

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

STUDIES OF THE COAT

Janet Ross.

IN THE

NEW ZEALAND ROMNEY N-TYPE SHEEP.

---oOo---

PART I KEMP IN THE NEW ZEALAND ROMNEY N-TYPE FLEECE.

PART II PRE-NATAL DEVELOPMENT OF THE N-TYPE BIRTHCOAT.

---oOo---

CODE NUMBER 148.

PART I

KEMP IN THE NEW ZEALAND ROMNEY N-TYPE FLEECE.

---oOo---

INTRODUCTION.

Kemps may be defined as hairy fibres which are shed after a short period of growth. Birthcoat kemps are succeeded by fibres in the same follicle, and there may be varying amounts of this second generation that are also shed. Thus, successions of kemp often continue throughout the life of the sheep making the fleece uneven in a way usually undesirable. Previous studies (Dry 1940) have shown that selection against high abundance of halo-hairs is effective in eliminating kemp. Although kemps are associated with coarse fleeces with high abundance of halo-hairs, they are not always present. A hairy birthcoat follicle after growing and shedding a kemp may produce fibres of persistent growth; hence this study should have significance for breeders of Mountain Sheep which characteristically have hairy birthcoats. It is understood that a thick, hairy birthcoat of halo-hairs with a minimum of kemp in the adult fleece is desirable in the Scotch Black-face lamb.

The various characteristic fibre types of the sheep's fleece have been studied and classified by Dry (1933). According to the collection of these types present in one sample of wool, certain characteristic arrays can be recognized (Dry 1934). These arrays can be arranged in a series :- those with sickle-fibres are non-Plateau with few halo-hairs

and include Saddle, Ravine, Valley and Plain arrays; those without sickle-fibres are Plateau, coarse arrays with many large hairy halo-hairs. The former type of array, non-Plateau, is found on finer woolled sheep such as Wensleydales, fine Romneys etc. while the latter type of array, Plateau, is found on N-type Romneys and Mountain breeds such as Scottish Blackface.

The time needed to determine whether the fleece will be kempy is the time required for a kemp to shed and be followed by succeeding fibres, i.e. about six months. It would be of advantage to breeders if this determination could be made soon after the birth of the lamb. For early recognition and also for a basis of selection, correlation of productive capacity with other characters has been a favourite subject with livestock breeders e.g. milking capacity. If correlations are real they can thus be very advantageous.

Now, by making use of previous knowledge of fibre types of Plateau array, it has been possible to find a correlation between the presence or absence of kemp in the adult fleece and the characterisation of fibre types in the birthcoat.

In the case of non-Plateau arrays, Dry (1940) has derived a theory, based on a correlation, for early recognition in the lamb's coat of presence of kemp in the adult fleece. Sickle-fibres which have proved to be the determinate fibres in the classification of arrays, are the determinate

fibres in this non-Plateau shedding generalisation. Plateau arrays rarely possess sickle-fibres, but if present at all they are in very few numbers and are often aberrant forms. The non-Plateau generalisation is therefore not applicable for N-type lambs with Plateau arrays.

It was necessary, therefore, to find some means for the early recognition of kemp in the N-type fleece where it is so often in such considerable abundance. Throughout this study, criteria are examined in order to establish a method for this recognition based on the characteristics of the fleece and its component fibre types.

MATERIAL AND METHODS.

The study was made on wool samples taken from the standard back position, that is, the middle line at the level of the last rib, of 81 New Zealand Romney lamb and hogget fleeces. The animals were all of the specifically bred "N-type" i.e. with a very high abundance of halo-hairs at birth and with coarse hairy fleeces in the adult sheep. Arrays were therefore all Plateau or near-Plateau.

The individual fibres were sorted out separately from small samples, classified and counted. The groups of fibres were laid out on black velvet in serial order, i.e. the supposed order of actual fibre initiation in the skin (Dry 1933). Thus an "array" can be recognized according to the types present.

Owing to the extreme difficulty in accurately illustrating individual fibres of the fleece, the writer is largely indebted to professional aid for the photographs presented.

TYPES OF KEMP.

In N-type sheep (Fig. 1) where there is a great abundance of halo-hairs, these large fibres and often other hairy birthcoat fibres such as super-sickle-fibres, hairy-tip-curly-tip fibres and even some curly-tip fibres (Figs. 4-9), are shed after three months' growth. These are known as kemps of Generation I (G1). There may be an odd halo-hair of persistent growth. Succeeding fibres in their follicles (Fig. 10) may or may not be shed after about another three months - Generation II (G2); similarly a third generation, (G3) may follow; and so on until in the adult animal with abundant kemp, it is possible to recognize the generations as distinct layers of kemp in the staple (Fig. 11).

It may be said that a fibre either is, or is not, shed but G2 kemps are found of varying lengths. In a few rare cases they are very long and not shed until the usual time for shedding of G3 fibres (Fig. 12). The longest kemps show "crisis thinning" like an attempt at shedding, and then regain their original vigour.

If there is little G2 kemp, (less than 75 kemps per 100 halo-hairs), the kemp fades out almost completely in the next two generations. Two samples of those examined were exceptions where there were odd kemp successors up to G4.

Abundance of kemp is well sustained throughout the life of the sheep. One outstanding exception to this is surprising. Lamb No. 36 had abundant G2 kemp, then none at all

in G3, and the G3 persistent successors of No. 36 were all fine and woolly. However, wool fibres are due to a lessened activity of the follicle cells and are rarely shed. It would therefore appear that some check to the growth of the follicle cells had occurred in this case and kemps were not produced. The G2 kemps themselves were slim, short and much crimped. Some hairy-tip-curly-tip and all curly-tip fibres showed a marked reduction in hairiness after birth and were woolly and sparkling. There was also a large number of super-sickle A or small halo-hairs. In Plateau arrays, much kemp on the first fleece is sustained in later years (Dry 1941).

ABUNDANCE OF KEMP

CORRELATED WITH FLEECE CHARACTERISTICS.

In spite of the large number of halo-hairs on the birthcoat of these N-type sheep, they do not always show successions of kemp, and may not show any kemp at all. The second generation fibres (G2) may be of persistent growth (Fig. 13).

In this study, a measure of the amount of G2 kemp is given in terms of the number of halo-hairs that are succeeded by kemps, and is calculated as the number of G2 kemps per 100 halo-hairs in a sample of wool. In some cases, follicles of large birthcoat fibres other than halo-hairs may also produce secondary kemp, the number exceeding 100. In other cases, a few halo-hair follicles as well as those of other birthcoat fibres, give rise to G2 fibres of persistent growth, and then there is little kemp, the number being less than 100. Even when only three-quarters of the halo-hairs are followed by secondary kemp, this amount is still regarded as undesirable. An arbitrary figure therefore, between 75-110 kemps per 100 halo-hairs, is fixed as denote an intermediate amount of kemp.

Of the 81 sheep available with G2 kemp in the fleece on the back, there were ³⁵~~34~~ with abundant kemp i.e. with more than 110 G2 kemps per 100 halo-hairs, ~~16~~¹⁶ with medium

kemp i.e. between 75-100 kemps per 100 halo-hairs, and 29 with little or no kemp i.e. from 0-75 kemps per 100 halo-hairs.

A comparison between these three groups was made to study any relationship there might be between the presence or absence of kemp and any outstanding features in the birthcoat. There have been several suggestions put forward by previous workers. Lochner (1931) working with only 11 lambs, stated that a long open curly type of fleece is undesirable and he considered length of the hairy birthcoat fibres (heterotypes A and B), to be associated with kemp. Dry (1941) has given a more detailed study of the persistence of large birthcoat fibres and suggests tentatively that this might provide a basis for selection against later kemp. The individual fibre types and the features associated with kemp have been studied by Dry (1940) and Sutherland (1939) in N-type (Fig. 1) and non-N-type (Figs. 1 and 3) fleeces, but no definite conclusions were given for the N-type fleece.

GENERAL FLEECE CHARACTERISTICS.

In the material available for this study, general fleece characteristics have been considered. Direct observation, supported by a few measurements showed that length of staple was not a reliable criterion for presence of much secondary kemp.

Lambs graded for the number of halo-hairs present on the back at birth often show a reduction of these on the withers (Fig. 2). It was thought that this was the result

of some check which may also show some effect on the abundance of kemp on the back. Lambs in the three groups of kemp abundance were classified and tabulated according to the presence or absence of a reduction of halo-hairs on the withers (Table I).

TABLE I *

	Abundant kemp	Medium kemp	Little kemp
No reduction	22	12	9
Slight reduction	7	5	5
Marked reduction	5	1	15

* The figures in the table refer to the number of animals in each group.

No reduction of halo-hairs on the withers, which may indicate an extremely tough birthcoat, was found on the majority of lambs that had much later kemp. A marked reduction of halo-hairs on the withers was very common on lambs that later showed little kemp.

Passing from early to later starting fibres along the array series, there is a reduction in hairiness. This reduction may be gradual or it may be more abrupt, in which case it is called a "precipice" (Dry 1940). Data on the relationship of the presence of a precipice with abundant G2 kemp is given in Table II.

In this table the number of animals having varying amounts of kemp are classified and tabulated into two groups, those with a distinct precipice and those with a gradual reduction in hairiness and four doubtful cases.

TABLE 11 *

	Abundant kemp	Medium kemp	Little kemp
Distinct precipice	15	8	6
Doubtful precipice	3	-	1
No precipice	7	4	14

* The figures in the table refer to the number of animals in each group.

There is found to be a tendency for the occurrence of abundant kemp when a definite precipice is recorded and similarly in cases of little kemp, the majority show a gradual reduction in hairiness along the array series.

GENERAL FEATURES IN THE ARRAY.

One of the chief factors causing persistence of fibres, is the pre-natal check (Dry 1933), a restricting force acting before, this check showing many effects on the fibres of the fleece. It may determine fibre characterisation, and acting as a setback, may dampen its vigour, thus preventing shedding.

All samples were therefore arranged in order of strength of the pre-natal check as far as this could be judged on presence of checked birthcoat fibres. Those arrays with

no super-sickle fibres are the least affected by the check and are said to be "very tough" (Fig. 8). Those with odd super-sickle fibres are "tough" arrays. Those with many super-sickle type A' and super-sickle type B fibres, indicate a strong check and are mild. The presence of odd sickle-fibres indicates an even stronger check. In Table III the lambs in the three groups of kemp abundance are classified into these four grades of toughness in order to illustrate the relationship between the occurrence of kemp and the toughness of the array.

There were 13 very tough arrays in the material studied, consisting of birthcoat fibres only, of halo-hairs and hairy-tip-curly-tip fibres and no super-sickle fibres. All had abundant kemp except one lamb, No. 135. This exception had very little G2 kemp but the halo-hairs showed an unusual but marked thinning in the neck region just before birth of the lamb (Fig. 4.f.). It is suspected that there has been some environmental setback before birth which has caused the thinning in the halo-hairs themselves and weakened their follicles so much that the G2 successors were not shed.

All the remaining arrays with super-sickle fibres present showed varying amounts of kemp, some more and some less. There seemed no means of placing these arrays in descending order of toughness to correlate further with the kemp.

TABLE 111 *

	Abundant kemp	Medium kemp	Little kemp
Very tough array No super-sickle fibres	9	3	1
Tough array Odd super-sickle fibres	8	2	1
Mild array Many super-sickle fibres	11	11	11
Mild array Many super-sickle and odd sickle-fibres	6	2	16

* The figures in the table refer to the number of animals in each group.

THE LARGE BIRTHCOAT FIBRES.

Dry (1940) studied the shedding of the birthcoat fibres and concluded that "When shedding of big birthcoat fibres in addition to halo-hairs is free, the rule is much G2 kemp. When shedding of birthcoat fibres is not free then the rule is little G2 kemp". In judging freedom of shedding of the birthcoat, the pre-curly-tip fibres, halo-hairs and super-sickle fibres were taken into account. Lochner (1931) has also stressed the association of the persistence of birthcoat fibres with reduced kemp.

The freedom of shedding was arbitrarily graded into three groups (Table IV) and it was found that in cases where all the pre-curly-tips were shed there was, with only two exceptions, abundant or medium kemp. Poor shedding was found to be definitely associated with little kemp. In cases where some

pre-curly-tip fibres persist, kemp was of varying abundance.

TABLE IV *

	Abundant kemp	Medium kemp	Little kemp
All pre-curly-tip fibres shed	27	8	2
Pre-curly-tip fibres equally shed and persisting	6	7	12
Very few pre-curly- tip fibres shed	1	3	15

* The figures in the table refer to the number of animals in each group.

Further counts were taken on a study of each of the large birthcoat fibre types taking separately halo-hairs, super-sickle type A, super-sickle type A', super-sickle type B and hairy-tip-curly-tip fibres (Figs. 4-9).

Sutherland (1939) stated that whenever halo-hairs persist, later kemp is scarce. There were four cases where a few halo-hairs persisted, two of which were exceptions to this generalisation. A detailed study of the halo-hair types themselves was also undertaken and there was found to be great variation in shape of tip, in length before and after birth and in a certain tendency towards thinning in the neck region of the halo-hairs of different animals (Fig. 4). These characteristics were examined in relation to the kemp situation.

The style or shape of halo-hair tips often approaches the curl of the tips of the hairy-tip-curly-tip fibres forming

a gradual transition between these two types with many intermediates (Fig. 8). In 22 arrays with some halo-hairs like the hairy-tip-curly-tip there is abundant kemp. Lamb No. 111 is an exception with little kemp, but in this case there is not a transition from true halo-hairs to true hairy-tip-curly-tip fibres but ^{all} the halo-hairs are actually ^{very like} large hairy-tip-curly-tip fibres. Arrays with a distinct difference in style of tip between large halo-hairs and small hairy-tip-curly-tip fibres usually have many super-sickles and may or may not have abundant kemp.

Three animals showed one outstanding feature - a very marked faltering or uneven portion in the neck region of the halo-hairs (Fig. 4.d.) which in all three cases was associated with very little later kemp. In the remaining sheep, however, no consistent correlation concerning the neck region could be seen.

In a limited number of lambs, the length of halo-hairs was measured (Table V) and there was found to be great variability in the length of both pre- and post-natal portions but this showed no relationship to variations in amount of kemp. An inspection on the numbers of halo-hairs per 500 total fibres (Table XI) also shows no significance regarding kemp.

Whatever the cause, halo-hairs of the N-type are very variable in abundance and characterisation and are not reliable as a guide for the presence of later kemp.

TABLE \bar{V} *

Lamb No.	Av. length in cms. of halo-hairs			Grade of Kemp Abundance
	Pre-natal	Post-natal	Total	
6	3.5	5.2	8.7	Abundant
7	2.9	6.5	9.4	Little
28	3.1	6.9	10.0	Little
39	3.6	3.3	6.9	Little
44	2.4	5.3	7.7	Abundant
45	2.9	5.1	8.0	Medium
58	3.0	5.9	8.9	Abundant
59	3.7	6.0	9.7	Abundant
60	3.1	6.1	9.2	Abundant
65	3.2	4.1	7.3	Little
67	3.3	4.4	7.7	Abundant
69	3.6	4.8	8.4	Abundant
71	4.3	3.7	8.0	Abundant
73	3.8	6.1	9.9	Abundant
75	3.8	5.3	9.1	Abundant
80	3.2	5.5	8.7	Little
82	4.0	3.3	7.3	Abundant
84	3.4	5.1	8.5	Abundant
87	4.0	4.0	8.0	Abundant
89	3.2	6.1	9.3	Little
128	3.3	5.7	9.0	Medium
135	3.9	5.5	9.4	Little

Lamb No.	Av. length in cms. of halo-hairs			Grade of Kemp Abundance
	Pre-natal	Post-natal	Total	
141	3.0	5.2	8.2	Medium
144	3.6	4.6	8.2	Medium
158	3.2	5.8	9.0	Medium
162	3.6	3.7	7.3	Medium
169	3.6	5.2	8.8	Abundant
177	4.3	4.9	9.2	Abundant
180	3.7	5.0	8.7	Medium
182	3.8	3.9	7.7	Abundant
184	3.8	4.5	8.3	Little
189	4.2	4.8	9.0	Medium
193	3.8	5.8	9.6	Abundant
197	3.2	4.9	8.1	Abundant
198	3.7	4.9	8.6	Little
264	2.9	4.8	7.7	Abundant
209	3.6	4.4	8.0	Medium
231	3.2	4.2	7.4	Medium
267	3.8	5.1	8.9	Abundant

* The figures are approximate as the region of the hair at the time of birth of the lamb cannot always be accurately judged.

It was suggested by Dry (1940) in his early work

on mild Plateau arrays, that abundant G2 kemp may be correlated with free shedding of the super-sickle fibres of type A'. Super-sickle type A' (Fig. 6) is visibly affected by the pre-natal check and since the non-Plateau kemp succession generalisation centred on the checked fibre of the sickle type (Fig. 9), it seemed logical to consider the super-sickle A' which is also visibly checked in the Plateau array.

A detailed count of all the samples showed that only 56 of the 81 samples possessed the super-sickle A' fibre type, and in many of these the numbers of super-sickle A' fibres were few, often only an odd one or two in a sample of 500 total fibres. Hence the freedom of shedding of these birthcoat fibres could not always be accurately judged.

Samples in the groups of kemp abundance, were classified and tabulated according to the freedom of shedding of super-sickle A' fibres (Table VI).

TABLE VI *

	Abundant kemp	Medium kemp	Little kemp
Many super-sickle A' fibres shed. Free shedding.	15	10	15
Super-Sickle A' fibres equally shed and persisting	3	2	2
Very few super-sickle A' fibres shed. Poor shedding.	-	2	7

* The figures in the table refer to the numbers of animals in each group.

This analysis showed many exceptions to the above tentative generalisation, free shedding often being followed by poor G2 kemp. Poor shedding of super-sickle A' fibres is associated with little kemp.

A similar situation was found in the attempt to correlate free shedding of the super-sickle type A and super-sickle type B fibres with secondary kemp. These fibre types were scarce and hence not suitable as key types. Lochner (1931), stated that sometimes heterotype B fibres i.e. halo-hairs and super-sickle type A fibres, do not shed and this fact reduces probability of kemp.

Lambs in the three groups of kemp abundance were classified and tabulated into grades according to the freedom of shedding of the super-sickle A fibres (Table VII) and according to the freedom of shedding of the super-sickle B fibres (Table VIII).

TABLE VII *

	Abundant kemp	Medium kemp	Little kemp
All super-sickle A fibres shed. Free shedding.	20	6	7
Super-sickle A fibres equally shed and persisting	-	3	4
Very few super-sickle A fibres shed. Poor shedding.	-	1	3

TABLE VIII *

	Abundant kemp	Medium kemp	Little kemp
All super-sickle B fibres shed. Free shedding.	10	3	9
Super-sickle B fibres equally shed and persisting	1	3	4
Very few super-sickle B fibres shed. Poor shedding.	-	-	9

The figures in these tables refer to the number of animals in each group.

It is seen that poor shedding of super-sickle type A fibres and super-sickle type B fibres when these are present, is associated with little kemp, but free shedding shows variable results.

The data was further examined to find a generalisation that would be applicable to all Plateau arrays. Dry (1940) has previously noted that on animals studied having much G2 kemp, it nearly always happened that hairy-tip-curly-tip fibres have shed freely.

After detailed counts of fibres in the 81 animals (Table XI), extreme shedding of hairy-tip-curly-tip fibres i.e. more than 45% of the total numbers of hairy-tip-curly-tip fibres was found to be associated with abundant kemp, and when all of these fibres show persistent growth, i.e. no hairy-tip-curly-tip fibres shed, there is little kemp. Cases of intermediate shedding of the hairy-tip-curly-tip fibres,

i.e. from 0-45% of the hairy-tip-curly-tip fibres shed, showed great variation in the amount of kemp (Graph 1). This is more clearly seen in Table IX where the lambs in the three groups of kemp abundance are classified according to the freedom of shedding of the hairy-tip-curly-tip fibres.

TABLE IX

	Abundant kemp	Medium kemp	Little kemp
Hairy-tip-curly-tip fibres freely shed. (More than 45%)	15	1	1
Some hairy-tip-curly-tip fibres shed. (0-45%)	19	16	12
No hairy-tip-curly-tip fibres shed. (All persist- ing)	-	1	16

* The figures in the table refer to the number of animals in each group.

It was noted that among this intermediate group of animals, those with little kemp had very few hairy-tip-curly-tip fibres and those with abundant kemp had many. Counts of samples from all the animals were then tabulated (Table XI) and graphed to show the number of hairy-tip-curly-tip fibres compared with the amount of kemp (Graph II). The correlation was significant, $r = 0.37$, significant at 1% level. (This figure must be accepted with reserve since the classing of fibre types entails qualitative judgement which can scarcely remain constant in the examination of samples differing in numerous details.

An analysis of Graph 11 (Table X) shows that lambs

with more than 31 hairy-tip-curly-tip fibres in 500 total fibres have abundant kemp with 14 exceptions, whilst lambs with few hairy-tip-curly-tip fibres, less than 26 per 500 total fibres, have little kemp, with 3 exceptions.

TABLE \bar{X} *

	Abundant kemp	Medium kemp	Little kemp
Many hairy-tip-curly-tip fibres. (more than 31 in 500 total fibres)	29	16	10
Medium hairy-tip-curly- tip fibres (Between 26 and 31 in 500 total fibres)	2	1	4
Few hairy-tip-curly-tip fibres. (Less than 26 in 500 total fibres)	3	1	15

* The figures in the table refer to the number of animals in each group.

If these exceptional arrays are traced back to their position on the graph of the comparison of kemp with freedom of shedding of hairy-tip-curly-tip fibres (Graph I) it is found that they all lie within the extremes of shedding mentioned above. Eleven of the first 14 lie on the line of no shedding of hairy-tip-curly-tip fibres. All three of the exceptions with few hairy-tip-curly-tip fibres and abundant kemp show exceptionally free shedding of these few hairy-tip-curly-tip fibres.

A generalisation can therefore be stated that when there are a large number of hairy-tip-curly-tip fibres present

in a sample, then abundant G2 kemp is to be expected in the later fleece unless all these hairy-tip-curly-tip fibres are of persistent growth, when there will be little kemp.

When there are a few hairy-tip-curly-tip fibres, little G2 kemp is to be expected unless the majority of these few hairy-tip-curly-tip fibres are shed, when there will be abundant G2 kemp.

Among the 81 lambs in this study, 4 were exceptions to this final generalisation and these are discussed below.

TABLE XI (See Graphs I and II).

Lamb No.	Halo Hairs	G.2. Kemp	H.T. C.T. Shed	H.T.C.T. Persist- ing	H.T. Total Nos.	% H.T. C.T. Shed	No. G2 Kemps per 100 halo-hairs
1935 and 1941							
44	18	30	26	4	30	86.6	166.6
59	24	29	38	19	57	66.6	120.8
73	14	37	14	58	72	19.4	264.3
193	21	33	22	22	44	50.0	157.1
264	24	27	6	57	63	9.5	112.5
1150	33	39	41	34	75	54.7	118.2
6	17	30	1	48	49	2.1	176.5
58	9	20	15	60	75	20.0	222.2
60	21	25	24	28	52	46.1	119.0
67	23	35	10	64	74	13.5	152.1
71	18	25	12	54	66	18.1	138.8
84	26	30	1	29	30	3.3	115.3
87	23	34	28	17	45	62.2	147.8
177	21	25	25	62	87	28.7	119.0
197	21	27	18	55	73	24.6	128.5
169	12	16	13	6	19	68.4	133.3
1157	11	24	9	10	19	47.3	218.2
69	15	36	44	22	66	66.6	240.0
267	22	31	39	19	58	67.0	140.9
182						27.6	148.1

TABLE XI (Cont)

Lamb No.	Halo Hairs	G.2. Kemp	H.T. C.T. Shed	H.T.C.T. Persist- ing	H.T. Total Nos.	% H.T. C.T. Shed	No. G.2. Kemps per 100 halo-hairs
75	21	28	11	77	88	12.5	133.3
82	27	32	7	46	53	13.2	118.5
144	20	22	5	25	30	16.6	110.0
162	22	21	8	26	34	23.5	95.4
189	11	11	14	42	56	25.0	100.0
45	18	19	1	60	61	1.6	105.5
128	13	14	16	72	88	13.1	107.7
158	17	15	8	67	75	10.6	88.2
180	25	22	13	70	88	20.4	88.0
209	19	18	4	48	52	7.7	94.7
1213	13	12	3	76	79	3.7	92.0
1159	29	23	8	32	40	20.0	79.0
1189	17	15	3	75	78	3.8	88.2
1223	11	8	-	31	31	0.0	72.7
141	24	18	-	53	53	0.0	75.0
231	19	15	7	10	17	41.1	78.9
65	18	8	13	10	23	56.5	44.4
7	15	6	1	2	3	33.3	40.0
28	27	13	4	16	20	20.0	48.1
39	23	6	3	22	25	12.0	26.1
89	6	2	6	13	29	31.5	33.3
198	16	10	3	20	23	13.0	62.5

TABLE XI (Cont)

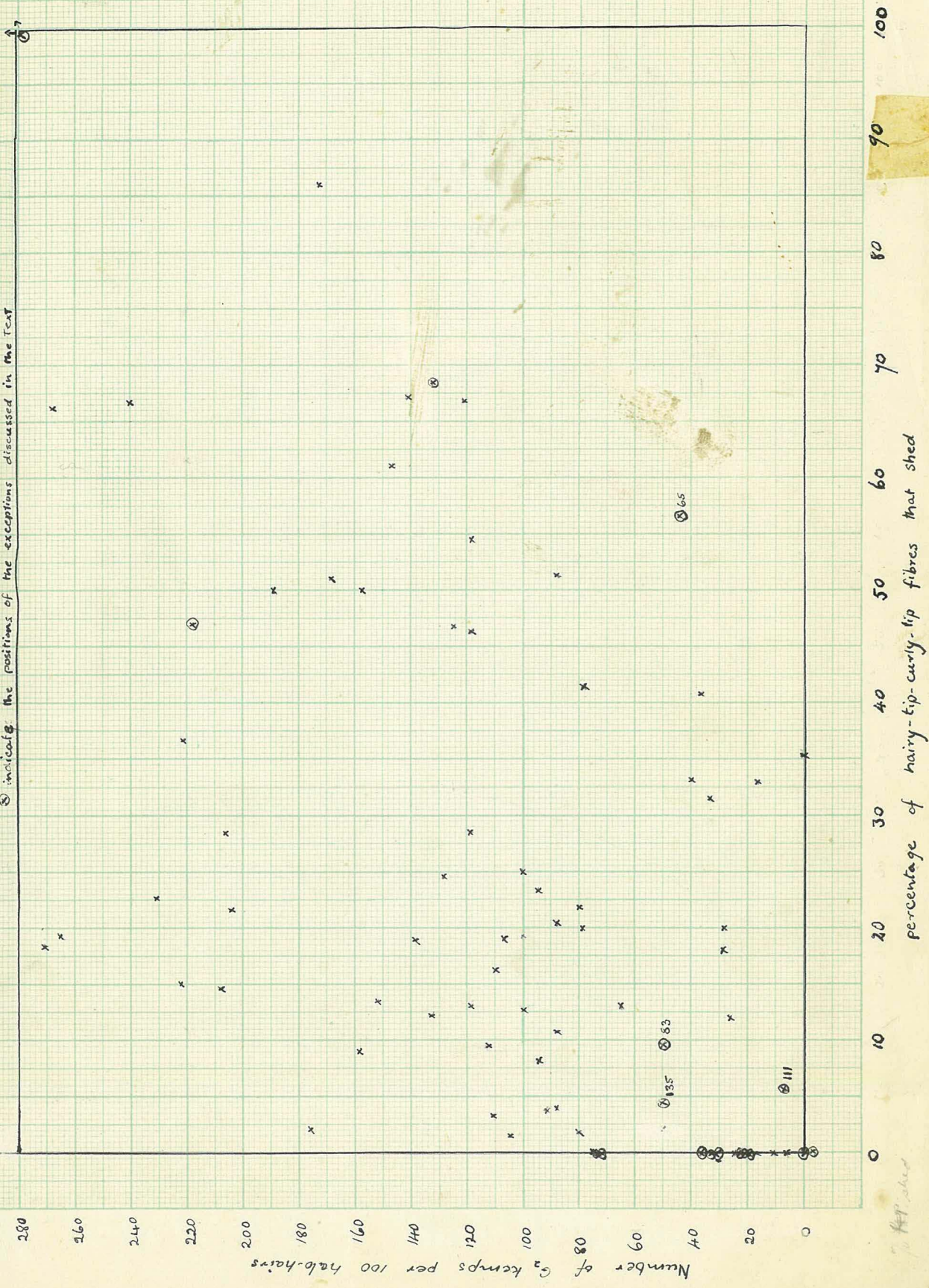
Lamb No.	Halo Hairs	G.2. Kemp	H.T. C.T. Shed	H.T.C.T. Persist- ing	H.T. Total Nos.	% H.T. C.T. Shed	No. G.2.Kemps per 100 halo-hairs
199	6	1	2	4	6	33.3	16.6
1204	8	3	6	8	14	42.8	37.5
80	15	5	-	63	63	0.0	33.3
184	25	8	-	31	31	0.0	32.0
904	19	7	-	28	28	0.0	36.8
1124	6	-	-	41	41	0.0	0.0
31	13	3	-	14	14	0.0	23.1
1219	15	11	-	19	19	0.0	73.3
1229	33	6	-	26	26	0.0	18.2
1173	9	1	-	16	16	0.0	11.1
1175	9	1	-	23	23	0.0	11.1
135	32	16	3	64	67	4.5	50.0
<u>Year 1942</u>							
32	19	36	24	24	48	50.0	189.5
64	22	59	53	27	80	66.7	268.2
96	22	29	31	29	60	51.6	168.1
33	14	29	14	35	49	28.6	207.1
41	16	20	38	43	81	46.9	125.0
54	23	51	32	55	87	36.8	221.7
75	14	38	12	53	65	18.4	271.4
79	12	19	9	90	99	9.0	158.3

TABLE XI (Cont)

Lamb No.	Halo Hairs	G.2. Kemp	H.T. C.T. Shed	H.T.C.T. Persist- ing	H.T. Total Nos.	% H.T. C.T. Shed	No. G.2 Kemps per 100 halo-hairs
80	22	46	9	65	74	12.1	209.0
95	16	37	22	75	97	22.6	231.2
155	23	47	20	72	92	21.7	204.3
49	13	60	13	-	13	100.0	461.5
22	18	16	18	17	35	51.4	88.8
117	15	12	2	107	109	1.8	80.0
62	11	11	25	104	129	19.3	100.0
36	20	16	17	61	78	21.7	80.0
169	27	27	12	82	94	12.7	100.0
154	31	21	-	101	101	0.0	67.7
6	15	-	6	11	17	35.2	0.0
21	7	2	2	9	11	18.1	28.5
83	16	8	8	75	83	9.6	50.0
111	14	1	5	85	90	5.5	7.1
89	23	5	-	75	75	0.0	21.7
160	25	5	-	53	53	0.0	20.0
167	18	4	-	75	75	0.0	22.0
28	18	-	-	34	34	0.0	0.0
86	16	1	-	17	17	0.0	6.2

Graph I. Showing the relationship between the number of G_2 kempfs and the percentage of hairy-tip-curly-tip fibres that shed, on data from 81 lambs. (Table XI).

② indicate the positions of the exceptions discussed in the text



Graph II. Showing the relationship between the number of G_2 kempes and the number of hairy-tip-curly-tip fibres on data from the back of 81 lambs. (Table XI)

⊗ indicate the positions of the exceptions discussed in the text.



DISCUSSION

Many characteristics of the fibre types suggest that shedding can be regarded as a vigorous activity of the follicle and persistent growth of fibres is the result of a check to this vigour. Halo-hairs, which are the fibres with the largest pre-natal region, are the most freely shed, then the other types in order of toughness. Wool fibres which are slower growing, rarely shed.

On many animals, the post-natal length of most of the hairy-tip-curly tip fibres that shed, is longer than the post-natal length of the halo-hairs. It would seem that less vigour has enabled them to persist longer. Non-genetic factors, such as bad environmental conditions which affect and reduce general activity, may also reduce the vigour of the follicles. Poor feeding of pregnant ewes has been associated by Leslie (1935) with a reduction in the abundance of halo-hairs in the birthcoat of their lambs.

In some cases, reduced vigour may cause actual thinning of the hair and wool fibres are produced. It will be shown later in a pre-natal study, that the vigorous fibres which usually shed, have follicles deep in the skin and are much larger than wool-producing follicles.

It is a general rule in the development of the coat of mammals that the earlier the fibres are initiated the larger their size (de Meijere 1894). This principle of initial advantage causing large fibres, is discussed later in a pre-natal study. Late initiation cannot be accepted as the only cause of less vigour and persistence.

Another factor in the restriction of vigorous growth is the pre-natal check. Persistence is thus regarded (Dry 1933) as one of its manifold effects. A fibre may be restricted by the check before birth and show little or no effect in hairiness, yet three months later, instead of shedding it will persist.

There is a correlation between the amount of shedding of the sickle-fibres and the amount of later kemp in non-Plateau arrays (Dry 1940). The sickle-fibres are given their characteristic form by the check, hence we are led to consider the pre-natal check to be an important force in determining shedding or persistence.

In these studies of Plateau arrays, it has been difficult to regard persistence as due to any one of the above causes, but the pre-natal check probably plays a large part.

The association between kemp and numbers of hairy-tip curly tip fibres means that kemp is most frequent when the fibres have grown most vigorously before birth, i.e. when there are many fibres with hairy pre-natal regions. Any reduction in

the number of hairy-tip-curly-tip fibres would indicate reduced vigour caused by some check. It has been noticed also, that abundance of kemp has been associated every time with those features that indicate a "tough" array or a weak pre-natal check such as the absence of super-sickle fibres, no reduction in the numbers of halo-hairs on the withers, and a precipice along the array. It was thought then that the pre-natal check may determine the number of hairy-tip-curly-tip fibres in an array and if this were so, the number of hairy-tip-curly-tip fibres would be an indication of toughness.

Lambs in the three grades of numbers of hairy-tip-curly-tip fibres were classified and tabulated according to the toughness of the array (Table XII).

TABLE XII *

	Many H.T.C.T.	Medium H.T.C.T.	Few H.T.C.T.
Very tough array No super-sickle fibres	14	-	-
Tough array Odd super-sickle "	11	-	-
Mild array Many super-sickle "	25	4	4
Very mild array Many super-sickle " and odd sickle fibres	5	3	14

* The figures in the table refer to the number of animals in each group.

In all the arrays with few hairy-tip-curly-tip fibres, there are many super-sickle fibres, so that all these arrays are mild.

Of the 55 arrays with many hairy-tip-curly-tip fibres, 30 have many super-sickle fibres and the remaining 25 comprise the toughest group with no super-sickle fibres. Hence all the very tough arrays have many hairy-tip-curly-tip fibres.

It was previously stated above that a judgement of the toughness in a Plateau array with many super-sickle fibres was difficult, but a count of the numbers of hairy-tip-curly-tip fibres may be taken as a guide.

Proceeding a step further, it is possible to state that very tough arrays with no super-sickle fibres are very weakly checked and have abundant G2 kemp. Less tough arrays with many super-sickle fibres but many hairy-tip-curly-tip fibres are somewhat checked but still have abundant G2 kemp. Mild arrays with many super-sickle fibres and few hairy-tip-curly-tip fibres are more checked than the above cases and have little G2 kemp.

From Table XIII in which the lambs in the three grades of numbers of hairy-tip-curly-tip fibres are classified according to the presence or absence of a reduction of halo-hairs on the withers, it is seen that the great majority of lambs with many hairy-tip-curly-tip fibres show no reduction in the

number of halo-hairs on the withers, and most of those with few hairy-tip-curly-tip fibres show a marked reduction. Again there appears to be a close association between the number of hairy-tip-curly-tip fibres and the toughness of the array.

TABLE XIII *

	Many H.T.C.T.	Medium H.T.C.T.	Few H.T.C.T.
No reduction	36	4	2
Slight reduction	13	1	4
Marked reduction	6	2	13

* The figures in the table refer to the number of animals in each group.

The amount of G2 fibres shed thus appears to be influenced by the pre natal check, but there must be other factors concerned other than the pre-natal check since in a few cases, even with many hairy-tip-curly-tip fibres, there is little kemp i.e. when all the hairy-tip-curly-tip fibres are of persistent growth. It is difficult to believe that the pre-natal check has influenced the hairy-tip curly-tip follicle just enough to prevent it from shedding the fibre yet not enough to change its pre-natal characterisation. If this were so it is difficult to see why some plain curly-tip fibres without hairy-tips are often shed. Sickle-fibres too, which visibly show effects of the check may be shed in non-Plateau array.

In discussion on his non-Plateau succession general-

(1940)

isation, Dry considers the pre-natal check to influence shedding of the sickle-fibres. A survey was made of the borderline arrays between Plateau and non-Plateau i.e. those arrays with sickle fibres present, but with halo-hair abundance approaching that of Plateau array. There were 9 of such arrays in the material studied. Both the non-Plateau and the present Plateau generalisation for later kemp, applied in these cases with one exception, a Saddle array, which followed the non-Plateau but not the Plateau rule. This lamb, No. 20 '41, had few hairy-tip-curly-tip fibres, 7 in 500 total fibres, with two of these shed. There was however, much G2 kemp. Therefore on the Plateau generalisation little G2 kemp was expected. Not only were there a few hairy-tip-curly-tip fibres but also many ordinary curly-tip fibres shed, showing that the shedding of the curly-tip fibres as a whole was remarkably free.

A consideration of the exceptions to the above Plateau generalisation, showed that many of them can be explained on the facts of vigour just discussed.

Lambs 135, 111 and 83, in spite of having many hairy-tip-curly-tip fibres and some shedding of these, still have little kemp. The nature of the halo-hairs here shows signs of reduced vigour. No. 135 has a decided thinning in the pre-natal region of the halo-hairs (Fig. 4.f.). In No. 111 the halo-hairs grow for a long period after birth before shedding, which perhaps indicates that the follicles have not

sufficient vigour to shed earlier and hence not sufficient vigour to shed their succeeding fibres. The tips are also small and tend to the hairy-tip-curly-tip style. The halo-hairs of lamb No. 83 are unusually small before birth and could almost be classified as super-sickle type A. All these exceptions therefore show signs of reduced vigour and it is not surprising that there is little G2-kemp.

Lamb No. 65 showed very few hairy-tip-curly-tip fibres and even though the majority of these are shed there is still little kemp. This is classified as a mild Plateau array with many super-sickle fibres and these are shed freely. There is a gradual reduction in hairiness down the array series which suggest little latter kemp, and no reduction in halo-hair abundance on the withers, which suggests abundant later kemp. Shedding of the hairy-tip-curly-tip fibres is freer than is expected in an array with little G2 kemp.

These exceptions again show that the amount of G2 kemp although largely influenced by the pre-natal check, must be determined by many different forces. It is concluded that the amount of pre-natal check as judged by the numbers of hairy-tip-curly-tip fibres in a sample may roughly indicate the amount of later kemp expected but for a more accurate determination of kemp, the shedding of these hairy-tip-curly-tip fibres must be taken into account as in the final generalisation.

The fact that kemp is associated with the presence of many hairy-tip-curly-tip fibres and also with a tough array is important, since it supports the belief that the presence of abundant kemp in the fleece is inherited. The difference between Plateau and non-Plateau arrays depends on the "toughness" of the array i.e. the presence or absence of checked fibres, sickle and super-sickle fibres, and in breeding experiments, these differences are found to be inherited. Genetic factors are also concerned in the difference between the fibre-type arrays, Saddle and Valley, within the non-Plateau group (Dry 1940). Since this difference between arrays is inherited, it is logical to believe that differences of toughness within the Plateau array are also inherited and hence it should be possible to breed for a non-kemp condition in an N-type sheep.

- 30 -
SUMMARY.

Several generalisations for early recognition in the lamb of later kemp in the fleece have been reviewed and the application of each has been shown to be inadequate. A more detailed study has shown that the presence of later kemp can be determined roughly at birth of the lamb by the abundance of hairy-tip-curly-tip fibres present, and a more accurate prediction can be made three months after birth when these hairy-tip-curly-tip fibres are shed.

A small number of hairy-tip-curly-tip fibres has proved to be an indication of a mild Plateau array, and large numbers of hairy-tip-curly-tip fibres are present in all very tough arrays. It is considered possible to breed for a non-kemp condition in an N-type sheep.

LITERATURE CITED.

- DRY, F. W. 1933 The Pre-Natal Check in the Birthcoat
of the New Zealand Romney Lamb.
J. Text. Instit., 24 (4): T161-T166.
-
- 1933 Hairy Fibres of the Romney Sheep.
~~Halo-Hairs and their Inheritance.~~
N. Z. J. Agric., 46 : 10-22.
-
- 1934 Hairy Fibres of the Romney Sheep.
Fibre-Type arrays.
N. Z. J. Agric., 48 : 331-343.
-
- 1940 Recent Work on the Wool Zoology of
the New Zealand Romney.
N. Z. J. S. & Tech., 22 (4A) ;
209A-220A.
- LESLIE, A. 1935 The Frequency of Distribution of
Halo-Hairs in Lambs of Poorly and
Well-Fed Ewes.
Cant. Agric. Coll. Lincoln, N. Z.
- LOCHNER 1931 The Development of the Black-faced
Fleece.
Ph.D. Thesis., Edin. Univ.
- de MEIJERE, J. C. H. 1894 Über Haare der Säugetiere besonders
über ihre Anordnung.
Morph. Jb., 21 : 312-424.
- SUTHERLAND, J. A. 1939 A Study of Plateau Array.
M.Agr.Sc. Thesis. Univ. N. Z.

PART II

PRE-NATAL DEVELOPMENT OF THE N-TYPE BIRTHCOAT.

---oOo---

INTRODUCTION

Many descriptions of the development of the single follicle and its accessory structures in the skin have been given in the literature and the N-type Romney coat is found to follow the normal course.

It will be shown that the standard follicle types (Wildman and Carter 1939) and their arrangement into groups in the skin (Carter 1943), is similar in the N-type and in the non-N-type fleeces, but the fibre types these follicles produce are very different in the two types of fleece (Dry 1933). Thus it is the aim of this study to investigate the physiological factors concerned in the production of different fibre types from the various standard follicle types. Histological stages in the development of a single follicle are only briefly surveyed, the study dealing mainly with the effect on the coat of the follicles as a group, the physiological factors of growth, the relative timing of the developmental stages and the mechanical effects of density and size of the follicles.

The importance of these factors in follicle development on the nature of the fleece as a whole, was first recognized by Duerden and Ritchie (1924) who observed a group arrangement of follicles in the foetal skin of the South African Merino. De Meijere (1894), in his classical work, is

the founder of the fundamental trio group in the foetal skin. The importance of the follicle bundle in determining staple form was further emphasized by Duerden (1939) in his comparison between British breeds. A comparison of sheep with other primitive mammals is discussed by Gibbs (1938).

Wildman (1932) studied differences between early development of follicles of wool and hair producing areas, suggesting that follicles that will produce hairy fibres are initiated early, and follicles destined to produce wool fibres appear later in the skin and in larger numbers. Galpin (1935, 1936) compared stages in follicle development with rates of growth of the skin and considered a sudden increase in rate of skin expansion would have a profound effect on the follicles causing more vigorous growth, and hence the production of hair in place of wool.

Carter (1943) has stressed the great importance of the follicle group, stating that follicle arrangement and density are important factors on the resulting fibres. The size and shape of the follicle papilla were features studied by Rudall (Unpublished) and which were thought to be related to the type of fibre produced.

It was found necessary (Dry 1933) to postulate some inhibiting force to explain the differences in fibre types of the fleece, and the name pre-natal check was given to an assumed restricting force acting before birth. The influence of this check is visible in the fine neck or pre-natal

region of the sickle-fibres and in the fineness of the tips of the curly-tip fibres. Sickle-fibres and curly-tip fibres may be fine in the post-natal region and this is considered to be a delayed effect of the pre-natal check. Persistent growth of birthcoat fibres is another result of this force. In one case sweat glands of a checked curly-tip fibres were lacking and the pre-natal check is thought to be responsible for this (Dry 1933 quoting Hefford). For a study of the above factors causing differences in follicle growth, the development of the N-type fleece consisting of known fibre types namely abundant halo-hairs and super-sickle fibres etc. (Fig. 1) is compared with the development of the non-N-type studied by Carter (1943) and Galpin (1935).

It is understood that the foetuses studied by Carter and Galpin may have been destined to have some halo-hairs on the main area of the body (Fig. 3) but certainly not approaching N-type abundance.

The differences between the post-natal coats of N-type in this study and non-N-type Romney sheep are known from breeding experiments to be inherited, the N-type being determined by a single dominant gene (Dry, McMahon and Sutherland 1940). Thus as the animals studied by Carter (1943) and Galpin (1935) are non-N-type, the differences in early development observed between N and non-N-type in this study will be of a genetic nature and the forces determining this

difference and making the coat of N-type character, will show something of the mode of working of a dominant gene. Rates and timing figure prominently in the physiological theory of the gene (Ford and Huxley 1927, Goldsmidt 1938) and in the present study they are shown to be important.

MATERIAL AND METHODS.

Thirty-seven New Zealand Romney N-type foetuses obtained by Dry, in known stages of development (dated from service) were studied. The male parent of them all was the same dominant N ram who had been proved by his breeding performance to be homozygous. The birthcoat was therefore destined to be coarse and hairy in having abundant halo-hairs.

This study on "pedigreed" material was made possible by the breeding work on the experimental stock of N-type sheep founded upon a single ram of N-type character which was shown to be conditioned by a single dominant factor for which he was heterozygous. This ram, born in 1931, was given to the Massey College by Mr. N. P. Nielsen, after whom, in the initial letter "N", the type is named.

Twenty-four foetuses have been stored in formol-saline for some years and much washing of skin snippets was necessary before staining. Many had hardened and had precipitated opaque substances in the skin which prevented the penetration of stain in bulk samples. Thirteen fresh foetuses were obtained, washed and placed in formol-saline, the latter solution being changed after twenty-four hours.

For a comparison of the times of follicle initiation, skin snippets were taken from the nine standard positions (Galpin 1935), the poll, ventral and dorsal neck, stomach,

brisket, withers, britch, side and back. The back is the standard position from which the post-natal wool samples were taken. The side is the standard position, mid-side or lateral thoracic region, studied by Carter (1943).

In general, the histological technique was that described by Carter (1939) with special care to keep the skin snippets orientated horizontally. Much of the material available for this work had been preserved for a long period and was already contracted and rather folded so that flattening of the skin snippets under a glass slide was more practicable than impaling them on needle blocks. Sections were cut at 6 microns in a series parallel to the surface of the skin and stained with haematoxylin and eosin. In some cases, vertical sections were also made. Bulk samples of the very early stages were stained with haematoxylin and eosin.

STAGE OF FOLLICLE INITIATION.

According to previous theories, coarse hairiness of early fibres is attributed to an early initiation of their follicles. Thus they were thought to be well established before the pre-natal check becomes powerful or before the main fibres of the fleece crowd them.

Galpin (1935) reports the first appearance of follicles on the poll at 49 days and on the whole surface at 56 days. Carter (1943) finds the first signs of follicle anlagen in the most advanced regions, poll and face, as early as 35 to 40 days and follicles are established over the whole surface not later than 55 to 60 days.

Skin snippets were examined from nine different body regions of the N-type foetuses in very early stages. The earliest stage at which follicles were recorded was 49 days when primary X follicles were found on the poll and neck regions. At 59 days primary follicles covered all the areas examined; the poll, ventral and dorsal neck, stomach, brisket, withers, britch, side and back. On the most advanced region, the poll, primary Y follicles were also recorded. The time of initiation of follicles in the N-type (Table 1) was thus found to agree with that given by Galpin (1935) and Carter (1943) for finer-woolled sheep. The coat of the hairy N-type fleece (on this investigation) does not begin to grow earlier than that of the finer fleece.

TABLE 1.

EARLY STAGES OF DEVELOPMENT ON DIFFERENT AREAS OF THE N-TYPE FOETUS AT DIFFERENT AGES.

Age of Foetus Days.	Poll Area A.	Ventral Neck Area B.	Dorsal Neck Area B.	Stomach Area C.	Brisket Area C.	Withers Area D.	Britch Area D.	Side Area D.	Back Area E.
42	-	-	-	-	-	-	-	-	-
49	X	8 X	3 X	2	-	-	-	-	-
55	X+Y	34 X	20 X	5 X	2 X	2	-	-	-
59	X+Y	50 X+Y	30 X	13 X	20 X	22 X	5 X	3 X	2 X
62	XX+Y			X	20 X+Y	X	23 X	30 X+Y	20 X
63	XX+Y			X+Y	X+Y			X+Y	X+Y
66								X+Y	X+Y
68								X+Y	X+Y

The numbers in the Table refer to the approximate number of follicles present in

1 sq. mm. of skin.

FURTHER STAGES OF FOLLICLE DEVELOPMENT.

Complete descriptions of the development of a follicle have been given by many writers, but few have compared the age of the foetus at which these stages occur. Carter (1943) tabulates the stages in follicle development and the age of the foetus, and his table is used for comparison (Table 11).

TABLE 11

THE RELATION BETWEEN FOETAL AGE AND THE STAGE OF DEVELOPMENT
OF THE FOLLICLE GROUP IN THE N-TYPE ROMNEY AND ON THE NON-N-
TYPE MERINO

Age of Foetus	Stage of Development of follicle group in N-Type	Stage of Development of follicle group in Merino (Carter 1943.)
59	Primary X follicles	Primary X follicles
62	Primary X follicles	
63	Primary X follicles	
66	Primary X and early primary Y follicles	
68	Primary X and primary Y follicles	Primary X and early primary Y follicles
71	Primary xX and Y follicles	Primary X and Y follicles
72	Primary xX and Y follicles. First signs of sudorifer- ous gland in the large primary foll- icle	
74	xxX and / follicles	Primary xXx and y follicles

TABLE 11 (Cont.)

Age of Foetus	Stage of Development of follicle group in N-Type	Stage of Development of follicle group in Merino (Carter 1943. 20)
75	xXx and yYy - Trio	
76		
78	Trio well established. Sudoriferous glands with all members of trio.	
79		Sudoriferous glands seen with all members of trio.
81		
82	Trio well advanced.	Primary (central trio) sebaceous glands appear.
86	Sebaceous glands with central trio follicles.	First secondary follicles appear.
88		
90		Primary (lateral trio) sebaceous glands appear.
92	Secondary follicles. Primary X (central trio) fibres and muscle arrector pili forming. Hair canal forming in primary follicles.	
95		
96	Hair canals. Lateral trio fibres and muscle arrector pili forming.	Primary (central trio) fibres and muscle arrector pili forming.
98		Primary (lateral trio) fibres and muscle arrector pili forming.

TABLE 11 (Cont.)

Age of Foetus	Stage of Development of follicle group in N-Type	Stage of Development of follicle group in Merino (Carter 1943. 20)
99		First secondary sebaceous glands.
100		Primary fibres at level of hair canals.
102		Primary (central trio) fibres emerge.
104	Primary (central and lateral trio) fibres emerge.	
106		Primary (lateral trio) fibres emerge.
113	Secondary fibres well formed. Ratio primaries to secondary : follicles 2.6-3.0	
115		Secondary fibres forming. Ratio 1.0-2.9
119	Early secondary fibres pierce the epitrichium. Ratio 3.0-3.6	
134		Early secondary fibres pierce the epitrichium. Ratio 3.0-3.9.

This study is concerned mainly with the side region.
on the side

Follicles are initiated at 59 days of foetal development and at this time are scattered in small numbers over the area, about 2 follicles per square millimetre of skin. They continue to appear gradually in the skin until at 66 days follicles

of varying sizes are seen (Fig. 14). The larger or first formed follicles are called primary X, and the smaller follicles are called primary Y but there is no sharp distinction between the two groups as Galpin (1935) described in the New Zealand Romney.

The early development of the follicles follows the normal course described by previous writers and is an aggregation of cells in the Malpighian layer which grows obliquely down into the mesoderm connective tissue.

Primary x follicles appear at 72 days when the first signs of sudoriferous glands are also seen in the large primary X follicles. These glands are simple bag-like structures, not coiled as in the Merino. Primary y follicles follow soon after this to complete the trio stage at 75 days. The trio consists of follicles arranged as xXx and yYy and marks a definite period in the development of the follicles. Primary X follicles are large, 50 microns in diameter, at the trio stage (Fig. 15) and the primary y follicles are about 40 microns but there have been no measurements of trio follicles at this stage in non-N-type for comparison. It was observed, however, that these trio follicles were much smaller and more numerous on the side than those at a corresponding stage on the poll region of the N-type foetus. As the trio period advances, the linear arrangement of follicles becomes marked.

Bilobular sebaceous glands appear first in the central trio (primary X and Y) follicles at 86 days (Fig. 16), then later in the lateral trio (primary x and y) follicles before 92 days.

The next stage, 92 days (Fig. 17), shows a marked advance; post-trio or secondary follicles, usually two, often three in one trio group, are present, and an arrector pili muscle is seen associated with the central trio follicles, the fibres of which are well formed. A hair canal is also present in these large follicles.

The development of the hair canal can be traced from the sebaceous glands and follows the course described by Wildman (1932). At 92 days there appears some degeneration of cells occurring at the mouth of the funnel of the sudoriferous duct (Fig. 18) until at 96 days the hair canal is clearly seen with the funnel of the sudoriferous duct opening into it (Fig. 19). Before the stratum corneum is ruptured the canal is deflected along just below the surface. The central trio follicles have grown deeper into the corium during these stages and each has a large papilla and bulb. The fibre in the lateral trio follicle is soon formed and at 96 days has an arrector pili muscle associated with it. At 97 days (Fig. 20) the follicle trios are packed closely in rows with large spaces between the lines while the growing tip of the fibre of the central trio follicle is near the level of the sebaceous gland.

In the next stage available, 104 days, the fibres

^{the}
of central trio follicles are well through the skin. Lateral trio fibres also have emerged (Fig. 21). Many secondary follicles have been added and more are being separated from masses of darkly staining ^{primordial fibrogenetic} ~~meristematic~~ tissue, ^{the} mode of their formation being similar to that described by Duerden (1932)

Bands of connective tissue mark off the follicle bundles very distinctly at 113 days (Fig. 22). These strands are more marked between the rows of bundles than between adjacent bundles while the latter retain their linear arrangement. The first formed secondary fibres have grown rapidly and in many cases are near the surface of the skin. The great size of the large primary fibres seen in cross-section is in a striking contrast to the small fibres, since at this stage Carter (1943) illustrates primary fibres to be very little different in dimensions from the secondary fibres. The great irregularity in size of fibres, so well illustrated in the different fibre types of the N-type birthcoat, is marked even at this early stage. Also the size of sebaceous glands is smaller than Carter indicates (Carter 1943).

At 119 days (Fig. 23) the skin contains bundles of tightly packed follicles. Primary trio follicles have grown large fibres, ^{the accessory structures} ^{are well developed} sudoriferous gland, arrector pili muscle and sebaceous glands, and secondary follicles are rapidly differentiating from secondary primordial tissue. The fibres of the first formed secondary follicles with sebaceous glands

are piercing the skin.

The development of the coat on the back region was also examined and the characteristic features of each stage appeared to be no different from those found on the side. The latter however, was slightly more advanced (about 2 days) throughout the stages examined.

between
A COMPARISON [^] THE TIME OF DEVELOPMENTAL STAGES

IN THE COAT OF N AND OF NON-N-TYPE..

The length of the pre-trio period from the time of the initiation of the first follicles, at 59 days, until the complete trio is formed, at 75 days, is approximately 16 days.

The trio period begins with the formation of the trio arrangement of the primary follicles and is regarded as a distinct stage in development. The time of the first appearance of secondary follicles which marks the completion of the trio period has not been defined in the N-type material available.

They are ~~not~~ recorded ^{to be} well formed at 92 days which suggests that they were first initiated several days earlier. However, they certainly are not present at the 86 day stage when they are recorded in the Merino, nor at the 88 day stage. On the limited N-type material ^{available} the reality of this delay in appearance of secondary follicles cannot be tested. The duration of the trio period is then approximately estimated to be seventeen days, about the same length as the pre-trio period.

The duration of the early stages or primary phase of follicle development, the pre-trio and trio periods, therefore correspond with those found by Galpin (1935) and Carter (1943) for non-N-type sheep. (Table 11).

At 96 days, soon after the completion of the trio period, the fibre in the central trio follicle is seen at the

level of the sebaceous glands, so that the time required for formation of the complete primary follicle with its accessory structures is 37 days. Lateral trio fibres follow soon afterwards, two days before their formation in non-N follicles. There is thus a suggestion that growth in N-type is more rapid at this stage. Since the hair canal in large primary follicles is just below the stratum corneum at 97 days and the tip of the growing fibres follows ^{of the fibres} emergence through the skin probably takes place shortly after this stage. At 104 days they are well through the skin, the length of fibres above the surface, 850 microns, being about equal to that below in the follicle. Lateral trio fibres are also through the skin at this stage (Fig. 21).

The primary fibres once they are formed, appear to grow at a greater rate in N-type than in other foetuses during the post-trio period. Emergence of primary fibres is at least two days sooner than Carter (1943) has recorded and is seven days earlier than Galpin (1935) ^{shows.} Galpin notes fibres piercing the skin at 111 days stage. However, owing to the necessarily limited number of foetuses available, confident conclusions on this point of rapid growth of primary fibres cannot be drawn.

Early secondary fibres, well developed at 113 days, are approaching the surface of the skin and hence appear to require less than 21 days for complete formation. This is 10 days shorter than the time recorded for secondary follicle

formation in the Merino. Emergence of the earliest secondary fibres at 119 days is also markedly earlier than in the Merino. The rate of growth of the follicles of the post trio period is thus ~~very rapid in N-type~~.

When the foetal age is tabulated with the stages of follicle development in N-type and compared with that in non-N-type (Table 11) there is seen to be a close correspondence in all the early stages of ~~these two~~ types but after the 88 day stage the N-type coat grows more rapidly being slightly more advanced (2 days) at 92 days, 96 and 104 days, and markedly (15 days) more advanced at 113 and 119 days, than the non-N-type coat.

DENSITY OF FOLLICLES AND PROPORTION OF FOLLICLE TYPES.

Terentieva (1939, finds two periods of intense formation of hair-producing rudiments on the side region of the Russian Merino, the Askanian Rambouillet; the first ^{is} at 75 days at trio formation, then at 120 days there is a new intensification in the formation of hair rudiments. Carter (1943) also emphasizes the presence of a peak in follicle population at 120 days.

At initiation, the follicle population in N-type is sparse, new follicles appearing gradually, until at 63 days before the primary Y follicles appear, there are 46 follicles per square mm. of skin. The previous writers give no measure of density for non-N-type at this stage. On the poll region of N-type, at the same stage (59 days) there are only 29 follicles per square mm. but the latter are much larger. Post-natal data on sample of wool from non-N-type (Galpin 1936) and from a small number of N-type sheep, show that the fibre types present on the poll are more checked, smaller and less hairy than those of the back and side positions. The fact that the size and density of follicles differs at initiation in these regions may thus be significant in determining post-natal features.

At the trio stage, 75 days, they also appear to be more thickly populated on the side than on the poll at the same stage, 63 days.

Follicles at the 113 and 119 day periods appear to be greatly packed but it is considered unlikely that this is the result of an inrush of secondary follicles since the

large size of the primary fibres leave very little room in the follicle bundle for an intense development of secondary follicles (Fig. 23). A quantitative determination of density would require accurate technique to avoid the shrinkage and folding of the skin which was marked in the material available for these observations.

Wildman (1932) stated that on hair producing areas, the face and lower limbs, the major part of the total follicle population consists of primary follicles. Carter (1943) found that such a population did not occur in the body regions and even in the primitive Mouflon the secondary follicles far outnumbered the primary follicles.

The proportion of primary and secondary follicles in the skin is expressed as a ratio of primary follicles, P , to the total population, $P+S$, at 113 days. When the first formed secondary follicles are approaching the surface of the skin the ratio ($\frac{P+S}{P}$) is 2.6-3.0 and at 119 days after the secondary follicles have pierced the skin the ratio is 3.0-3.6.

The Merino skin at a similar stage of follicle development, at 134 days, shows a higher ratio, 3.0-3.9, indicating the presence of more secondary fibres, ^{then in N-type,} but the difference is not significant. The fact that the N-type ratios are higher than those of the Merino at the same foetal age (Table 11) shows that secondary follicles appear more rapidly in the N-type skin.

Since Carter (1943) noted that the solitary and
(Figs 20, 22, 23)
couplet primary follicles assume greater dimensions than the
two types of primary follicles during pre-natal development,
it was thought that there may be a greater proportion of these
types in N-type than in finer breeds. Counts from the skin
at four post-trio stages show that the proportion of solitary
and couplet follicles to primary trio follicles was between
9-13%. They are definitely in the minority and primary trio
follicles form the fundamental follicle group in N-type. The
composition of the follicle group does not appear to differ
significantly from that of the non-N-type.

RELATION BETWEEN FOLLICLE TYPES AND FIBRE TYPES.

A standard classification of the follicle types of the foetus has been given by Wildman and Carter (1939).

Follicles appearing in the pre-trio and trio phases are primary follicles with sudoriferous duct, arrector pili muscle and sebaceous glands. Those appearing during the post-trio phase are secondary follicles which may possess a sebaceous gland but otherwise lack accessory structures. Fibre types of the N-type lamb

at birth are classified by Dry (1934) :- halo-hairs, super-sickle-fibres, sickle-fibres, hairy-tip-curly-tip fibres and curly-tip fibres and they are distinguished by the form of their pre-natal region (Figs. 4-9).

It is highly desirable to know which type of follicle grows each particular fibre type but on present material this relationship cannot be worked out completely.

On post-natal studies Sudall (Unpublished) has reported the presence of sweat glands, sebaceous glands and arrector pili muscle to be associated with halo-hairs, fibres of the sickle group and some curly-tips. It is concluded from this that these fibres are produced from the primary follicles ^{above} which, from the classification, are known to possess accessory structures.

An examination was made of the style of tip of fibres above the skin on the side and back regions at 113 and 119 days (Fig. 24). At 113 days four main types of tips were recognized. The largest tips with a long unmedullated apical region, are characteristic of halo-hairs. The shorter, straight tips with

medulla extending almost to the extreme end are like the super-sickle tips. Small curved tips, with a little medullation at the base, are clearly those of hairy-tip-curly-tip fibres. Finally there are very small tips with no medulla like ordinary curly-tips, but these latter may become hairy at a later stage. As the secondary fibres have not pierced above the skin at 113 days, the fact that these fibres are found well above the skin is evidence that they are from primary follicles. Hairy-tip-curly-tip fibres arising from primary follicles are in this way comparable to the super-sickle fibres as their appearance on the foetal skin is often just as early as the super-sickle fibres. They therefore properly belong to the pre-curly-tip group (halo-hairs, super-sickle and sickle-fibres) in the classification of fibre types and this fact, which has bearing on the importance of hairy-tip-curly-tip fibres in an early judgement of a kempy fleece is discussed later.

In the N-type coat, hairy-tip-curly-tip fibres may have very hairy tips, then there is often a sudden reduction in the hairiness along the series of fibres in the array to plain curly-tip fibres without a hairy pre-natal region, but it is not yet determined whether this sudden reduction in tip hairiness marks the line between the production of fibres from primary and from secondary follicles.

From these facts it is concluded that primary

follicles produce halo-hairs, fibres of the sickle group
hairy-tip-curly-tip fibres and perhaps some curly-tip fibres;
secondary follicles produce the remaining curly-tip fibres
which make up the bulk of the birthcoat.

DISCUSSION.

It has been important to note in this study that both hairy-tip-curly-tip fibres and fibres of the sickle group arise from similar follicle types, the primary follicles, and appear at the same stage in foetal development. This fact emphasizes the relation between these two fibre types which has already been suspected after a study of kemp succession in the Romney fleece. For early recognition of a kempy fleece (Dry 1940) found the sickle-fibres to be key types in the non-N-type fleece, and in this study of the N-type coat, hairy-tip-curly-tip fibres are found to be the determinate types. Prominence comparable with that previously given to sickle-fibres in the non-N-type fleece, should therefore be given to the hairy-tip-curly-tip fibres in the N-type coat.

The belief that the coat of the N-type sheep began its growth much earlier than that of the non-N-type has formed the basis of much speculation. Wildman (1932) considered the extra vigour of hairy fibres to be the result of early initiation of the hair-producing fibre. This was modified in the view that a force acting later, pre-natal check, (Dry 1933) causes a depression in vigour. It is thought that an early start would enable a fibre to become firmly established to withstand this depression. Since the coarse fibres of N-type are found

to arise at the same stage in foetal life as the less hairy fibres of non-N-type, this cannot be the main factor in development responsible for fibre differences.

The most striking difference between N-type and non-N-type in the development of the coat, is the rapid rate of growth of follicles in N-type after the 92 day stage of foetal development. The capacity of the fibres to grow as a result of a rapid rate of skin expansion is one explanation of its extra vigour. Galpin (1936) in a study of relative growth rates, reported a slight depression in the rate of skin expansion at about 86 days.

A relatively low rate of skin expansion at this stage, and a greater density of follicles produces a crowding effect resulting in a reduction of follicle activity. Carter (1943) describes an exuberant development of secondary follicles at the beginning of the ^{period which continues until} post-trio, until the density of the total follicle population rises to a peak at 120 days. There is then intense overcrowding for a brief period, until an increase in the rate of skin expansion allows a greater growth of connective tissue between the follicles.

If it is intense overcrowding which depresses the follicles it is difficult to see why the fibres are smaller and less vigorous before the 120 day stage than corresponding fibres in N-type. Also this stage in N-type would be expected to show less overcrowding, since the first fibres are not depressed by

the check and produce hair, when on the contrary, the skin is tightly packed. The very large fibres ~~themselves~~ present in the follicle bundle at 113 days and 119 days appear to fill a large proportion of the bundle and they alone seem to cramp the secondary fibre tissue and even the sebaceous glands.

As far as can be seen, follicles are added at a uniform rate. On material available, irregular periods of follicle formation suggested by other writers (Terentjiva 1939 and Carter 1943) have not been observed.

The constituents of the individual follicle bundle in N-type show great differences in size. The large primary fibres, particularly those of the central trio are in striking contrast to the small secondary fibres. These extremes of vigour within the same bundle, are marked when the fibres are compared with those in finer breeds illustrated by Carter (1943). The irregularity and unevenness of the N-type fleece shown in the great differences between the large hairy birth-coat fibres and the finer curly-tip fibres is thus seen at an early stage.

The "nine" stage described by Galpin (1935) and questioned by Duerden (1939) has proved to be a false group consisting of three adjacent trios. Carter (1943) has explained that if a "nine" group existed, the majority of fibres in the fleece of the Romney would be primary fibres and shows that in no sheep does this occur. The present study on N-type

New Zealand Romney foetuses has supported these observations of Duerden and Carter. There may be more primary follicles present in the N-type coat but certainly no "nine" stage.

Duerden (1939) states that fine wool fibres have a different origin from kemps, all growing from secondary follicles. Now there have been found some fibre-type arrays without any pre-curly-tip fibres (halo-hairs, super-sickle and sickle-fibres) at all, the coat consisting only of non-medullated curly-tip fibres e.g. in the Wensleydale fleece. Since most curly-tip fibres probably arise from secondary follicles in N-type, it is wondered if such an array of fibres can be produced from secondary follicles only. On the results of this study this seems doubtful for the following reasons. Secondary follicles arise at a late stage in development and it has been shown that the fine coat does not begin its growth later. The early follicle arrangement in groups appears to be fundamental in mammals, particularly the trio stage. The follicle group on the skin of the adult sheep may lose its form but the primary trio group is a basic arrangement. The first formed primary fibres of the Merino are small and less vigorous than N-type and this suggests that even smaller initial fibres could be produced and still be primary fibres.

SUMMARY.

Follicle types in the foetal skin of the New Zealand Romney N-type have been examined in relation to the fibre types they will produce in the adult fleece. Since primary follicles are found to grow hairy-tip-curly-tip fibres and fibres of the sickle group, equal prominence should be given to the position of these in the classification of fibre-types.

Stages in the development of the N-type coat have been compared with those previously described for Merinos and other finer sheep, and factors held by previous workers to be responsible for differences in the production of hair or wool fibres are surveyed. No difference has been found in the age at which follicle initiation has been found nor in the fundamental group arrangement. The main difference resides in the size and rapid growth of the follicles after the 88 days stage in N-type foetal development, this difference being determined either by the rate of skin expansion or by the inherent rate of growth of the follicles themselves.

LITERATURE CITED.

- CARTER, H. B. 1939 A Histological Technique for Estimation of Follicle Population per Unit Area of Skin in the Sheep. J. Coun. Sc. Ind. Res. Aust., 12 (3) : 250-258.
- 1943 Studies in the Biology of the Skin and Fleece of Sheep. Coun. Sc. Ind. Res. Bull., 164.
- DRY, F. W. 1933 Hairy Fibres of the Romney Sheep. Halo-hairs and their Inheritance. N. Z. J. Agric., 46 : 10-22.
- 1933 The Pre-Natal Check in the Birth-coat of the New Zealand Romney Lamb. J. Text. Instit., 24 (4) : T161-T166.
- 1934 Hairy Fibres of the Romney Sheep. Fibre Type Arrays and Hairiness. N. Z. J. Agric., 48 : 331-343.
- 1940 Recent Work on the Wool Zoology of the New Zealand Romney. N. Z. J. Sci. & Tech., 22 (4A) : 209A-220A.
- DRY, F. W.,
McMAHON, P. R.
& SUTHERLAND, J. A. 1940 A Mendelian Situation in the Birth-coat of the New Zealand Romney Lamb. Nature, 145 : 390.
- DUERDEN, J. E. 1939 The Arrangement of Fibre Follicles in some Mammals with Special Reference to Ovidae. Trans. Roy. Soc. Edinb., 59: 763-770.
- DUERDEN, J. E. &
RITCHIE, M. I. F. 1924 The Development of the Merino Wool Fibre. S. Afr. J. Sc., 21 : 480-497.
- FORD, E. B., AND
HUXLEY, J. S. 1927 Mendelian Genes and Rates of Development in Gammarus Cheureuxi. Brit. J. Exp. Biol. 5 (2) : 112-134.

- GALPIN, NANCY, M. 1935 The Pre-Natal Development of the Coat of the New Zealand Romney Lamb. J. Agric. Sc. 25 : 344-360.
- 1936 Biological and Statistical Studies of the New Zealand Romney Lamb with Reference to Relative Growth Gradients. D.Sc. Thesis., Edinb. Univ.
- 1936 Relationship between Post-Natal Coat Characters and Pre-Natal Follicle Density as Affected by Increase in Foetal Size. Nature, 138 : 585-586.
- 1936 Britch-Poll Fibre-Type Array Gradient in the New Zealand Romney Lamb. Emp. J. Exp. Agric. 4 (14) : 116-128.
- GIBBS, H. F. 1938 Development of Skin and Hair of the Australian Opossum. Proc. Zool. Soc. Lond. B 108 (pt. 3).
- GOLDSMIDT, R. 1938 Physiological Genetics. McGraw-Hill, New York : 51-77.
- de MEIJERE, J. C. H. 1894 Über Haare der Säugetiere besonders über ihre Anordnung. Morph. Jb., 21 : 312-424.
- TERENTJEVA, A. A. 1939 Pre-Natal Development of the Coat of some Fine-Woolled Sheep. C.R. (Doklady) Acad. Sci. U.S.S.R. 25 : 557-560.
- WILDMAN, A. B. 1932 Coat and Fibre Development in some British Sheep. Proc. Zool. Soc. Lond., 102 (Pt. 2) : 259-285.
- WILDMAN, A. B. & CARTER, H. B. 1939 Fibre-Follicle Terminology in the Mammalia. Nature 144 : 783-784.
- CARTER, H.B. & BELSCHNER, H.G. 1936 Fleece characteristics of Stud Merino Sheep, in relation to the degree of wrinkleness of the skin of the breech.