3		8	
Group II	Medium	6		10		7		4		3		3	
	Poor	2	8	-	11	2	9	3	8	-	4	1	5
	Bad	-		1		-		1		1		1	
	Very bad	-		-		-		-		-		-	
	no crimp	2		-		3		1		1		1	

Regularity in order from best:

1 Half britch 2 Britch 3 rump;
4 withers 5 back 6 side

TABLE XXIX

THE DEPTH OF THE CRIMP

		Withers		Back		Side		Rump		Half Britch		Britch.	
Group I	Deep	6	9	3	12	1	5	1	12	4	12	8	14
	Normal	3		9		4		11		8		6	
Group II	Shallow	6	6	4	5	5	8	1	3	3	4	2	2
	Trace	-		1		3		2		1		-	
	No. crimp	2				3		1		1		1	

Deep crimp, in order of frequency: Britch, withers, half-britch, back, rump, side.

Normal crimp, in " " " rump, back, half-britch, britch side, withers

Shallow crimp " " " " withers, side, back, half-britch britch, rump

Trace of " " " " side, rump half-britch, back

Depth of crimp : 1 Britch; 2. Rump, 3 Half-britch 4 Back 5 Withers 6 Side.

TABLE XXX.

THE WAVE LENGTH.

	Withers	Back	Side	Rump	Half Britch	Britch
Long	2	3	7	9	11	13
Medium	9	9	5	4	5	3
Short	4	5	1	2	-	-
No crimp	2	-	3	1	1	1

TABLE XXXI

GENERAL CHARACTER OF CRIMP

		Withers		Back		Side		Rump		Half Britch		Britch	
Group I	Excellent	1	6	-	9	-	4	-	8	1	8	-	10
	Very good	1		2		1		3		3		3	
	Good	4		7		3		5		4		7	
Group II	Medium	8	9	6	8	6	9	3	7	5	8	3	6
	Poor	1		1		3		3		2		2	
	Bad	-		1		~~1~~		1		1		1	
	Very bad	-		-		-		-		-		-	
	No crimp	2				3		1		1		1	

In order from best: 1. Britch; 2 Back; 3 Rump
4 Half-britch 5. Withers
6 Side.

From the above tables we can draw the following short conclusions:

(1) The traits which count in the determination of the character of lamb's wool do not show any regularity and uniformity over the body. In other words, one trait is better marked on one body region, the other on another. Even for the same trait on the same body region there are marked differences due to great individual variability. However, in spite of the above reservation it is possible to show the general tendency in the relation between different body regions;

(2) The regularity of crimp shows better uniformity on the hind-quarter than on the fore-quarter. The most regular crimp is on the half-britch, britch and rump, whereas withers, back and side have less regular crimp and an appreciable number of staples were found having no crimped region, that is, the wool (see plates) is not straight, but wavy (except lamb No. 74 - the character of its wool will be discussed later on).

(3) For the depth of the crimp a table was computed dividing the depth into two groups. Each group comprises two classes, hence deep crimp means that the height of an arch is longer than its length. In a normal crimp the height of an arch is equal to its length, whereas in shallow crimp the length of an arch is longer than its height. Thus the depth of a crimp is better marked on the hind quarter too. It is worth pointing out that a crimp found in a number of chalky fibres, shows the very traits of so-called "thread". Kaczkowski and Muller (33) use this term to define an overbuilt crimp, that is a crimp having the height of its arches far too great. Such a crimp was found in fine Merino wool and was hitherto regarded as an indication of overselection, for higher count. Since the "thread" was found in chalky fibres, such an explanation is no longer tenable.

(4) The wave length: The data tabulated in Table XXX suggests the existence of a correlation between the wave length and the fineness (count) of the wool. The coarser the

wool the longer the waves of the crimp. Such a correlation, expressed as the number of crimps per inch, has been found chiefly for Merino wool by Zipser, Davenport and Ritzman, Duerden and others (2).

(5) The general character of the crimp may be understood as the summation of the regularity, the depth and the wave length of the crimp. As Table XXXI and plates show the crimp character in order from best is: Britch, Back, Rump, half-britch, Withers, and side.

It may be remembered (Table XXIV) that the coarsest wool in the crimped region was found on the britch region, and yet this region shows the best character of the crimp; it follows then, that there is no tendency to correlate the fineness of the wool with the character of the crimp. The side and back region, for example, have both very fine wool and yet the character of the crimp on the back is much better than on the side. (All the lambs were covered)

It is interesting to note that in extremely fine sickle fibres and some histerotrichs, the crimp was very poor indeed; on the other hand, some strong fibres show very good character of the crimp.

(6) Jljin and Thomasset (47) have found the different "Centres of Keratinization" acting with a certain degree of independence on different regions of the fleece. Galpin (26) working on the coat of the foetus found marked differences in the development of the follicles on different body regions. The same author has found different centres of depression causing different arrays on the different coat regions of the same lamb. The above papers suggest that the fleece cannot be regarded as one entity. The present investigation shows clearly that with regard to other characteristics of the fleece, different regions of the body behave differently (shedding, the character of the wool, the character of the crimp, etc.) A very striking example which illustrates some degree of regional

independence is furnished by Lamb No. 74. The staples pictured (fig.39) show that only the britch and back have the crimped regions. The rump shows a slight trace of the crimp whereas all the remaining staples have straight wool. The britch, the back and the rump are the regions where the best wool crimp character is to be found (see Table XXXI). These facts suggest that even for crimp characteristics, different "centres" on the fleece are to be found. From these centres there is what may be termed a flow all over the fleece and further these regions of the body showing the best characteristic may be regarded as the oldest in the sense of phylogeny.

SUMMARY.

1. There is no appreciable shifting of the skin with reference to the skeleton, on the hind-quarter, during the first 6 months of lamb's growth.

2. Fibre types arranged in pre-curly-tip group, curly-tip group and post-curly-tip group, are discussed. The characteristic features of each fibre type and fibre type array are reviewed, the stress is laid on the key type in each array, and on the qualitative differences between arrays and on the quantitative differences within a given fibre type array.

3. Halo-hair shape, length, coarseness and abundance are discussed; the way in which the latter is being reduced is shown.

4. The pre- and post-natal career of super sickles and sickle-fibres is discussed in the light of comparative anatomy of wool. The existence of typical and non-typical super sickles involves a single and/or double bond in arrays. The tip shape of typical and non-typical super-sickles is discussed in some detail; the

time the medullation appears and the rate of thickening play probably a significant role in determining the different variations in the tip-shape; non-typical super sickles and sickle fibres are always situated at the right wing of the fibre type series, whereas the typical ended fibres are situated on the left wing. The minute study on the tip shape may be of primary importance in distinguishing the fibre types in the investigation on the embryology of wool.

5. On their post-natal region birthcoat fibres are placed in four classes according to the behaviour of chalkiness and "crisis thinning".

6. General shapes of the tuft may be super imposed upon individual fibres.

7. The "toughness" of an array may be measured by the abundance of the key type and expressed as a per centage of a given fibre type or fibre type group.

8. The centre of gravity of the pre-curly-tip group is shifted from halo-hairs and super sickle A in Plateau to chalky sickle fibres in Saddle and fine sickle fibres in Ravine, Valley and Plain, in the latter array the shifting of the centre of gravity has reached the extreme end.

9. The time the fibres develop and the time of the outset of the work of the pre-natal check is probably responsible for the shifting of the centre of gravity in the pre-curly-tip group. The interaction of the same factors is probably responsible for the length of sickle-ended fibres and especially sickle-fibres and "intermediates."

10. For the sake of convenience the term "pre-natal check" is replaced by "head"check; thus "head" check is responsible for all the changes in the head of an array, notably for determining the arrays, whereas the "tail"check is employed to explain the changes in the tail of an array.

11. The abundance of super sickles and sickle-fibres in different arrays and body regions is tabulated and discussed.

12. The tip shape, length, and post-natal portion of H.T.C.T. fibres is discussed.

13. Fine H.T.C.T. fibres were found in one Vally on the withers.

14. H.T.C.T. fibres are always to be found in Plateau array.

15. The influence of body region on the abundance of H.T.C.T. fibres is detectable only in less checked non-plateau arrays; in well checked arrays the percentage of these fibres is negligible; in Ravine on half-britch the percentage of H.T.C.T. fibres is of some importance only when Plateau or "tough" Saddle array is found on the britch.

16. There is no relationship between the abundance of S.S.B. and H.T.C.T. fibres in Plateau arrays; further there is no significant correlation between either of them and the percentage of hairiness

17. The morphology of curly-tip fibres, with special reference to the tips form and post-natal structure is discussed in the light of the "head" check; the upper boundary for the expansion of the "head" check into the curly-tip group has tentatively been ascertained, this being 37% of checked C.T. fibres.

18. Histerotrichs start to pierce the surface of the skin about 3 days before the lamb's birth; their entry into the fleece is completed at about 5 months. The latter figure is regarded as the upper boundary for the development of a new histerotrichs.

19. From the table given by Burns concerning the growth of skin area, and from present investigation on the time the last histerotrichs are being added to the fleece, it was concluded that the density of the fleece, that is, number of fibres per unit area, is decreasing after the lamb is five months old.

20. Histerotrichs grow in two waves topped with two distinct peaks, either of which may be higher or lower.

21. It was calculated that the rate of histerotrich growth is about 0.6 mm. per day.

22. The highest abundance of histerotrichs was found in Plateau and the lowest in Plain arrays.

23. It was concluded that the drop in halo-hair abundance is correlated with a simultaneous drop in histerotrich abundance.

24. The more improved the Valley array the lower the percentage of histerotrichs.

25. A high coefficient of variation of histerotrich abundance may suggest a multifactorial inheritance of histerotrich abundance.

26. Orange G very rapidly dyes the sheath of shed fibres.

27. Shedding is correlated with array and body region; the highest percentage of shed fibres was found in Plateau, the lowest in Valley, the strongest shedding was found on the back, the weakest on the withers.

28. The non-typical ended pre-curly-tip fibres do not shed freely.

29. Shedding in the curly-tip group is negligible in my material.

30. It is suggested that in order to get rid of kemp hairiness, selection should be based on truncated arrays.

31. Fine super sickle B, fine sickle fibres, and one histerotrich were found to be shed in normal fashion.

32. A number of fibres were found, which appeared as if about to shed "smokily" but actually did shed in normal fashion.

33. There is relationship between the arrays and the abundance of G_2; the less checked the array the more hairy G_2 fibres.

34. The relation between G_2 and body regions corresponds with that of G_1.

35. In kemp production the follicles of the first fibres, that is halo-hairs and their closest associates play the decisive role; it is emphasised that selection against kemp hairiness should be based on truncated arrays.

36. The present investigations confirmed Galpin's result as to the posterior-anterior gradients.

37. There is a relationship between hairiness and arrays; also, there is a relationship between the behaviour of hairiness down the staple and array. Plateau arrays show not only the highest percentage of hairiness but also the highest percentage of samples "hairy throughout", Valley arrays have but 7 per cent of samples "hairy throughout", others being "less hairy at butt" or "hairy tip only".

38. The hairiness is diminishing when we pass from britch to half britch in gradual fashion, hence, if the starting point is grossly hairy we cannot expect any marked diminution in the percentage of hairiness on the hind quarter.

39. Hairiness in the array is attacked from three sides - from the head, the tail and "crisis level". "Head" check and "tail" check are responsible for the diminution of hairiness on the head of the array and on the tail of the curly tip series, respectively; one of these forces is probably responsible for "crisis thinning". These two checks do not show any high correlation, hence the correlation between the array and hairiness is obscured; an array with a very weak "head" check may have a very strong "tail" chekk and vice versa; that is why the variations in the percentages of hairiness within a given array are great. Only in Plain array the correlation between these two checks is very high and Plain arrays can show a trace of hairiness, at most. Truncated

Valley array being closely associated with Plain arrays should show a higher correlation between "head" and "Tail" checks than all the remainder.

40. It is suggested that in order to get rid of hairiness, no matter whether kemp-hairiness or non-kemp hairiness, the ideal plan would be to base the selection on truncated Valley array and the crucial position should be the britch.

41. The high coefficient of variation in the percentage of hairiness suggests multifactorial inheritance; on the other hand the very low coefficient of variation does not necessarily mean that we are dealing with a simple Mendelian situation.

42. The precipice situated in six regions on lamb No; 74 (N-type) behaved differently; the most abrupt precipice was found on the side, the least or practically none on the back; Post-

precipice fibres need not be fine; they may show diversity in their diameter and length.

43. "Crisis thinning" is discussed in the light of the present investigation.

44. An attempt was made to prove that the recombination of genes is responsible for bringing about the atavistic characteristics of the coat on N-type. The genetic basis of the N-type coat here ~~is~~ discussed is multifactorial.

45. Two schools of thought of the problem of evolution of the fleece are reviewed.

46. The evolution of the fleece of the New ZealandRomney breed is discussed; there are three fibre types deemed to be the oldest in the sense of phylogeny, namely halo-hair in pre-curly-tip group, hairy-tip-curly-tip in curly-tip group, and histerotrich in post-curly-tip group. The first two fibre types belong to the outer coat, the last to the inner coat.

47. The percentage of the pre-curly-tip group does not shaw any significant changes, from one arra y to another - save occasional exceptions - only the centre of gravity is shifted in the course of evolution from halo-hairs in Plateau array to fine sickle fibres in Plain array.

48. The constituents of the pre-curly-tip group evolved from halo-hairs.

49. It was possible to ascertain that at least 77 per cent of curly-tip fibres have evolved from hairy-tip-curly-tip fibres; it was suggested also, that the non-typical ended fibres belonging to the pre-curly-tip group have/evolved from hairy-tip-curly-tip fibres.

50. Some of the histerotrichs, in the course of evolution, have become late curly-tip fibres.

51. Evolutionary tendency and the density of the fleece is discussed.

52. "Head" check and "tail" check are discussed from the evolutionary point of view.

53. The hypothesis associated with the name of Duerden and others about the evolution of the fleece is not tenable. The fleece of improved sheep comprises both inner and outer coat; the separation of kemp-hairiness from non-kemp hairiness has no phylogenetical justification; both of them are derived from the outer coat; The same follicle can give either kemp or wool; a kemp in one period and wool in another.

54. A general consideration of evolution from the standpoint of genetics, is outlined and emphasis is laid on the role of "small" mutations in evolution. It is thought that the additive effect of "small" mutations together with artificial selection has brought about the evolution of the fleece.

55. A preliminary report on the character of lamb's wool is given.

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APPENDIX.

Legend for use with Tables covering Lambs Nos. 1 - 84 will be found on page which should be unfolded. Key to abbreviations used is also contained thereon.

Folded portions of Tables should also be opened out.