STUDIES ON THE INCIDENCE OF KEMP IN THE FLEECE OF SCOTTISH MOUNTAIN BLACKFACE SHEEP, WITH SPECIAL REFERENCE TO INHERITANCE.

by

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INTRODUCTION.

The investigations described in this thesis were undertaken to determine whether hereditary factors control the presence of kemp fibres in the fleeces of Scottish Mountain Blackface sheep and, if evidence of heredity were found, to attempt to elucidate the mode of inheritance concerned.

The belief that kemp fibres depend for their expression upon hereditary factors is widely held by sheep breeders and in particular perhaps by owners of Scottish Mountain Blackface flocks. Various scientific workers, Barker (1) and Darling (2) dealing with Scottish Blackface sheep, and Roberts (3) dealing with the Welsh Mountain breed, *inter alios*, have put forward evidence of a generalised nature that kemp fibres are inherited in differing degrees in individual sheep. So far as the writer is aware, however, scientific data relating to the inheritance of kemp accumulated from fleece analyses of flocks of pedigreed sheep have not, up to date, been published for the Scottish Mountain Blackface breed.

DESCRIPTION OF THE SCOTTISH MOUNTAIN BLACKFACE BREED.

Origin.

It is impossible, by reference to records or to the literature, to state definitely the origin of this breed. A number of markedly diverse theories are held. Ewart (4) considers that the Blackface breed together with the Merino, is descended from Ovis ammon. Pease (5) is of the opinion that the ultimate ancestry of the breed extends to Ovis vignei through the European Blackfaced horned breed. Archibald (6) and Wrightson (7) inter alios, contend that the Blackface breed originated as a result of cross-breeding native British sheep with animals which escaped from the wrecked vessels of the Spanish Armada. In the absence of more definite information it is difficult to attempt to discriminate between these theories. It may be stated, however, that it appears improbable that the small number of sheep which would survive after the foundering of the Spanish war-ships could have formed the foundation stock of a breed which has become so distinctive. Moreover, the Spanish Armada has been held responsible for the origin of many other breeds of British sheep, and/

and it is feared that in the absence of more definite information this theory of origin must remain speculative only. The fact that sheep, similar in many ways to the Blackface, are found on the north-western slopes of the Pyrenees as noted by Darling (2), should be regarded only as circumstantial evidence since there appears to be no objection to the supposition that this Pyreneean breed and the Blackface breed might have descended from a common ancestry. Further, Hector Boethius, quoted by Macdonald (8), and others, stated that Blackface sheep were established in the valley of the Esk in 1460, a date considerably previous to the coming of the Spanish Armada.

<u>History.</u>

There is much diversity of opinion as regards the history of Scottish Mountain Blackface sheep, It seems reasonable to suppose that this breed and the allied mountain breeds of the North of England sprang from the same stock. This supposition is in accordance with the suggestion, made by Low (9), Watson (10) and others, that Blackface sheep were first introduced into Scotland from the Pennine chain. A number of writers, among them Youatt (11), Archibald/

Archibald (6) and Mitchell (12), refer to the popular belief that the first Blackface sheep to become established in Scotland were introduced to Ettrick about 1503 by James IV. This does not agree with the statement by Hector Boethius, referred to above, that only Blackface sheep were to be found in the valley of the Esk in 1460, some forty years earlier.

Although the facts concerning their introduction to Scotland are wrapped in obscurity, there is no doubt that Blackface sheep were firmly established in the Border districts, in Lanarkshire, and in parts of Ayrshire long before the eighteenth century. It was not until about 1750, however, that they were introduced into Dumbartonshire, according to evidence collected by Watson (10). Within a few years of this date Blackface sheep had reached Argyllshire, Perthshire, Inverness-shire and Ross-shire according to the same author, Low(9), MacKenzie (13), Archibald (6), Macmillan (14), and others.

Since this time (the second half of the eighteenth century) the breed has increased steadily in popularity with the result that it now occupies the position of the largest breed, in point of numbers, in the British Isles.

Distribution/

Distribution.

In Scotland the Blackface breed of sheep is found principally on the highest upland areas, including most heather covered hills where sheep are grazed. It is almost exclusively the breed of sheep found in Inverness-shire, Perthshire and Argyllshire, while in Aberdeenshire, Angus and Dumbartonshire, also parts of Fifeshire and Stirlingshire it is the most popular breed for hill grazings. It occurs in Ross-shire, but the sheep population of this county together with that of Sutherlandshire is composed mainly of Cheviots.

Blackface sheep are found on many of the Western Islands, also in Bute and Arran.

In the Southern half of Scotland the breed is well established in Lanarkshire, Peeblesshire, in the Lammermuir hills, in Ettrick and the upper valley of the Tweed; in the high-lying parts of Ayrshire and Dumfriesshire and in Wigtownshire and Kirkcudbrightshire. It occurs on the hills throughout the countries of Berwick and Roxburgh whence it extends over the border.

Although the Blackface breed of the North of England is essentially the same as the Scottish breed/

breed, it has a separate flock-book.

In Ireland, Blackface sheep are found in northern and western districts.

Breed Type.

The face and legs are, ideally, black and white in colour although all gradations from entirely black to practically white occur. Both sexes are horned. In the female the horns are curved backwards, and seldom attain more than a half turn. In the male, the horns are much stronger and usually grow through about three-quarters of a turn during the first year after birth. In an aged male (6-7 years) the horns usually show two complete turns (Fig. 1). The fleece is long, often reaching almost to the ground. An average figure for fleece weights can be taken as 4 to 4½ lbs. for ewes, and 6 to 10 lbs. for rams, though these figures are often exceeded in individual animals.

Compared with the larger lowland breeds the Blackface is somewhat small in size and shorter in the leg, but the lambs give remarkably good carcases, and mutton from fat yearling wethers compares very favourably/

favourably with that produced by any other breed.

The sheep are very active and extremely hardy. They live for the most part under environmental and nutritional conditions which are exceedingly rigorous. On the majority of Blackface hill farms it is not the practice to supply extra feeding for the sheep except during severe snowstorms. On many grazings the ewes are allowed to lamb on the lower slopes of the hills, without further protection from inclement weather than that afforded by a stone dyke. The average lambing percentage for the breed under hill conditions may be taken as between 80 and 90 lambs per 100 ewes.

Photographs of a typical Blackface ram and ewe are given in Figs. 1 and 2.

Fleece Characteristics.

In the Blackface breed the fleece is not so much highly specialised as relatively unchanged from that of its primitive ancestors. The sheep have to encounter in winter severe weather conditions and an exceedingly heavy rainfall. Consequently, they/

Fig. 1. Photograph of a typical Blackface ram. (Photograph kindly supplied by the North British Agriculturist Ltd.).

Fig. 2. Photograph of a typical Blackface ewe. (Photograph kindly supplied by the North British Agriculturist Ltd.).

they must possess fleeces which give adequate protection from cold and "shed off" rain and sleet. Breeders have made little effort to "improve" the Blackface fleece by endeavouring to eliminate the long coarse fibres, since these are necessary for the animals' protection. The fleece has, however, been modified as a result of generations of controlled breeding, but it still remains essentially primitive in nature.

In general characteristics the fully grown fleece of an adult typical Blackface is arranged in a series of locks or staples, broad at the base and tapering to a long fine tip. The broad base, which should be capable of being readily separated from adjacent staples, consists of fine wool fibres and the proximal portions of the long hairy fibres; the distal pointed ends of the staples are formed of hairy fibres only. Kemp fibres when growing are confined to the base of the staple: when shed they may work up to the middle or tip of the staple whence they become entangled in the growing wool, and are sometimes regarded as "dead" fibres by breeders.

Running from the neck to the root of the tail along the middle line of the back there is typically a/

a well-defined parting of wool. In a well-covered animal this should present a series of more or less equal sized staples lying alternately to right and left of the middle line, each staple being thick and dense at its base, and no bare skin being shown. In a thin fleece the part extends down to the skin, and rain and snow can penetrate to the inside of the fleece. Normally the fleece is thickest over the back and hind quarters and thinnest over the withers. The wool on the belly and the forearms is shorter and fewer long fibres are found. On the britch the wool is longest and coarsest, while the insides of the thighs and forearms are sparsely covered by short thick hairs. Wool is present on the scrotum.

The fibres composing the fleece of the Blackface sheep can be divided into three main types which have been named: (i) wool fibres; (ii) long hair fibres and (iii) kemp fibres. Typical wool fibres are relatively short and are extremely variable as to fineness between individual sheep and, on broad lines, between the breed population in different districts. Microscopically, the fibres show all the characteristics of true wool fibres. The long hair fibres are very long, ranging/

ranging from 4 to 8 inches in the female and from 7 to 12 inches in the male. These fibres are coarse and, when examined under the microscope, are seen to be medullated. Kemp fibres are coarse and stiff and show a very characteristic wave. These fibres have a dead white appearance; the length range is from 1 inch to 3 inches.

The microscopic characters of the different fibre-types in the Blackface Fleece are described by Blyth (15 and 16) <u>inter alios</u>. Darling (2) investigated the relationships of the three classes of fibres. He found that there was considerable variation in the proportions of the three types present in different parts of the body. He gave as average figures for percentages by count: Wool 73.5%; long hair 20.5%; kemp 6.0%; and for percentages by weight: Wool 42.0%; long hair 52.0%; kemp 6.0%.

Kemp Fibres.

Kemp fibres occur in the fleece of the Scottish Mountain Blackface breed of sheep in relatively large proportions. They actually represent the vestigial/

vestigial remains of the coarse outer-coat fibres of primitive sheep, as was pointed out by Duerden(17 and 18) and Roberts (3). It is to be expected, therefore, that kemp should occur in large proportions in the more primitive breeds such as the Blackface. Kemp is also very prevalent in the fleeces of the North of England mountain breeds, for example, the Lonk and Swaledale and in the Welsh Mountain breed.

In the Blackface breed, kemp fibres are very easily recognised by their macroscopic characters, which may be summarised as follows:

1. The fibres have a dead-white appearance, unless pigment is present, when they usually appear brown or black. This is due to their large medulla, containing air, which causes light to be refracted.

2. All typical kemp fibres show a pronounced wave (see Fig. 3).

3. In most cases the fibres are very coarse.

4. The length range is from 1 to 3 inches at the end of the growth period. The great majority of Blackface kemp fibres are included in this range; there are occasionally exceptions, but these are not sufficiently numerous to merit special/

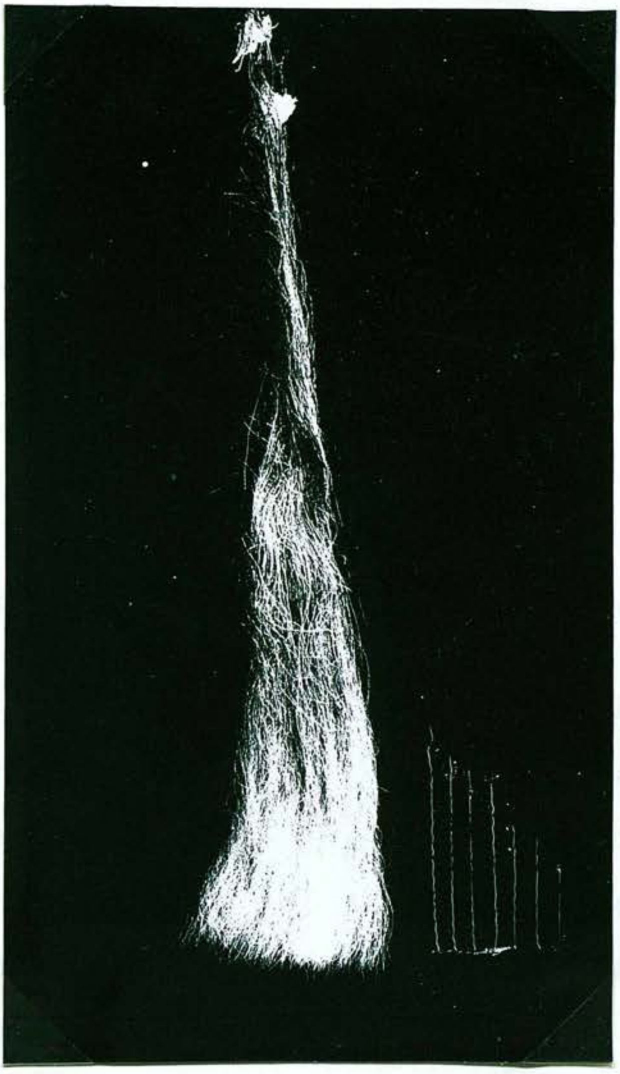

Fig. 3. A typical kempy sample of Blackface wool, with some kemp fibres separated. The two light patches at the top of the sample are adhesive used in mounting.

special notice.

5. All typical kemps exhibit a sudden thinning at their distal extremities to a very fine tip. At the proximal extremity of a completely grown fibre there is also a slight thinning immediately above the level of the follicle. This can be observed only in those fibres which have been shed naturally, and the thin proximal portion of the shaft is followed by a terminal bulb. Where kemp is examined in a sample which has been clipped from the living sheep, this thin area can seldom be seen.

6. Kemp fibres are extremely brittle.

In Fig. 3 a typical kempy sample of Blackface wool is shown with a number of kemp fibres separated. There is no difficulty in recognising typical kemp fibres in the Blackface fleece by visual examination. In the great majority of cases, kemps exhibit these typical macroscopic characters. It sometimes happens, however, that wool samples removed from individual sheep contain a number of fibres which are very definitely atypical. This will be discussed later.

With regard to the incidence of pigment, it appears that kemp fibres exhibit pigmentation more readily/

readily than other types of fibres. Thus, if a sheep has any tendency towards pigmentation in its constitution, the kemp fibres will first exhibit it, and both the long hair and wool fibres may be free from colour.

Kemp fibres exhibit an annual growth, the highest growth-rate being reached in the period from early spring to October or November. The fibres are then shed. It is worthy of note that, in ordinary farming practice, the sheep are clipped about midsummer. It is not possible to say what effect, if any, this has on the subsequent growth of kemp before the autumn, at present.

Blackface wool is not used in the manufacture of textile materials except in certain local industries, notably for "Harris" and other rough tweeds. The presence of kemp in such cloths is desirable since it is regarded as a guarantee that the articles are genuine "homespuns".

Owing to the coarseness and length of the long hair fibres and the presence of kemp fibres, Blackface wool is unsuitable for spinning and weaving by the delicate machinary in use in modern woollen mills.

At/

At the present time the best quality strong Blackface wool is exported to Italy, according to the Scottish National Development Council (19). The same authority also states that the price paid for wool suitable for the Italian market is approximately 20 per cent. higher than for wool suitable for other purposes.

Parnell (20) collected details of the grades of Blackface wool produced and the uses to which the various grades are put. The following information was obtained from this author:

The shortest, finest wool, produced in the Hebrides, Skye and the west coast of Ross-shire, is used for the manufacture of "Harris" and other rough tweeds, an inferior type of hosiery and coarse blankets. Individual ewe-fleeces from all districts of Scotland may be classed in this grade. There is a short, somewhat silky type of Blackface wool produced chiefly in the south-west of Scotland which is used for the manufacture of yarns for export to the continent. Again individual ewe-fleeces of this class may be produced in all districts. The finer intermediate types of wool, produced in all districts, are used for the manufacture of carpets, and, at the present time, are the least valuable. The/

The strongest types of Blackface wool are exported to Italy for use in the manufacture of mattresses. This class of wool is produced mainly in Lanarkshire and western Peebles-shire, but it also occurs in Stirlingshire, Perthshire and parts of Angus and Argyllshire.

Parnell makes no reference to the effect of the presence of kemp on the relative usefulness of each grade of wool. Evidence has been collected by the writer, however, that kemp fibres are most undesirable in all grades of Blackface wool except those used for the manufacture of rough tweeds. For the Italian market, which is by far the most important outlet for Scottish Blackface wool, a small amount of kemp in the fleece is not regarded as a serious defect, but grossly kempy fleeces and fleeces containing pigmented kemp fibres are extremely disliked.

So far as the writer is aware, the wool brokers have not adopted any system of grading Blackface wool according to its kempiness, their only method of grading being based on the suitability of a particular clip for a specified market, as noted above. Consequently, in the absence of a preferential price for fleeces practically free from, or containing only a small amount of, kemp, many breeders tend to neglect/

neglect the consideration of the kempiness of the fleece when selecting their breeding stock. The Scottish National Development Council (19) states that "the percentage of kemp fibres in both Blackface and Cheviot wools is still too high to enable these wools to realise their maximum potential values on the market". Continuing, the Council expresses the opinion that, in due course, these wools will be purchased on quality standards, when grossly kempy fleeces will command lower prices than kemp-free wool.

It seems probable, therefore, that breeders of Blackface sheep will find, within the next few years, that it is necessary to breed sheep carrying fleeces which contain the smallest possible amount of kemp in order to obtain advantageous prices for their wool. The aim of this investigation is to indicate, if possible, the lines on which such selective breeding should be conducted.

Further, while this work has been concerned entirely with the Scottish Mountain Blackface breed, it is claimed that its application has a wider significance. In most of the finer-wooled breeds of sheep, kemp has been almost eradicated by many generations/

generations of selective breeding. Individual animals in all breeds, however, are constantly "throwing back" and producing kemp fibres in their fleeces. This is especially the case in the Cheviot breed; in fact, many prominent Cheviot breeders state that there is more kemp in the fleeces of Cheviot sheep at the present time than there was twenty years ago. This may prove a limiting factor in the development of the Scottish Border tweed industry.

It seems reasonable to assume that the actual mode of inheritance of kemp will be the same for all breeds, since kemp is a vestige of the outer coat fibres in the common ancestors of our modern domesticated breeds of sheep. If, then, the present work succeeds in demonstrating something of the mechanism of the inheritance of kemp in the Scottish Mountain Blackface breed and in suggesting the lines on which selective breeding should be carried out in order to eliminate these fibres, there seems to be no reason to suppose that this information should not apply to the Cheviot and other fine-wooled breeds.

MATERIAL USED AND EXPERIMENTAL METHODS.

Investigations on the Distribution of Kemp over the Body. The Technique adopted for Sampling.

This investigation was commenced in the autumn of 1930 and all the work has been carried out at the Institute of Animal Genetics, University of Edinburgh.

In order to study the inheritance of kemp, the first essential was to find some reasonably accurate method of comparing the amount of kemp present in the fleeces of living sheep. From previous work by Darling (2), it was obvious that there was considerable variation in the distribution of kemp over the body and it was clear from this work and from general observation that in most sheep little or no kemp was present in the area around the shoulder and on the thorax even in animals which exhibited much kemp in the skin of the back. To obtain more exact data, preliminary fleece analyses were commenced on Blackface sheep kept at the Institute of Animal Genetics.

While this work was in progress, some important observations on the distribution of kemp in the Blackface/

Blackface breed were made by Mr William C. Miller, to whom the writer is greatly indebted for permission to use the data and photographs shown in Figs. 4-8 and described below:

One of the Blackface ewes kept at the Institute of Animal Genetics died from peritonitis and there was some delay in disposing of the carcase. Rapid decomposition set in and upon examination some three days after death it was found that the wool fibres and long hair fibres could be easily pulled out but that the kemp fibres were still firmly held in their follicles. All wool and long hair fibres were removed by hand and photographs of the carcase, with the kemp fibres in situ, were obtained. Subsequently, pieces of skin, each one square inch in area, were removed from various locations and the kemp fibres on each were counted. This procedure was repeated with other Blackface sheep which died and with a number which were slaughtered to supply material for certain physiological work being carried out by another worker. Every carcase was not found to be satisfactory, and only those in which wool and long hair fibres could be readily plucked without disturbing kemp fibres were used.

In each case very similar results were obtained. The kemp fibres were found to be very densely distributed/

distributed over a bilaterally symmetrical area on the dorsal aspect of the sheep extending from about the level of the eighth thoracic vertebra to the tail-head and for about two inches laterally on each side of the mid-dorsal line, becoming broader posteriorly over the croup. Outside this area, the density was found to decrease somewhat and, at from four to five inches from the mid-dorsal line, the occurrence of kemp practically ceased except over the rump, where the dorsal area spread out and extended downwards over the flanks; the density, however, was considerably less in the latter region. As regards the remaining parts of the body, the thorax was found to be practically free from kemp, except for one or two small tufts, but the lower parts of the abdomen showed a fair incidence of kemp fibres, though their density in this area was not high. The above description is illustrated by Figs. 5-8.

These photographs all relate to the same carcase and are included as being absolutely typical of the results obtained in this analysis of the distribution of kemp over the body.

In Fig. 4 a diagrammatic representation of the/

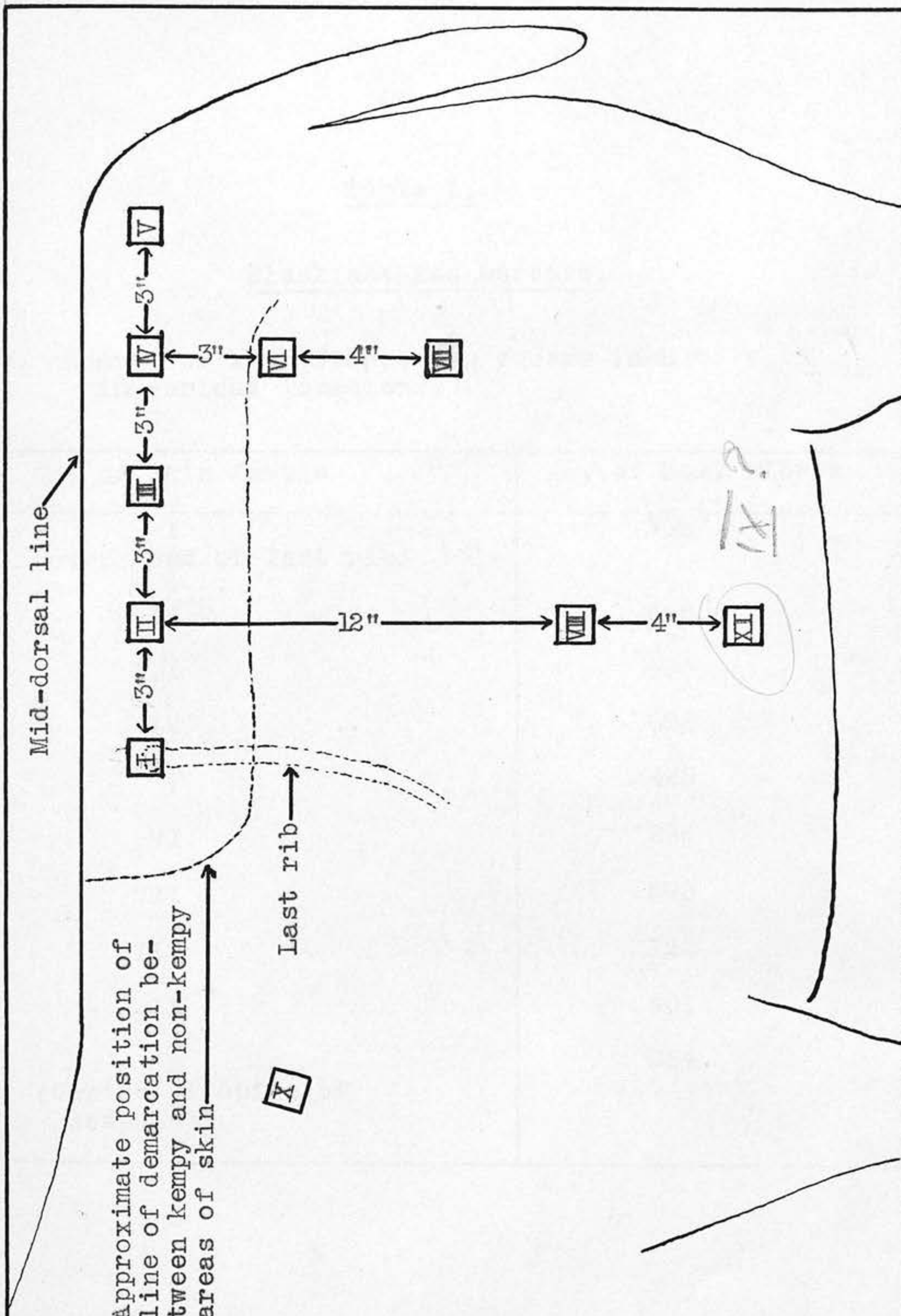

Fig. 4.

Diagram to show the locations of the skin samples, each 1 sq. inch in area, removed from carcase of Blackface ewe.

Table I.

Blackface Ewe Carcase.

Number of kemp fibres per square inch of skin in various locations.*

No. of Skin Sample	No. of Kemp Fibres
I (Over head of last rib)	706
II	646
III	696
IV	593
V	425
VI	296
VII	578
VIII	122
IX	401
X (Centre of spine of scapula)	254

*Figures for the left side only are given.

Fig. 5.

Photograph of carcase of blackface ewe, to show the kempy patch over the dorsal region after removal of wool and long hair, from above.

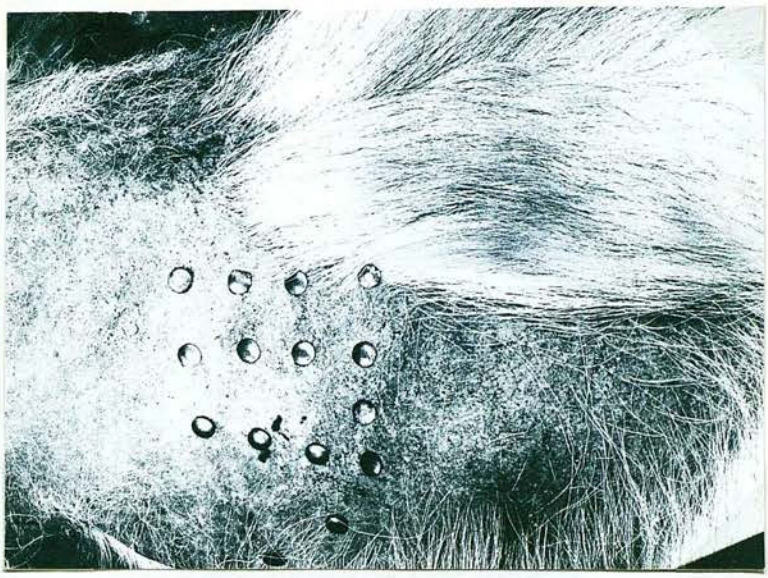

Fig. 6.

Photograph of carcase of Blackface ewe, showing well defined margin of dorsal kempy area. The drawing pins indicate the position of the last four ribs.

Fig. 7.

Photograph of carcase of Blackface ewe from the side, showing the dorsal kempy area, and the distribution of kemp over the flank and lower parts of the abdomen.

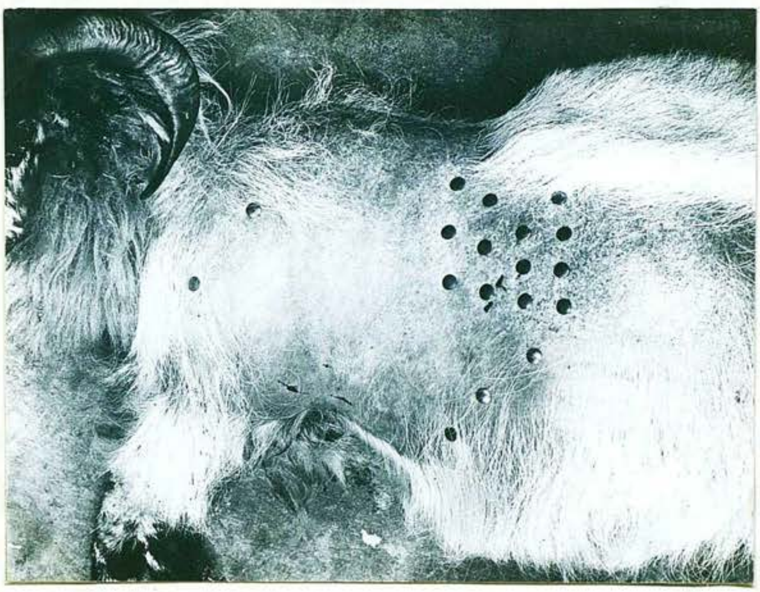

Fig. 8.

Photograph of carcase of Blackface ewe from the side, showing the commencement of the dorsal kempy area and the absence of kemp on the thorax. The drawing pins indicate the line of the spine of the scapula, the last four ribs, and the posterior edge of the last costal cartilage.

the locations of the areas from which square inches of skin were removed is given and details of the actual numbers of kemp fibres counted in a typical case will be found in Table I (page 25).

By reference to Table I it will be seen that the variability of the density of distribution of kemp was low between areas I, II and III, but became higher in areas IV and V. The variability between areas VI to X was, clearly, very high, and the density in each of these areas was lower than that of areas I to III. In other words, the variability of the density of kemp distribution was very low in a bilaterally symmetrical area extending from a point somewhat in front of the last rib to the level of the croup and for about one and a half inches on each side of the mid-dorsal line. Further, the density of distribution in this area was maximal for the whole skin surface.

These observations, replicated a number of times, were found to agree closely with the results of a detailed analysis of the distribution of kemp over the body in the Welsh Mountain breed made by Roberts (21).

Since/

Since the analysis detailed above had been closely followed by the writer and the results were very kindly placed at his disposal by Mr William C. Miller, the preliminary fleece analyses to obtain similar data were no longer required. Accordingly, this work was discontinued.

From the nature of the distribution of kemp over the body, it was clearly necessary, in order to study the inheritance of kemp, to compare not the kemp content of whole fleeces so much as the kemp content of the dorsal areas of maximum density. The argument might be advanced that, since the variability of the kemp content is extremely high outside the area, the whole fleece should be sampled in order to obtain some measurement of this variability for each individual; and that this together with the measurement of maximum kemp content within the dorsal area would give figures for the kempiness of the sheep which would be truly comparable with similar figures obtained from other sheep in the same way. After careful consideration, however, it was thought that a measurement of the maximum kemp content obtained from the dorsal area alone would provide sufficient information to enable/

enable a comparison between fleeces of living sheep to be made. Any major difference between the kemp contents of any two fleeces would be at once indicated by the kemp contents of these maximal areas. For example, a fleece showing a very small amount of kemp in the dorsal area could be classed at once as relatively free from kemp. Similarly, a fleece containing much kemp in this area could at once be classed as kempy. In the quantitative measurement of a character such as kempiness, it is obviously impossible to obtain an absolute figure unless every kemp fibre in the fleece were to be removed and measured by weighing or otherwise. Again, in a biometric investigation into the inheritance of a specific character, where the expression of that character is measured by a method of sampling, it is not possible to discriminate between the finer shades of difference.

In view of these considerations, it was decided that no useful purpose would be served by ascertaining the variability of the kemp content on the remainder of the body for each individual sheep and that a fair measurement of the kempiness of the fleece could be obtained by removing samples from within/

within the dorsal area of maximum density.

Since it was established that variability of the kemp content is low within this dorsal area, there was no object in removing large samples, or in removing more than a small number of samples. Ideally one, or two at most, samples taken from the mid-dorsal line at the level of the second or third lumbar vertebra should furnish reasonably accurate data of the kemp content in the area. Unfortunately, in the Blackface breed, there is a parting (known to the breeders as a "shed") in the fleece along this line; therefore, it is necessary to remove samples from locations situated a little to the side in order to avoid including fibres have become broken or otherwise damaged by exposure to the weather near their points of insertion.

To establish uniformity in the technique of sampling, it was advisable to select a definite anatomical point on the sheep to fix the locations from which samples should be removed. The head of the last rib was found to be the most convenient "landmark" for this purpose. This is very readily found by touch on the living sheep and the sampling area decided upon was just medial to this point.

In/

In practice, the finger was placed on this projection and the lock of wool immediately adjacent on the medial side was clipped off close to the skin with sharp scissors. This was repeated on the opposite side, so that two samples were removed from each sheep. The approximate size of the area of skin from which each sample was removed was two and a half square centimetres, about one inch from the mid-dorsal line, and consequently situated well within the dorsal area of maximum kemp content.

It was necessary to determine the time of year which would be most suitable for sampling. In view of the fact that the maximum growth period of kemp fibres terminates about the end of October, it was considered that the best time for sampling would be during the month of November when kemp fibres had ceased to grow and were beginning to be shed. Thus it has been the standard practice throughout this investigation to remove two samples from each sheep during the month of November.

It was realised that the kemp in these samples represented the result of growth only from the time of shearing in the previous summer. Since, however, the date of shearing Blackface sheep does not vary greatly/

greatly from district to district, errors arising from the comparison of the fleeces of sheep shorn at different periods of the year were unlikely to occur. In the case of sheep kept on the same farm no error could arise, since all adult sheep are shorn within the space of one or two days.

Material.

(a) Samples obtained from sheep belonging to breeders in many districts of Scotland.

In November 1930 many of the prominent breeders of the better class of Blackface sheep in Scotland were visited and samples were removed from a selection of their stud rams, also from 6-8 month old lambs sired by these rams and born the previous spring. It was found, however, that these latter samples were unsuitable for use in a genetical investigation because the system of marking the lambs, in most cases, was such that mistakes in assigning their respective sires were liable to occur and the dams were seldom recorded in any way.

On examination of the lambs' samples it was found that, in the majority of cases, a large proportion of birthcoat fibres, both shed and unshed, were/

were present. Thus it was impossible to make analyses of kemp content in samples from lambs of this age. It has since been shown, Lochner (22), that birthcoat fibres may persist in the Blackface fleece for up to twelve months after birth. Further, the accuracy of any fleece comparison between sheep under twelve months of age and adult sheep tends to be vitiated by the fact that the fleece of the young sheep represents the growth of fibres from some time before birth, while the adult fleece represents fibre-growth from the time of the last shearing only.

Thus, since it had been decided to remove samples for the purposes of this investigation only in the month of November, it was clear that the youngest sheep which could be included would be approximately eighteen months old; that is, their fleeces would be sampled in the November following their first shearing.

The rams' samples were analysed and provided figures to indicate the degrees of kempiness exhibited by the better type of Blackface stud rams.

(b) /

(b) <u>Samples from a breeder whose sheep have been accurately marked and recorded for the past ten years.</u>

A short time after commencing this work, a Perthshire breeder who was interested in the breeding of non-kempy sheep, offered to put the whole of his Blackface sheep stock at the writer's disposal for sampling purposes. It was found that this gentleman had kept a flock-book for the past ten years, and had personally attended to the work of marking and recording the sheep. He very generously allowed the flock-book to be kept at the Institute of Animal Genetics to be available for constant reference.

The farm worked by this breeder is a hill farm of two thousand acres, rising to an altitude of 3421 feet. There are about a hundred and seventy acres of grassland on the low ground divided into eight paddocks. The lower slopes of the hill are covered with a mixed herbage of grass and heather, while the higher altitudes are entirely covered with heather. The stocking of the farm consists of about four hundred Blackface ewes and gimmers. The number of Blackface rams is maintained at eight.

About eighty aged ewes are disposed of each summer and about one hundred ewe-lambs are retained for/

for breeding. It is customary to send these ewe-lambs away to winter grazing during their first winter. These return to the farm the following summer and are added to the breeding stock, being mated in the autumn, that is , when they are about eighteen months old.

The adult sheep find sufficient nourishment on the hill in normal winters and only receive supplementary feeding during severe snowstorms.

The control of mating is very carefully arranged. In November of each year, the ewes and gimmers are divided into groups according to their age and parentage as shown in the flock-book. Each group is then driven into one of the paddocks and one of the rams is allocated to it. The number of the ram is then noted against the number of each of the ewes in the flock-book. This is repeated for each group. The groups are allowed to remain, each with its particular ram, in their respective paddocks for some six weeks, that is, until ample time has been allowed for all the ewes to be served. The rams are then taken in and the ewes and gimmers are driven to the hill.

About two weeks before the first lambs are expected, all the sheep are brought down to the lower slopes/

slopes of the hill and some are actually put into the paddocks, especially the gimmers. When the lambs are born, each is marked with a numbered ear-tag. The number on this tag is entered against the dam's number in a notebook. Since the number of the ram bred to the ewe is already entered in the flock-book, a complete record of the parentage of each lamb born is readily made in this way. A small percentage of mistakes occurs owing to the misreading of numbers and a few sheep each year lose their tags on account of these becoming fixed in wire fences and being torn out as a result of the sheep's struggles. In the great majority of cases, however, there is a complete record of parentage which now extends back in many cases to include both pairs of grandparents.

At the end of June the male lambs are castrated (with the exception of one or two likely to make useful breeding rams) and they are marketed for slaughtering at the end of August. The female lambs required to maintain the stock are selected at this time, and the surplus marketed.

It will be understood from the foregoing brief description of flock management that, with the exception/

exception of a small number of stock rams, only female sheep were available for sampling. On a commercial farm where ram lambs are not bred for sale, the great majority of the Blackface wether lambs never produce clipped fleeces, although the stock ewes may yield five or six fleeces. It is therefore more important to consider the female progeny in any wool study in the field.

In November 1931 samples were removed from every sheep on the farm. Two samples were taken from each sheep in accordance with the method described previously. In November 1932 further samples were obtained chiefly from sheep eighteen months old.

Some of the rams which sired the then existing stock had been disposed of before this investigation was commenced so that, unfortunately, no measurement of their kemp content could be obtained.

Laboratory Treatment of the Samples.

In the laboratory the first consideration was how to express the kemp content of the samples. There were two possible methods: that of finding the percentage by count of kemp fibres present in the sample or that of finding the percentage by weight. The/

The count method is by far the more laborious, since every fibre, wool, long hair, and kemp, in each sample has to be counted. The time required to do this for some thousand samples would, obviously, be considerable, and the method has several further disadvantages. It takes no account of the relative lengths or of the relative finenesses of the three types of fibre in the sample. It would be possible by this method to have two samples with the same values for percentage by count of kemp and the same mean lengths of wool and long hair, in one of which the mean length of kemp was 0.5 in. and in the other 2.5 in., and consequently greatly different proportions by weight. Since all the sheep from which the main series of samples were removed were clipped at the same time, the sample showing kemp fibres of mean length 0.5 in. would represent a superior fleece from the point of view of relative kempiness than the one in which the mean length of kemp fibre was 2.5 in. Yet the percentage by count figure would be the same. Again, it is conceivable that two samples might be encountered, having a similar number of kemp fibres per unit area of skin, in one of which the wool and the long hair fibres were exceedingly fine and very densely/

densely distributed, while in the other the wool and long hair fibres were coarse and thinly distributed. The figure for percentage by count of kemp fibres for the latter would be very high and for the former very low. This would be extremely misleading. Moreover, Darling(2) showed that there is no significant correlation between weight and count percentages of kemp.

Most of the above disadvantages are obviated by using the percentage by weight method. It is much less laborious, since only the kemp fibres have to be separated from the other types and no counting is necessary. By this method, also, the total bulk of the kemp fibres is measured - long fibres will weigh more than short and coarse fibres more than fine. This applies equally to the wool and long hair fibres. This method of estimating kemp was recommended and used by Roberts (3) and (21) and by Kronacher and Lodemann (22).

It is admitted that this method is not absolutely ideal. For example, to take an extreme case, it would be theoretically possible to obtain the same figures for percentage of kemp by weight for a sample containing relatively few long coarse kemp fibres/

fibres and for one containing relatively many fine short kemp fibres. It has been observed, however, that the degree of fineness of kemp fibres does not appear to vary beyond comparatively narrow limits, so that, with a few exceptions, the percentage by weight method gives a figure for a particular sample which is comparable, to a fair degree of accuracy, with a similar figure obtained from another sample.

After experimenting with various methods of removing the kemp fibres from the sample, it was found that the most satisfactory method was as follows: The sample was held at the proximal end in the left hand over a board covered with black velvet. Small bundles of long hair fibres were pulled out from the distal end and placed on one side of the board, any kemp fibres clinging to these being picked up with forceps and placed on the other side of the board. When all the long hair fibres had been pulled out in this way, leaving only wool and kemp fibres in the left hand, the same procedure was repeated, small bundles of wool fibres with kemp fibres clinging to them being pulled out and the kemp separated by means of forceps. In this way each sample was divided into a non-kemp and a kemp fraction/

fraction. The fractions were then placed in separate envelopes ready for subsequent treatment.

In the great majority of cases, no difficulty was experienced in distinguishing the kemp fibres, since they exhibited to a marked degree the macroscopic characters described in a previous section. In some cases, however, there were few typical kemps, but the long hair fibres were very coarse and showed kemp-like characteristics. In other cases the samples contained large numbers of Heterotypes. (A Heterotype for the purposes of this work is a fibre which exhibits all the characteristics of kemp for part of its length, the rest of the fibre showing the characteristics of wool or long hair). Such phenomena are believed to be due to derangements of the sheep's metabolism, either by illness or by intensive rich feeding. The latter cause is thought to be the most likely explanation since most of the cases encountered were in samples taken from breeders' stud rams which are usually subjected to special forcing diets.

No attempt was made to analyse such atypical samples since any endeavour to classify the kemp fibres in them would have been purely arbitrary and no value could have been attached to the percentage figures/

figures obtained. The total number encountered constituted less than 5% of all the samples analysed.

A large proportion of the samples were found to contain very little kemp. It was soon learned, by noting the actual kemp percentage figures obtained for such samples, that it was possible to tell by eye, from an examination of the kemp fraction on the board, when the amount of kemp did not exceed one per cent. In order to curtail the time required for this part of the work such samples were classified at once as containing less than one per cent. of kemp. From time to time, in order to check the accuracy of these estimations the non-kemp and kemp fractions of a sample of very low kemp content were subjected to the standard degreasing and scouring treatment as described below, and the percentage weight of kemp found. In no case was this found to exceed one. The direct classification by eye of these samples as containing less than one per cent. was therefore regarded as satisfactory.

A preliminary examination of the samples collected revealed the fact that, while some were comparatively clean and free from foreign matter in the form of sand, peat, etc., a large number were contaminated with these substances to a considerable extent and all showed the presence of varying amounts/

amounts of wool grease. It was clear, therefore, that some standard method of removing wool grease and foreign matter must be used in order to obtain comparable figures for the percentage weight of kemp. It was noticed that when the samples were pulled to pieces in the operation of separating the kemp fibres, much of the débris was thrown down on the sorting board; in most cases, however, a considerable amount persisted in the small bundles of fibres after they had been pulled out of the sample. It became apparent that the process of hand-sorting for removal of kemp fibres was also useful in removing a proportion of the foreign matter in the samples, and it was decided that sorting should be always carried out before treating the samples for removal of wool grease and other impurities.

A study of the literature revealed that authorities agreed that, in the preparation of laboratory samples for subsequent analysis, two distinct treatments were necessary: one to remove the particles of sand, dried dung, peat, etc., also water-soluble suint - scouring; the other to remove wool/

wool grease and water-insoluble suint - degreasing. It seemed to be generally agreed that a dilute solution of saponin in distilled water was the best agent for scouring and either benzene or ether was recommended for degreasing. Benzene was considered the better of the two, King (24), Roberts (25), since it is not adsorbed by the wool fibres and is much safer than ether. Barritt and King (26) made a careful study of the various methods of preparing laboratory samples for subsequent analysis and adopted the following procedure:-

1. Treatment with sulphur-free benzene.
2. Removal of surplus benzene and drying in warm air.
3. Hand-sorting to remove foreign matter.
4. Two or three treatments with benzene and drying in warm air.
5. Further hand-sorting.
6. Scouring in very dilute solution of saponin in distilled water.
7. Thorough washing in distilled water.
8. Drying in warm air.
9. Conditioning for a few days.

It was decided that the principles laid down as/

as above by these authorities must be accepted as a basis for any standard treatment adopted in this investigation. Roberts (25) used an essentially similar method except that he maintained the temperature of the benzene at 40°C. and omitted the hand-sorting operations. Bearing in mind the fact that Barritt and King were preparing samples for an accurate chemical analysis of sulphur content, it was thought that some simplification of their method would meet the requirements of the present work. Accordingly the following scheme was elaborated:

1. Hand-sorting into separate kemp and non-kemp fractions (and incidentally to remove much of the foreign matter).

2. Two treatments of the fractions with benzene at 40°C.

3. Drying by exposure to the laboratory atmosphere.

4. Scouring in $\frac{1}{8}$% solution of saponin in distilled water.

5. Washing in distilled water.

6. Drying and conditioning to laboratory atmosphere.

This modified scheme was regarded as a suitable basis on which to work out the details of a standard technique of scouring and degreasing for the similar treatment of all the samples.

Some wool samples were obtained from Blackface sheep/

sheep kept at the Institute of Animal Genetics to use in experimenting to find the most convenient methods to adopt in performing the various operations. It was necessary to keep in view the fact that a large number of samples had to be dealt with, so that economy in the time required for the scouring and degreasing processes was most important.

In the first method tried, the fractions were placed in small china jars, suitably labelled, and benzene was added. After an interval of half an hour the benzene was poured off, and a fresh supply added. At the end of a further half hour, the second benzene was poured off and the fractions were allowed to dry. When all the benzene had evaporated, $\frac{1}{8}$% solution of saponin in distilled water was added, and allowed to remain for half an hour, when it was poured off, and the fractions were washed in several changes of distilled water. The fractions were then ready for drying, conditioning and weighing.

This procedure was found to be inconvenient. In pouring off the liquids from the kemp fractions especially, some of the kemp fibres were invariably carried over and it was necessary to filter the discarded fluids in order to avoid losing many fibres. Again/

Again, the loose fibres in the jars were difficult to remove after the treatment was completed, having to be picked out with forceps. Also the scouring was very incomplete, and it was clear that agitation was required to cause the removal of the foreign matter. Accordingly, the same procedure was repeated, except that each fraction was enclosed in a small bag made of muslin, and these were shaken up and down occasionally during immersion in the saponin solution and subsequent distilled water washings. In this case, scouring was found to be much more complete, but the method was still very cumbersome. Further, the kemp fibres penetrated the muslin, and, while few escaped, the time required at the end of the process to pick out those partially protruding fibres was considerable.

It was clear, therefore, that a more efficient and more rapid method of carrying out the scouring and degreasing operations must be devised. Accordingly, a rough piece of apparatus was put together experimentally. This is shown in Fig. 9.

Numbered cylindrical containers, 2 inches long by $1\frac{1}{4}$ inches in diameter (Fig. 9, h) were made of very fine brass wire-gauze, of 3750 meshes per square inch. The sample-fractions were retained in the containers/

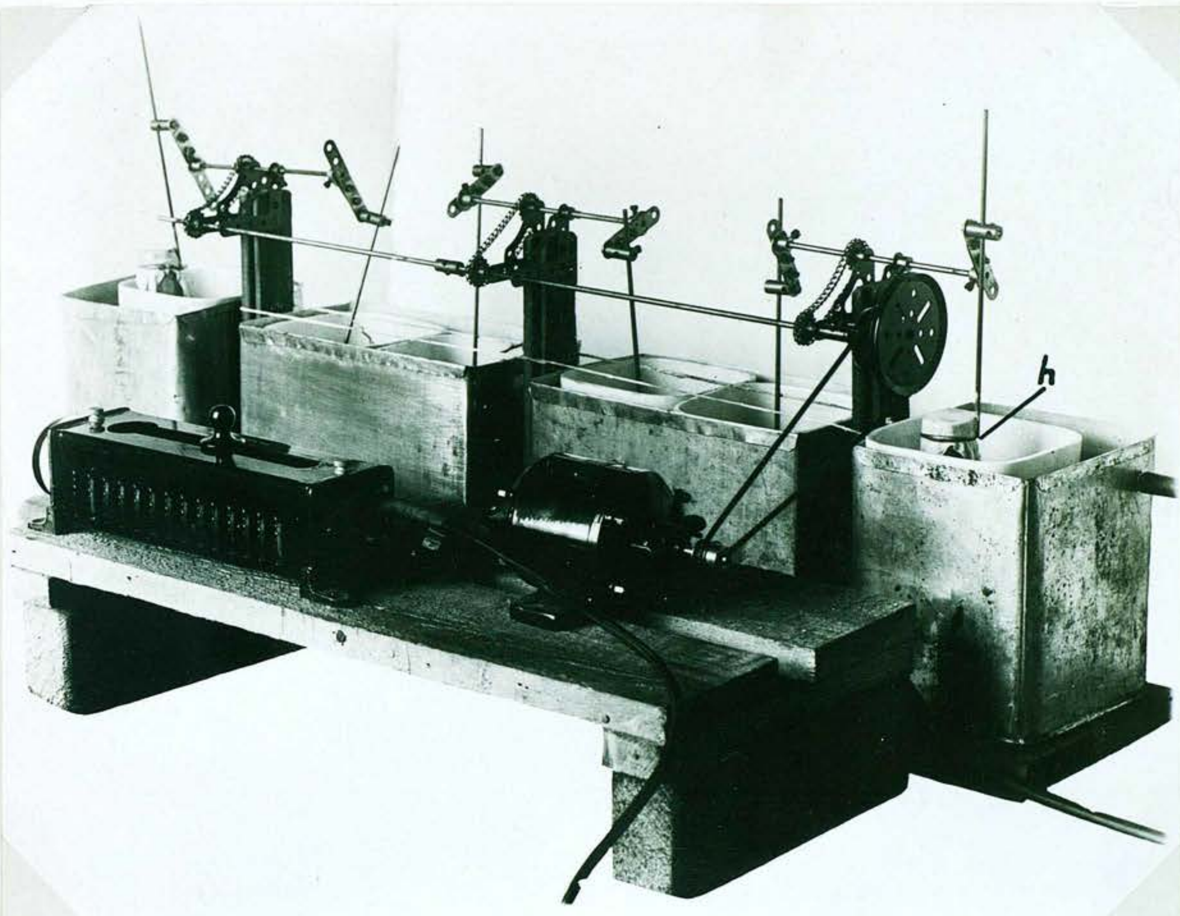

Fig. 9. Photograph of Experimental Scouring Apparatus.

containers by means of pieces of muslin held in position by rubber bands. The mode of action of the apparatus will be readily understood by reference to Fig. 9. The containers were attached, by means of long stems, to cranks which were caused to revolve by an electric motor. Vessels of suitable size, containing saponin solution or distilled water, were placed so that each container was alternately plunged into the liquid and removed as the cranks revolved. The saponin and distilled water baths were maintained at a temperature of 52°-56°C. by being placed in water baths maintained at this temperature. In using this apparatus the sample-fractions were placed in the numbered gauze containers and the muslin covers were placed in position. The containers were then placed, in batches of three, in benzene maintained at a temperature of 40°C. in an incubator oven for 30 minutes. At the end of this time, the three containers were moved to a second benzene bath and three fresh containers were placed in the first bath. After removal from the second benzene bath, the containers were well shaken to remove excess benzene, and placed over a steam radiator for half an hour. After this each was placed/

placed in one of the saponin baths of the scouring apparatus (the hot water circulation having been running for a sufficiently long time to ensure that the various baths were at the required temperature), attached to the crank and the motor was started. It was allowed to run for 30 minutes and then the three containers were removed from the saponin baths, rinsed roughly in a vessel containing a large volume of distilled water and replaced in the distilled water baths of the apparatus. At the same time three containers which had been drying over the steam radiator were placed in the saponin baths. The motor was again run for 30 minutes. At the end of this time the first three containers were removed from the apparatus and were ready for drying. The others were roughly rinsed and replaced in the distilled water baths as before, a further three being placed in the saponin baths. In this way, a number of sample-fractions were treated in an exactly similar manner in a relatively short time. Further, it was found that the plunging action of the apparatus, with the consequent emptying and filling of the containers, provided a very satisfactory scouring action. While some of the kemp/

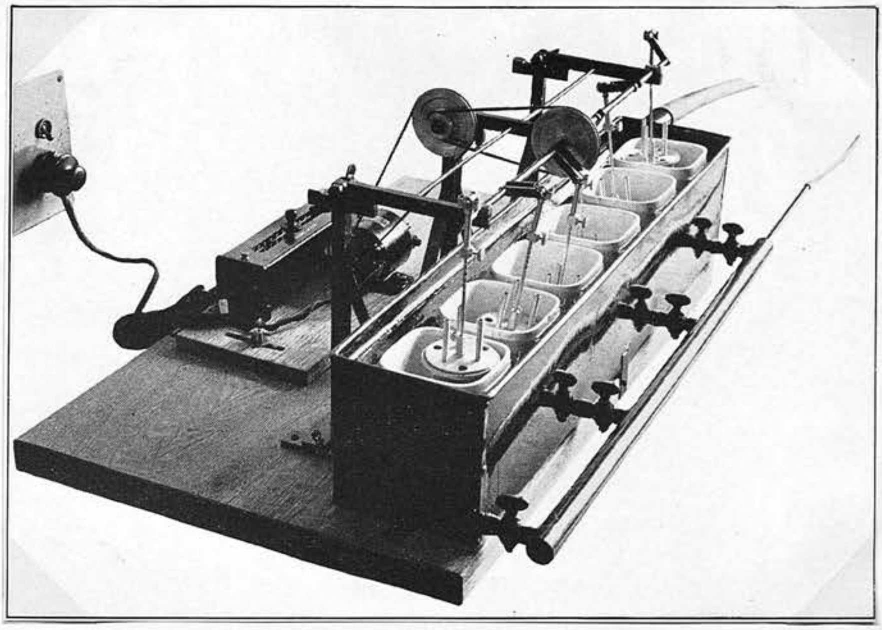

Fig. 10. Photograph of Permanent Scouring Apparatus.
(From the Journal of the Textile Institute, Vol. 23, No. 20)

kemp fibres protruded through the meshes of the gauze, it was exceptional for any to escape.

The above method of treatment was found to be highly satisfactory. The degreasing and scouring of the sample-fractions was carried out most efficiently and a number were able to be treated in an exactly similar manner in the shortest possible time. Accordingly, details of a permanent scouring apparatus were prepared and placed in the hands of an instrument maker. This apparatus is described by Miller and Bryant (27), Appendix I, pp. T267-T269, and is illustrated in Fig. 10. It will be noted that it was capable of scouring and rinsing eighteen sample-fractions simultaneously. The technique was also modified, since it was found by further experiment that degreasing in two changes of benzene at 40°C. for 15 minutes each followed by scouring (after evaporation of the benzene) in $\frac{1}{8}$% saponin solution (hot) for 15 minutes with constant agitation and rinsing in hot distilled water, cleansed the fractions most efficiently. There was, therefore, no advantage in using longer periods for the various operations.

Since wool and other fleece fibres are hygro-

scopic/

scopic, the only absolute weight of a wool sample is the absolute dry weight. It was shown by Barritt and King (26) that the rates of moisture regain of all classes of fleece fibres were almost identical. The determination of the absolute dry weights of the sample-fractions in order to find the percentage weights of kemp in the samples was thus unnecessary.

After removal from the apparatus, the containers were placed in an incubator oven, maintained at a temperature of 70°C., and left there for 12 hours. At the end of this time the sample-fractions were set aside to condition to laboratory humidity for 24 hours. They were then weighed and the percentage weights of kemp were calculated. The means of the percentage weights of kemp in the two samples removed from each sheep were found, thus providing a single kemp analysis figure for each animal.

RESULTS.

The data accumulated from the analyses of the wool samples collected as described in the foregoing section are set out and explained below.

It should be noted that although samples were obtained from some five humdred sheep in the experimental flock, owing to the impossibility of obtaining comparable wool samples from sheep less than eighteen months old, comparisons between the kemp percentage figures of dams and their offspring were necessarily limited to sheep which were adult (eighteen months old at least) when samples were collected. This accounts for the small number of dam-to-progeny comparisons.

It has been explained that the sires of a number of the experimental ewes sampled had been disposed of before this work was commenced. Consequently it was not possible to compare the kemp content of some of the ewes with that of their sires since the latter had not been sampled. Further, in each year of the flock-book records, the sires of about 10% of the lambs born were not definitely known, due to mistakes in reading ewe's numbers, tags being torn out of sheep's ears, and other causes/

causes. Analyses were made only of samples from sheep of which at least one of the parents had been sampled, with the exception of some of the percentage figures in the analysis of the ewe-flock as a whole, Fig. 11, page 62, and the kemp figures for the progeny groups of three rams which had not been sampled, Figs. 16, 17 and 18, pages 73, 74, 75.

The ages of the experimental sheep ranged from $1\frac{1}{2}$ to $4\frac{1}{2}$ years. The fleeces of sheep older than this were not analysed. The question of the influence of age on kempiness will be discussed later.

The relationship between the kemp analysis figures of 11 rams and 143 of their female progeny is shown in Table II, and of 72 ewes and their progeny (one daughter per ewe) in Table III. It will be noted that the coefficient of correlation of rams and their female progeny was $+ 0.28 \pm 0.08$ and of ewes and their female progeny $+ 0.25 \pm 0.11$. In order to obtain reliable tests of the significance of these coefficients reference was made to Fisher (28), Table V.A. It was found from this that for 143 pairs of variates a correlation coefficient of 0.28 corresponds to a value of $P = .01$, and for 72 pairs/

Table II.

The relationship between percentage of kemp in rams and percentage of kemp in their offspring.
Correlation Table.

Offspring

Rams	0.0–0.9	1.0–1.9	2.0–2.9	3.0–3.9	4.0–4.9	5.0–5.9	6.0–6.9	7.0–7.9	8.0–8.9	9.0–9.9	10.0–10.9	11.0–11.9	12.0–12.9	13.0–13.9	14.0–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–18.9	19.0–19.9	20.0–20.9	21.0–21.9	22.0–22.9	23.0–23.9	24.0–24.9	Totals
0.0–0.9	14	8	2	4	4	9	1	6	3	2	4	2	1	2	3	2	2	1	1					2		73
1.0–1.9																										
2.0–2.9																										
3.0–3.9																										
4.0–4.9																										
5.0–5.9																										
6.0–6.9	1					2		2	1		1	1		1			1						1			11
7.0–7.9																										
8.0–8.9																										
9.0–9.9																										
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15.0–15.9	2	2			1	3	1	2					1	1	1	1										15
16.0–16.9																										
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18.0–18.9	2	2	1			1			1	2	2	3	1			1	2			1						19
19.0–19.9																										
20.0–20.9	1	1			1			1				1														5
21.0–21.9																										
22.0–22.9																										
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26.0–26.9																										
27.0–27.9																										
28.0–28.9				1	1			2	1	1		2	1	2	2	3			2	1					1	20
Totals	20	13	3	5	7	15	2	13	6	5	7	9	4	6	6	7	5	1	3	2			1	2	1	143

Coefficient of Correlation = +0.28 ± 0.08

Table III.

The relationship between percentage of kemp in ewes and percentage of kemp in their offspring.

Correlation Table.

Offspring

Ewes	0.0–0.9	1.0–1.9	2.0–2.9	3.0–3.9	4.0–4.9	5.0–5.9	6.0–6.9	7.0–7.9	8.0–8.9	9.0–9.9	10.0–10.9	11.0–11.9	12.0–12.9	13.0–13.9	14.0–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–18.9	19.0–19.9	20.0–20.9	21.0–21.9	22.0–22.9	23.0–23.9	24.0–24.9	Totals
0.0– 0.9	5	1			1	2			1	1			1		1					1			1			15
1.0– 1.9		1	1	1	2	1								1	1	1			1							10
2.0– 2.9																										
3.0– 3.9											1															1
4.0– 4.9											2															2
5.0– 5.9						1																				1
6.0– 6.9																										
7.0–7.9																										
8.0– 8.9		1						1							1											3
9.0– 9.9																										
10.0–10.9				1		1					1															3
11.0–11.9												1														1
12.0–12.9				1												1										2
13.0–13.9		1			1	1				1									1						1	6
14.0–14.9									1						1											2
15.0–15.9							1			1				1		1							1			5
16.0–16.9																										
17.0–17.9						3		1	1			1														6
18.0–18.9			1			1										1		1	1							5
19.0–19.9																										
20.0–20.9																										
21.0–21.9												1	1													2
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36.0–36.9																										
37.0–37.9																										
38.0–38.9						1								1												2
Totals	5	4	2	3	4	11	1	2	3	3	6	4	2	3	4	4	2	1	3	2			2		1	72

Coefficient of Correlation =+0.25 ± 0.11

pairs of variates a correlation coefficient of 0.25 corresponds to a value of P = .05. Therefore, the correlation between the kemp analysis figures of the rams and those of their daughters is significant, but a similar correlation in the case of ewes and their daughters is low. However, undue weight should not be attached to the difference in the levels of significance of the two correlation coefficients since the number of pairs in the rams' series was almost twice the number of pairs in the ewes' series. Had the number of pairs of variates not differed so widely in the two cases, then this might have been regarded as evidence suggestive of sex-linkage. In the absence of recorded male progeny, it is not at present possible to determine whether for kemp content any influence of sex-linkage inheritance exists. A certain amount of preliminary evidence would appear to have been obtained but until opportunity for further work occurs it is not desirable to stress unduly this aspect of the problem.

In Fig. 11 the distribution of the kemp analysis figures in the experimental ewe-flock is given. There are 320 individual analyses included in the diagram/

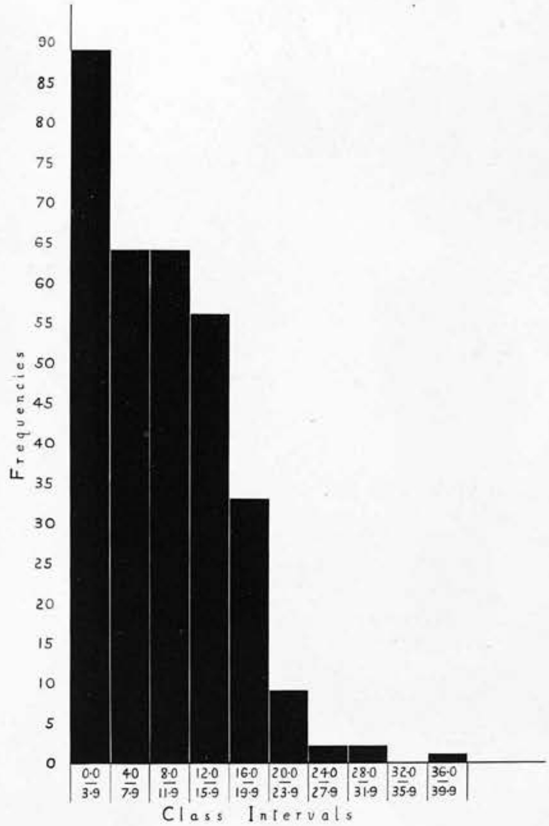


Fig. 11. Distribution of the kemp percentage figures for the ewe-flock.

Mean percentage = 8.97 ± 0.37.

No. of individuals = 320.

diagram. By reference to Table IV it will be noted that 27.8% of these sheep had kemp analyses of less than 4%, and 20.0% had analyses of from 4% to 7.9%. Thus 47.8% had kemp analysis figures of less than 8%. Of the remainder 47.8% had kemp figures ranging from 8% to 19.9% and 4.3% had analyses of over 20%. The mean kemp percentage figure in this ewe-flock was found to be 8.97 ± 0.37. Full details of the actual kemp analyses will be found in Appendix Table I.

It is worthy of note that the breeding sheep on this farm had been selected in such a way that individuals showing a very high proportion of kemp had been eliminated from the stock during some seven years before these investigations were commenced.

In Fig. 12 the distribution of the kemp analysis figures in stud rams belonging to breeders in many parts of Scotland is given, and details of the actual percentages will be found in Appendix Table II. These rams had been carefully selected for breed points, including comparative freedom from kemp. In this respect they were suitable for comparison with the ewe-flock above. It can be seen by reference to Fig. 12 and to Table IV that 32.3% of the/

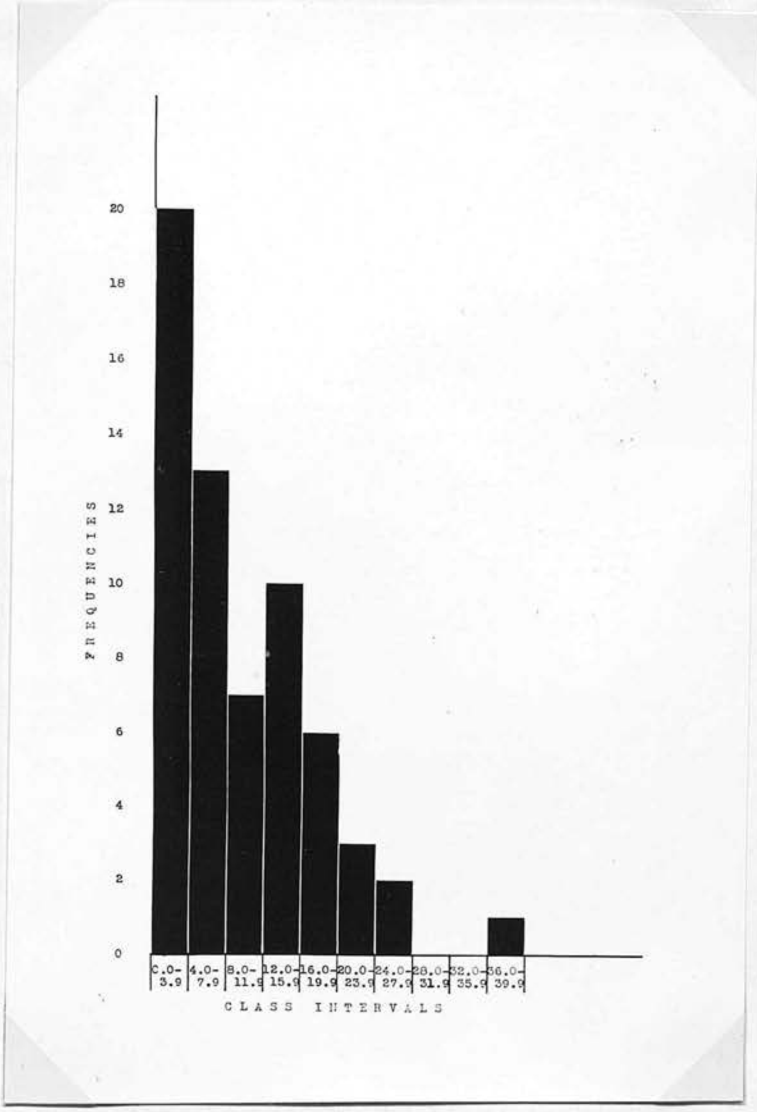


Fig. 12. Distribution of kemp percentage figures in a group of stud rams.

Mean percentage = 9.28 ± 1.03
No. of individuals = 62.

the rams had kemp analyses of less than 4% and 21.0% had kemp analysis figures of from 4% to 7.9%. Thus 53.3% had less than 8% of kemp in their fleeces. Of the remainder, 37.1% had kemp analyses ranging from 8% to 19.9% and 9.6% had analysis figures greater than 20.0%. The mean kemp percentage was found to be 9.28 ± 1.03.

Table IV.

	Less than 4%		4% - 7.9%		8% - 19.9%		20% and over.		Mean kemp per cent.
	No.	Percentage of whole	No.	Percentage of whole	No.	Percentage of whole	No.	Percentage of whole	
Stud Rams	20	32.3	13	21.0	23	37.1	6	9.6	9.28 ± 1.03
Flock Ewes	89	27.8	64	20.0	153	47.8	14	4.3	8.97 ± 0.37
Estimate for Average Commercial Flock		18.0		16.0		50.0		16.0	

From general experience gained during the course of this work, in which visits have been made to a large number of Blackface sheep farms in Scotland/

Scotland, and from an examination of large numbers of Blackface ewes, it can be confidently stated that there are few commercial Blackface flocks in which the mean percentage of kemp is as low as that of the stud rams referred to above or the ewe flock which was mainly used for the purpose of this experiment.

In Table IV an estimate is given of an average distribution of kemp in a typical commercial flock. The percentages must of necessity be approximate but an endeavour has been made to avoid assessing the values too highly. This is included solely for purposes of comparison.

The close similarity in the distribution of the kemp percentage figures in the ewe flock and in the group of stud rams can be seen from the figures. This is especially noticeable with regard to the first two classes, viz.: 0 to 3.9% and 4 to 7.9%.

In Figs. 13, 14 and 15 the kemp analysis figures obtained from groups of the female progeny of rams A, B, and C are shown; details of the actual kemp percentages are given in Table V. By reference to Table VI. it will be noted that, of the progeny of ram A (kemp analysis less than 1%) 46.7% had kemp figures of less than 4% and 24.4% had analyses of from 4% to 7.9%. Thus 71.1% of the daughters of this ram had less than/

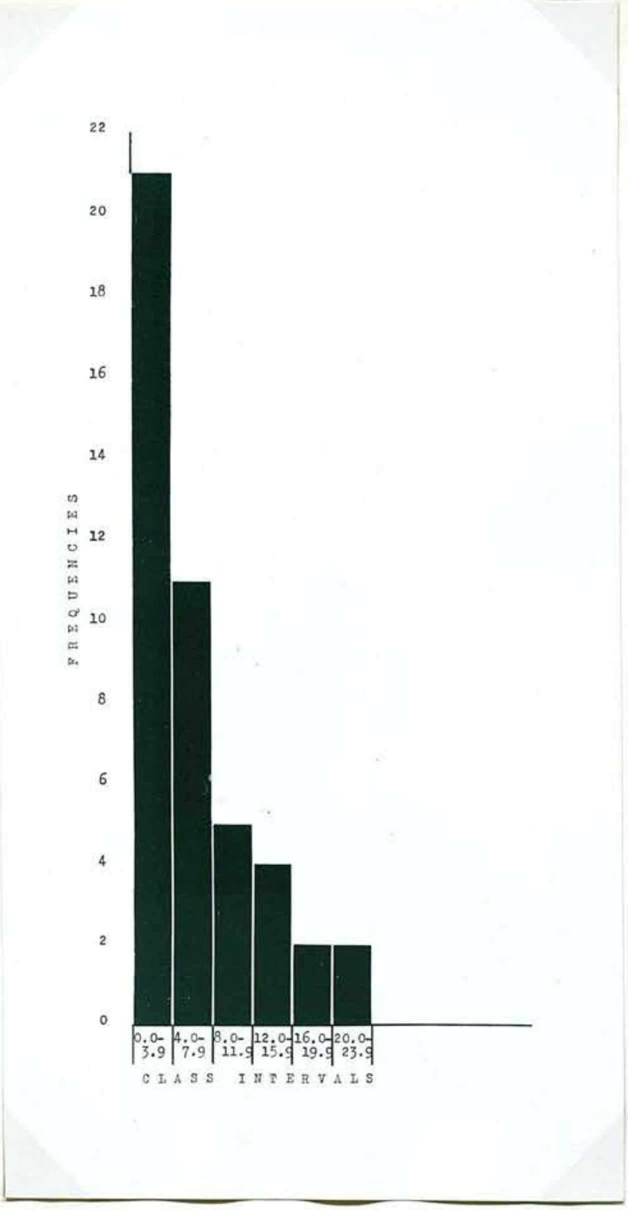


Fig. 13. Distribution of the kemp percentage figures in the female progeny of ram A.

Mean percentage = 6.19 ± 0.91

No. of individuals = 45.

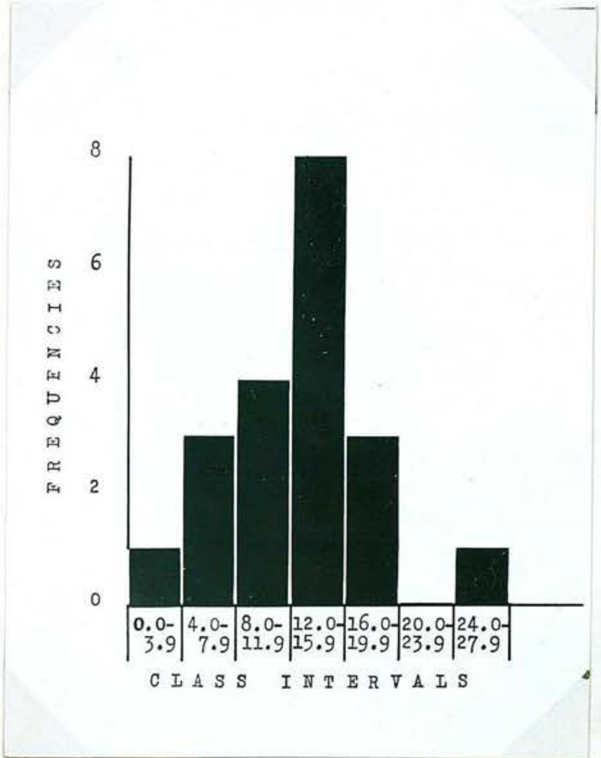


Fig. 14. Distribution of the kemp percentage figures in the female progeny of ram B.

Mean percentage = 13.05 ± 1.13.
No. of individuals = 20.

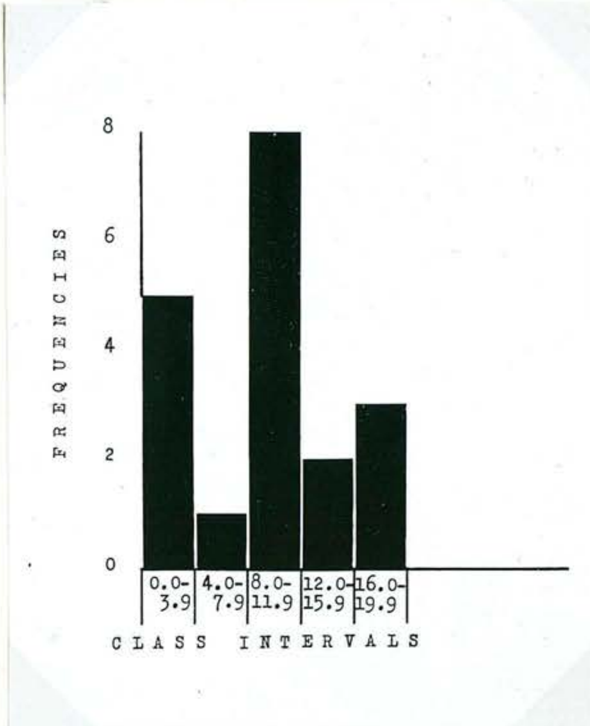


Fig. 15. Distribution of the kemp percentage figures of the female progeny of ram C.

Mean percentage = 9.25 ± 1.31.

No. of individuals = 19.

Table V.

Kemp Percentage Figures of the Progeny of Rams A, B and C.

	Kemp Percentage Figures of Progeny
	<1 <1 <1 <1 <1 <1 <1 <1 <1 <1 <1 1.19 1.22 1.23 1.32 1.59 1.94
Ram A	2.21 3.30 3.41 3.65 4.54 4.76 4.84 5.22
Kemp Percentage	5.75 5.94 5.98 6.79 7.04 7.25 7.44 8.57
<1	9.84 10.79 10.89 11.63 12.51 13.17 13.40 14.75
	16.13 17.58 23.61 23.70
	Mean = 6.19 ± 0.91
Ram B	3.65 4.51 7.10 7.74 8.70 9.65 11.72 11.90
Kemp Percentage	12.53 13.11 13.45 14.10 14.97 15.21 15.84 15.97
28.98	18.76 18.84 19.06 24.20
	Mean = 13.05 ± 1.13
Ram C	<1 <1 1.12 1.86 2.17 5.15 8.74 9.44 9.49 10.76
Kemp Percentage	10.80 11.25 11.94 11.96 12.36 15.65 16.08 16.26 19.87
18.35	Mean = 9.25 ± 1.31

than 8% of kemp in their fleeces. Of the remainder, 24.4% had kemp figures ranging from 8% to 19.9% and 4.4% had analyses of over 20%.

Ram B (Fig. 14), which had a kemp figure of 28.9% had only 20% of his progeny with less than 8% of kemp, and 75% with analyses of from 8% to 19.9% of kemp, the majority showing from 12% to 15.9%.

Of the daughters of ram C (Fig. 15), which had a fleece with 18.35% of kemp, 26.3% had kemp figures of less than 4% and 68.4% had analyses ranging from 8% to 19.9%, the greatest number of these being in the class 8% to 11.9%.

Table VI. /

Table VI.

Progeny of:-	Less than 4%.		4% - 7.9%		8% - 19.9%		20% and over.		Mean kemp percentage.
	Nos.	Percentage of whole	nos.	Percentage of whole	Nos.	Percentage of whole	Nos.	Percentage of whole.	
Ram A (kemp analysis <1%)	21	46.7	11	24.4	11	24.4	2	4.4	6.19 ± 0.91
Ram B (kemp analysis 28.9%)	1	5.0	3	15.0	15	75.0	1	5.0	13.05 ± 1.13
Ram C (kemp analysis 18.3%)	5	26.3	1	5.3	13	68.4	-	-	9.25 ± 1.31
Ram D (not sampled)	9	19.6	7	15.2	27	58.7	3	6.5	10.63 ± 0.98
Ram E (not sampled)	6	16.2	7	18.9	21	56.7	3	8.1	10.88 ± 1.23
Ram F (not sampled)	2	10.0	2	10.0	15	75.0	1	5.0	13.69 ± 1.24

Figs. 16, 17 and 18 show similar details for groups of the female progeny of rams D, E and F and details of the actual kemp analysis figures are given in Table VII. These three rams were disposed of before this work was commenced, so that no analysis of their fleeces could be made. The details of the progeny groups are given here because the distribution of the kemp percentage figures for each/

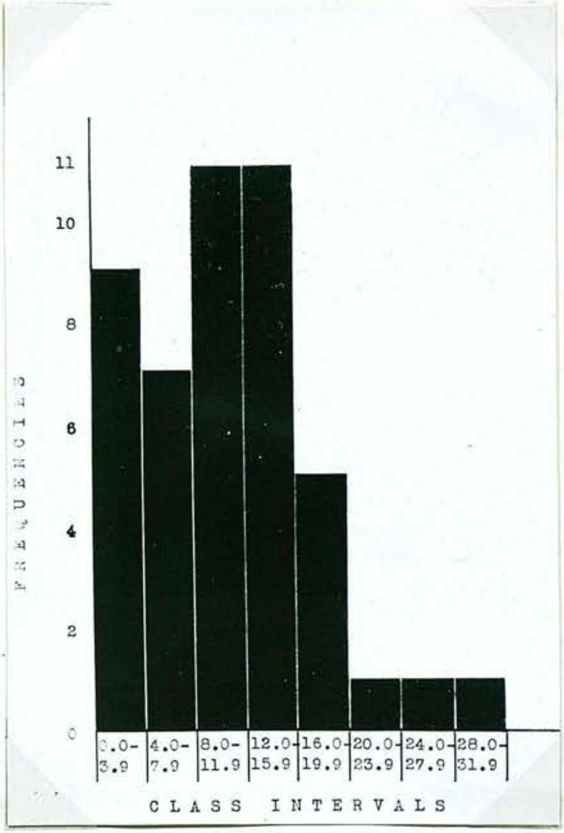


Fig. 16. Distribution of the kemp percentage figures in the female progeny of ram D.

Mean percentage = 10.63 $\pm$ 0.98

No. of individuals = 46.

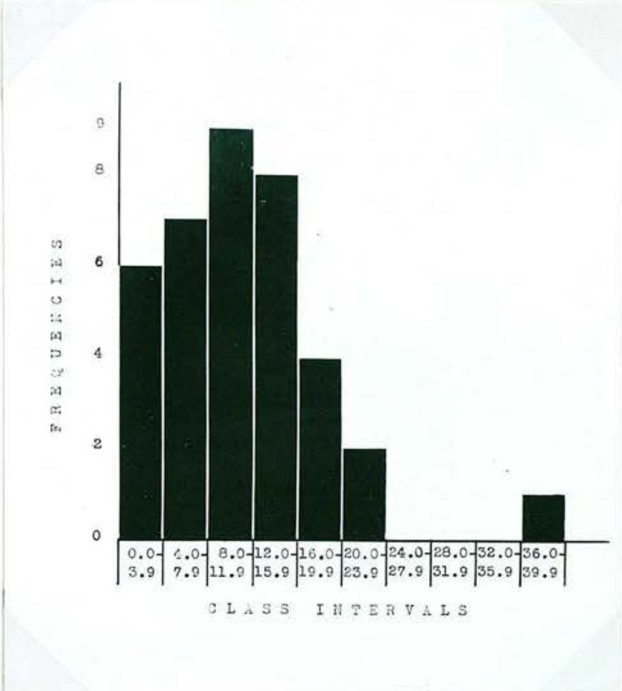
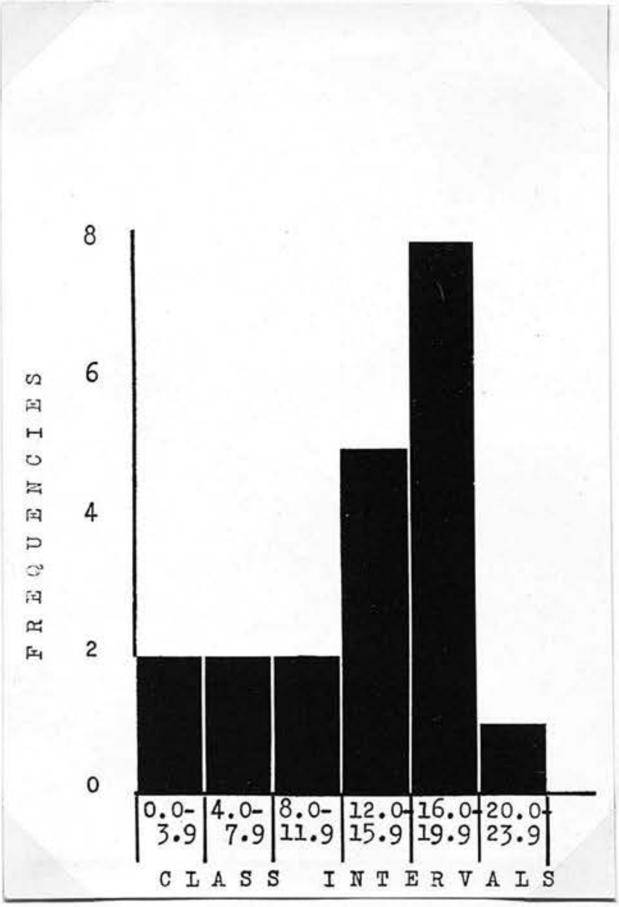


Fig. 17. Distribution of the kemp percentage figures in the female progeny of ram E.

Mean percentage = 10.88 ± 1.23.

No. of individuals = 37.



<u>Fig. 18.</u> Distribution of the kemp percentage figures in the female progeny of ram F.

Mean percentage = 13.69 ± 1.24.

No. of individuals = 20.

Table VII.

Kemp Percentage Figures of the Progeny of Rams D, E and F.

	Kemp Percentage Figures of Progeny
Ram D	<1 <1 <1 1.11 1.54 1.69 1.85 3.08 3.88 4.29 5.89
not	5.97 6.41 6.66 6.87 7.65 8.31 9.21 9.30 9.53 10.01
sampled	10.44 11.10 11.36 11.42 11.64 11.71 12.13 12.75 12.96
	13.11 13.25 13.26 13.49 13.93 14.67 15.08 15.66 16.03
	16.87 17.07 18.11 19.38 22.22 25.23 31.34
	Mean = 10.63 ± 0.98
Ram E	<1 <1 1.27 1.36 2.58 3.95 4.46 5.48 5.72 6.32
not	6.82 6.86 7.01 8.04 8.34 8.39 8.57 8.78 9.04
sampled	9.75 10.36 10.55 13.40 13.51 13.75 14.25 15.01 15.54
	15.85 16.29 16.70 18.08 18.50 21.87 23.27 38.93
	Mean = 10.88 ± 1.23
Ram F	1.34 1.55 6.44 7.74 9.90 11.11 13.60 14.27
not	14.45 14.72 15.59 16.08 16.38 17.03 17.60
sampled	17.87 18.53 18.93 19.50 21.37
	Mean = 13.69 ± 1.24

each group shows considerable divergence from that of the ewe-flock. Reference to the figures and to Table VI shows that the kemp figures of the progeny of rams D and E were distributed similarly, but the progeny of ram F were considerably more kempy, 75% having kemp percentages of from 8% to 19.9%. On the assumption that the ewe groups selected for each ram during the years he was used represented a random sample of the ewe flock as a whole - no conscious selection either for or against kempiness having been carried out in the particular matings involved - the kemp analyses of the six progeny groups above clearly indicate that different rams transmit widely different expressions of kemp content to their offspring. It is extremely unlikely that the differences in kempiness shown by the various progeny groups, when compared to the whole ewe flock, could have arisen by chance; and it is even more unlikely that the wide divergences displayed by the progeny of Rams A, B and F were accidental or coincidental.

In Table VIII the usual test for the significance of the difference between two means is applied for the difference between the mean kemp percentage or each progeny group and the mean kemp figure of the ewe-flock.

Table VIII.

Significance of the Difference between the Means of the Kemp Percentage Figures of the Various Progeny Groups and the Mean Kemp Percentage in the Ewe-flock.

Progeny of:	Mean kemp percentage figure	D-- difference from mean kemp percentage of ewe-flock	$S.E._D$ - standard error of the difference	$\frac{D}{S.E._D}$
Ram A	6.19	2.78	0.98	2.82
Ram B	13.05	4.08	1.19	3.42
Ram C	9.26	0.28	1.37	0.21
Ram D	10.63	1.65	1.04	1.59
Ram E	10.88	1.91	1.28	1.49
Ram F	13.70	4.72	1.29	3.65

It will be noted that the difference is clearly significant in the case of the progeny of rams B and F and closely approaches significance for the progeny of ram A, but there is no indication of significance for the progeny groups of rams C, D and E. It would seem that these three rams and especially ram C, were unable to influence the kemp content/

content of the fleeces of their progeny to the degree exhibited by, for example, ram B.

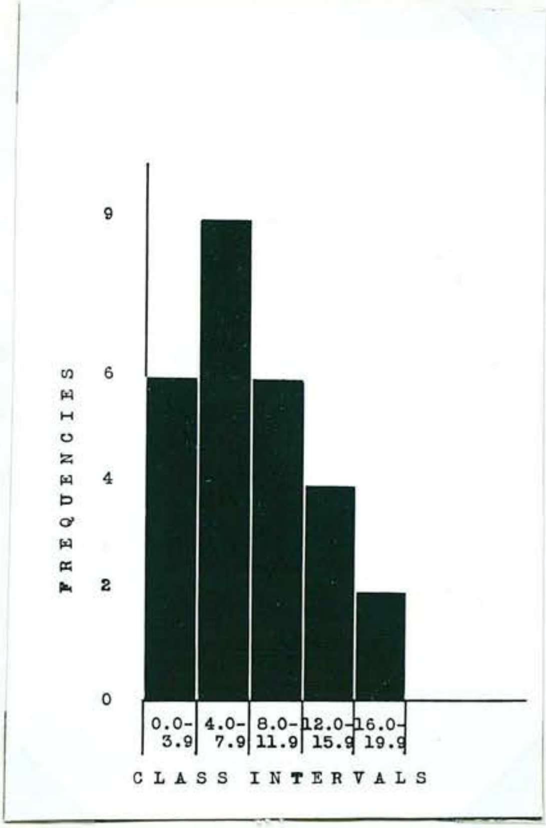
In Table IX the kemp analyses of rams G, H, J, K and L and some of their female progeny will be found. Since the number of progeny analyses available for each of these rams was small, and since the five rams had the same kemp figures, the kemp percentages of their progenies were combined in a composite diagram, Fig. 19, in which the distribution of the kemp percentage figures for the whole group is shown. It will be noted that 6 ewes (or 22.2%) had analyses of less than 4% and 9 ewes (or 33.3%) had kemp figures of from 4% to 7.9%. Thus 15 ewes (or 55.5%) had kemp percentages of less than 8%. The remaining ewes, 12 (or 44.4%), all had analyses of from 8% to 19.9%. By comparison with the kemp figures for the ewe-flock, Fig. 11, page 62, it will be observed that while a smaller proportion of the group under discussion had kemp percentages of less than 4, appreciably more had analyses of less than 8%; 55.5% against 47.8% in the ewe-flock. Compared with the progeny of ram A, Fig. 13, page 64, the present group appears to be definitely more kempy. Reference to Table IX, however, shows that the mean kemp percentage is 8.01 ± 1.01. It is evident that

there/

Table IX.

Kemp Percentage Figures of the Progeny of Rams G, H, J, K and L.

	Kemp Percentage Figures of Progeny.
Ram G Kemp percentage <1	10.56 14.99
Ram H Kemp percentage <1	1.32 4.56 5.27 5.50 5.61 7.35 7.92 9.36 10.56 15.21 15.48 16.86 18.35 Mean = 9.53 ± 1.44
Ram J Kemp percentage <1	<1 2.94 5.52 7.75 8.89 14.76 Mean = 6.72 ± 1.86
Ram K Kemp percentage <1	<1 1.13 5.28
Ram L Kemp percentage <1	<1 8.32 11.21
	Mean of Group = 8.01 ± 1.01



<u>Fig. 19</u>. Distribution of kemp percentage figures in the progeny of rams G, H, J, K and L, each of which had kemp analysis figures of less than 1%.

there is no significance in the difference between this mean and the mean kemp figure of the progeny of ram A.

In Table X the kemp percentage figures for rams M, N and O and groups of their progeny will be found. The total number in each group is too small to furnish much evidence of the breeding performance of these rams as regards the expression of kempiness in their progeny. It might, perhaps, be noted that ram N, like ram C, appeared to be unable to impart his degree of kempiness to many of his offspring.

The differences between the mean kemp figures of the groups and the mean flock kemp percentage are not significant.

In Table XI and Fig. 20 particulars are given of the kemp analysis figures of 57 groups of sire, dam and offspring. In the diagram the matings of each individual ram are separated by a horizontal line. The kemp analyses of 10 rams, ewes to which they were mated and the resulting female offspring are shown.

In the first case the ram (ram A) had an analysis of less than 1% and figures are given for 15 individual matings. It will be noted that four of the progeny (or 26.6%) had kemp figures of less than/

Table X.

Kemp Percentage Figures of the Progeny of Rams M, N and O.

	Kemp Percentage Figures of Progeny.
Ram M Kemp percentage 6.83	<1 5.00 5.15 7.65 7.86 8.29 10.65 11.67 13.46 16.20 22.11 Mean = 9.87 ± 1.71
Ram N Kemp percentage 15.82	<1 <1 1.37 1.68 4.08 5.40 5.43 5.67 6.28 7.01 7.04 12.14 13.85 14.36 15.55 Mean = 6.72 ± 1.26
Ram O Kemp percentage 20.51	<1 1.90 4.91 7.10 11.00 Mean = 5.08 ± 2.73

Table XI.

Kemp Percentage Figures for Rams, Ewes and Offspring in 57 Matings.

Percentage of kemp		
Sire	Offspring	Dam
	<1	<1
	<1	<1
	5.43	<1
	5.27	1.54
	13.40	1.36
	10.56	4.88
	10.79	4.99
<1	5.94	10.76
	3.30	12.90
	1.32	13.11
	18.35	13.93
	5.61	15.54
	5.22	17.07
	5.50	18.11
	11.63	21.37
	5.52	<1
<1	3.97	10.55
	8.89	14.42
	14.76	14.75

Percentage of kemp		
Sire	Offspring	Dam
	2.98	1.94
<1	10.56	3.41
	14.99	8.78
<1	1.13	1.21
	5.28	17.47
<1	11.21	31.34
	22.11	<1
	5.00	5.39
6.83	8.29	17.60
	5.15	17.92
	16.20	25.23
	<1	<1
	1.37	<1
	14.36	1.87
15.82	15.55	12.96
	4.08	13.12
	6.28	15.08
	5.43	38.93

Table XI (Contd.)

Percentage of kemp			Percentage of kemp		
Sire	Offspring	Dam	Sire	Offspring	Dam
	<1	<1		14.10	<1
	9.44	<1		19.06	<1
	12.36	<1		18.84	1.32
18.35	1.12	8.04		15.84	1.55
	10.76	10.89		3.65	1.72
	2.17	18.08		11.72	11.64
			28.98	24.20	13.26
				9.65	13.75
20.49	4.91	<1		13.45	15.53
				22.11	15.53
				7.10	17.58
				19.23	23.38
				13.11	38.93

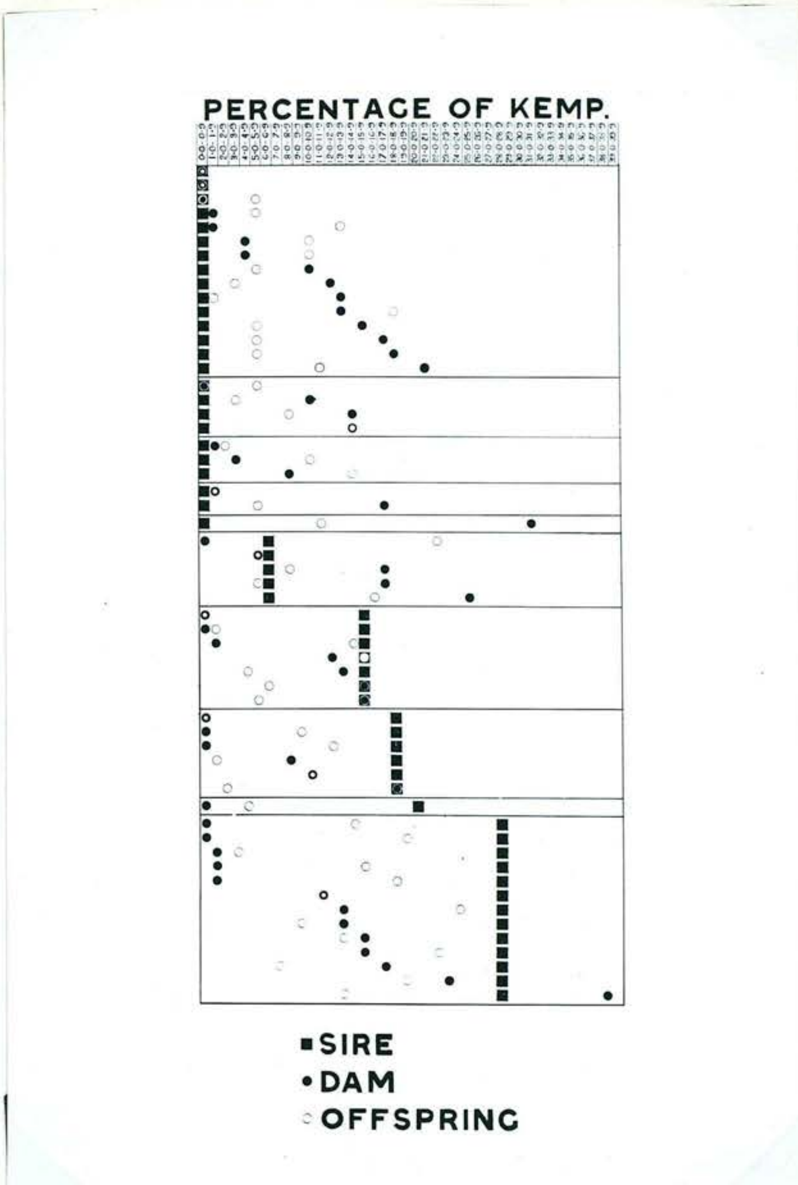


Fig. 20. Diagrammatic representation of the kemp analysis figures of sire, dam and offspring in matings of ten rams.

- sire, dam and offspring combined.
- sire and dam.
- sire and offspring.
- dam and offspring.

than 4%, and 10 (or 66.6%) had analyses of less than 8%, so that only five daughters (or 33.3%) had kemp analyses of more than 8%. Further, nine of the progeny (or 60.0%) had kemp figures identical with those of their parents, or intermediate between those of the sire and dams and six (or 40%) had kemp figures exceeding those of their parents.

Considering next the second-largest group of matings, those of ram B which had a kemp analysis of 28.98%, only one of the progeny (or 7.7%) had a kemp analysis of less than 4%, and two (or 15.4%) had kemp figures of less than 8%. Thus eleven daughters (or 85.4%) had over 8% of kemp in their fleeces. Eight of the progeny (or 61.5%)had kemp values identical with those of their dams or intermediate between those of their parents, while five (or 38.5%) had figures below those of both parents.

These analyses are interesting in that they furnish further evidence of the tendency shown by these rams in previous data (Figs. 13 and 14, pages 67 and 68) to transmit to their offspring a specific degree of kempiness.

The numbers of matings recorded of the other eight rams are too small to indicate the degree to which/

which each transmitted its expression of kemp to its offspring. It should be noted, however, that in eighteen of the twenty-nine matings (62.1%) of these rams, the offspring had kemp analyses identical with that of one of their parents or intermediate between their parents' analyses. Finally, out of the whole series of matings, in thirty-five cases (61.4%) the progeny had the same kemp analysis as one of their parents or analyses intermediate between those of their parents.

DISCUSSION.

In a search of the literature the writer has failed to find any published account of investigations on the inheritance of kemp carried out by means of the analyses of a large number of fleeces of adult sheep in a recorded flock. Roberts (3) states that, in the Welsh Mountain breed, the percentage of kemp in the adult fleece is correlated with the type of birth coat and that non-kempy adult fleeces correspond to a type of covering in the lamb which is definitely unsuitable for mountain conditions. Barker (29) reviewing Roberts's work, states that the type of birth coat exhibited by the lamb is governed by heredity. He does not, however, quote any scientific proof of this. White (30) refers to the relationship between kemp in the adult Welsh fleece and the type of coat of the lamb. He states further that the type of birth coat was found to be inherited and that more than one factor is concerned. These authors have not published data, so far as the writer is aware, which demonstrate the mode of inheritance of kemp in the Welsh Mountain breed.
Darling/

Darling (2) investigated the wool, long hair, kemp relationships in a number of selected Blackface sheep. He found that the range of variability of kemp was very great and deduces from this that kemp could be bred out of the fleece. Barker (29) makes allusion to the opinion held by many experienced breeders, that the presence of kemp is governed by hereditary factors. The writer has met breeders of Blackface sheep who were convinced that kemp could be practically eliminated from the breed by judicious selection of breeding stock. Personal opinions, however, even when based on much practical experience, do not constitute scientific evidence, and of this there appears to be an almost complete absence.

The literature contains many references to cross-breeding experiments made, in many cases, with a view to producing an improved type of fleece by the use of fine-woolled rams on ewes of coarse-woolled breeds.

Dechambre (31) found that the offspring from the cross between a medium fine-woolled Berrichon ewe with a hairy coated African fat-tailed ram had hairy coats like that of the sire. Güldenpfennig (32) obtained the following relationships between kemp and/

and wool fibres in the Somali breed and various crosses:

	Kemp : Wool weight
Somali male	4 : 1
Electoral x Somali ..	1 : 1.3
Mutton Merino x Somali ..	1 : 2
Dishley Merino x Somali ..	1 : 2.3
Franconian x Somali ..	1 : 1.4
Rhön x Somali	1 : 1.7

(Presumably Somali rams were used in each case)

Ewart (33) mated Blackface ewes to a Southdown ram. He found there was considerable variation both in body conformation and in fleece characters in the F_1 and F_2 generations, but all the progeny resulting from this cross were free from kemp.

Völtz (34) crossed ewes of the Pomeranian land breed with an Oxford ram. He reports that the mixed wool of the former (which contains kemp) is dominant over the Oxford down type of wool.

Spöttel (35) found that in the F_1 generations of crosses between Moufflon and Somali sheep with Merinos, a kempy type of fleece predominated and that other fleece characters in the F_1 were intermediate/

intermediate between the Moufflon or Somali and the Merino. He states further that in the F_2 generation kempiness predominates at first, but a gradual refinement occurs with advancing age.

Belekhov (36) analysed the fleeces of a Moufflon ram, Chuntuk ewes, and six animals of the F_1 generation obtained from this mating, three males and three females. In this and other Russian papers, much difficulty was experienced in following the writers' system of fibre classification, nor was it clear what Russian word is the exact equivalent of the English word kemp. It appears, however, that this writer obtained the following figures:

Percentage of kemp (lit. "dead hair") in:-

Moufflon male	-	96.41
Chuntuk females	-	Variable but negligible.
F_1 generation (average)		53.35

Ivanov, Belekhov, Dobrogorsky and Zhitnikov (37) in fleece analyses of F_1 animals from matings of a Lincoln ram to Hissar ewes obtained these results:-

Percentage of kemp (lit. "dead hair") in:-

Hissar females	-	50
Lincoln male	-	-
F_1 individuals (average)	-	7

Ivanov/

Ivanov, Belekhov and Greben (38) in the F_2 generation from crosses of Voloshian and Chuntuk ewes with Lincoln rams observed no segregation of fleece characters. They state that the F_2 resembles the F_1; that there was intermediate inheritance of fleece characters and that in the F_2 from Chuntuk ewes none of the Chuntuk characters such as coarse hair or kemp were found.

Among other Russian work dealing with the inheritance of fleece characters in crosses are papers by Belekhov (39) and (40), Belekhov and Greben (41) and Ivanov and Belekhov (42). These are all concerned with the crossing of coarse-woolled breeds with Merinos. Kemp fibres were not found in either the F_1 or the F_2 generations but there was a more marked segregation of characters in these crosses than was found, for example, in the Lincoln x coarse-woolled crosses. In summing up the suggestion is made that the number of factors involved in the Merino crosses is smaller.

The examples quoted of observations on the occurrence of kemp fibres in crosses between non-kempy and kempy breeds of sheep indicate that, if kempiness be inherited, the inheritance is not of a simple Mendelian type, but is probably governed by multiple/

multiple factors.

It is doubtful, however, whether analyses of kempiness in interbreed crosses have much in common with a survey of the incidence of kemp in a pure-bred flock such as the present work.

It might be argued that this investigation has not been conducted on correct genetical lines; that ewes and rams should have been sampled at the appropriate time and samples obtained from their progeny when these became adult. It is admitted that this would have been the ideal procedure, but it is emphasised that the best use had to be made of the material available in a limited time. Further, the flock of sheep which provided the bulk of the experimental material was managed on strictly commercial lines, and it was not possible to interfere with the ordinary farm routine.

It is claimed that the data produced establish beyond doubt the fact that the presence of kemp fibres in the fleece of the Blackface sheep is definitely controlled by heredity. If this were not so, the distribution of the kemp percentage figures for the progeny group of each of the rams would be expected to approach that of the whole flock/

flock. This has been shown not to be the case.

The ages of the experimental sheep varied between $1\frac{1}{2}$ and $4\frac{1}{2}$ years, and this might be thought to constitute a source of considerable error in comparisons of kemp content. No evidence was found, however, to show that the percentage of kemp in individual sheep varied to any appreciable extent between these ages. Darling (2) showed that with advancing age the percentage weight of long hair decreases and the percentage weight of wool increases. He produced figures for groups of Blackface rams of different ages as follows:-

		Mean percentage weight of wool	Mean percentage weight of long hair	Mean percentage weight of wool and long hair together. (the non-kemp fraction)
Shoulder staples	Shearlings ..	40	57	97
	2-shear ..	47	50	97
	3-shear ..	48	48	96
	4-shear ..	48	50	98
	aged ..	53	44	97
Haunch staples	Shearlings ..	34	59	93
	2-shear ..	36	56	92
	3-shear ..	38	50	88
	4-shear ..	41	49	90
	aged ..	44	48	92

It/

It will be seen that the figures for mean percentage weight of wool and long hair together are extraordinarily constant over the five age groups both for shoulder samples and haunch samples. These figures represent the mean percentage weight of the non-kemp fractions of the samples. It is clear, therefore, that decrease in the percentage weight of long hair with advancing age is balanced by the increase in the percentage weight of wool. It has been observed by the writer that, in some instances, very old sheep show a complete absence of long hair, thus upsetting the non-kemp to kemp ratio. Although this seldom occurs till sheep reach a very advanced age (over ten years), it was thought advisable, as a precautionary measure, to restrict the analyses to sheep not over $4\frac{1}{2}$ years old. Barker (29) states that "individual sheep examined over a period of years do not show any large differences between the proportions of kemp in different years", thus confirming the above findings.

The influence of factors other than genetic on the expression of fleece characters involves a wide field of investigation. This work, however, is not intimately concerned with such influences, since/

since all the experimental sheep, with the exception of breeders' stud rams, were kept on the same farm under the same climatic conditions, and all shared the same grazing land. It is not the practice on the farm in question to feed the stock rams intensively. These are kept out till a few weeks before they are mated to the ewes, when they are brought into the house and fed moderately well till they are allowed to run with the ewes. This brief period of hand feeding has no appreciable effect on the expression of kempiness in the fleece. Not less than 3-4 months' feeding are required to effect any marked change in the length or diameter of a kemp fibre in such a way as to cause material change in the percentage of kemp to total wool substance produced. The rams in question received hand feeding only for some 3-5 weeks before the mating season commenced. This was discontinued shortly after the rams were removed from the ewes, except during particularly inclement weather, snowstorms, etc.

With further reference to the results obtained in this work, it is clear that the expression of kemp in the fleece of Blackface sheep, as measured by/

by the percentage weight in the dorsal area of maximum density, is not controlled by a simple Mendelian type of inheritance. This statement is not, perhaps, justified with reference to the progeny groups of the various rams, where kemp analyses of the dams were not available. By reference, however, to the kemp analysis figures for rams, ewes and the resulting offspring in fifty-seven matings shown in Fig. 20, page 86, it is evident that neither the non-kempy condition shown by rams 1-5 nor the grossly kempy condition shown by ram B, behaves as a Mendelian dominant. The figures obtained from these matings, in fact, clearly indicate intermediate inheritance governed by multiple factors. Further reference to Fig. 20 will show that out of 25 matings of rams with kemp analyses of less than 1% in 15 cases (60.0%) the progeny had kemp figures of less than 8%. Similarly, in 32 matings of rams with analyses ranging from 6% to 28% the progeny in 12 cases (37.5%) had kemp percentages of less than 8%. Again, it will be found that the number of ewes with kemp analyses of less than 4% in this series is 22. Of these 12 (or 54.5%) had progeny with kemp figures of less than 8%. To consider/

consider the figures for these ewes in another way: There were 9 ewes with analyses of less than 4% of kemp mated to rams with kemp figures of less than 1%. Of these 7 (or 77.7%) had progeny with kemp analysis figures of less than 8%. There were mated to the other rams (kemp analyses ranging from 6% to 28%) 13 ewes with kemp percentage figures of less than 4%. In only five cases (38.5%) did the resulting progeny have kemp percentages of less than 8. The above figures indicate that the non-kempy condition of the fleece in the Blackface sheep is incompletely dominant over the more kempy condition. This is supported by the breeding performances of rams A, G, H, J, K and L, as illustrated in Figs. 13 and 19, pages 67 and 81.

If, then, the presence of kemp in Scottish Mountain Blackface sheep is inherited intermediately with a tendency for non-kempiness to be dominant, eradication or reduction to negligible proportions is within reach of the practical breeder by the use of rams with fleeces of very low kemp content, in conjunction with the rigid rejection for breeding purposes, of grossly kempy offspring. The level of kempiness tolerated in the offspring would be decreased/

decreased each season. It is thus theoretically possible to establish an almost kemp-free flock in the course of a very few generations, provided an adequate supply of rams with a low kemp content in the fleece and of good breed type were available. It would probably take a little longer in practice, however, since many points other than kempiness must be considered when selecting breeding stock, such as body conformation, size, colour, etc.

There appear to be no great obstacles, therefore, to prevent the breeders of Scottish Mountain Blackface sheep from first reducing by considerable proportions, and then practically eliminating kemp fibres from the fleeces of their sheep by intelligent selective breeding together with rigid culling of all reversions to the kempy condition.

It seems probable that it would be extraordinarily difficult to eliminate kemp entirely from Blackface sheep. During the examination of wool samples from some six hundred sheep in the course of this work, samples from the dorsal area of only one were encountered which contained no kemp. The large number classed as containing less than 1% all contained a few typical kemp fibres, though it/

it was always possible to obtain samples from the shoulder region of sheep in this class which were entirely free from kemp.

If the incidence of kemp in this breed were to be reduced to such negligible proportions, however, the remaining few fibres would not be a serious objection.

In a genetic experiment involving the analysis of samples of wool the time which must elapse before samples can be secured from progeny prevents rapid accumulation of evidence, since the sheep is essentially a slow-breeding animal. Under ideal conditions the future development of this work should follow a method which would aim at establishing firstly a family of sheep (rams and ewes) as nearly homozygous for absence of kemp as possible. Similarly a definitely kempy strain would be evolved. To effect this would probably take 6-8 years of controlled breeding. Not until this has been carried out with success, could reciprocal matings between kempy and non-kempy individuals be made with a view to determining what mode of inheritance is involved in the transmission of kemp; similarly the question of any influence of sex-linkage must await facilities such as are outlined above before it can be determined.

CONCLUSIONS.

1. The presence of kemp fibres in the fleeces of Scottish Mountain Blackface sheep is inherited.

2. The type of inheritance is that known as Intermediate Inheritance, depending upon a multifactor basis. No form of simple Mendelian inheritance is sufficient to accommodate the results obtained.

3. The lower degrees of kempiness encountered show a tendency to behave as partial or incomplete dominants over the varying higher degrees of kempiness.

4. The presence of kemp could be reduced to negligible proportions by the use of homozygous non-kempy breeding rams, and ruthless culling of kempy progeny.

5. It is improbable that absolute elimination of kemp could be achieved.

SUMMARY.

1. Notes on the origin, history and distribution of the Scottish Mountain Blackface breed of sheep are given.

2. The salient points of the breed type of the Scottish Mountain Blackface sheep are described; the characteristics of the fleece are discussed and a definition of kemp fibres as encountered in the wool of this breed is given. Observations on the macroscopic characters, growth, and economic importance of kemp in relation to the utilisation of Blackface and other wools, are included.

3. Investigations to discover the nature of the distribution of kemp over the body and the methods adopted in obtaining samples are described.

4. A short description of the system of flock management of the sheep which supplied most of the experimental material is given, with special reference to the methods employed to mark and record the ewes and lambs.

5. /

Summary (Contd.)

5. Laboratory methods used in making analyses of the wool samples are described in detail.

6. Data accumulated from the analyses of the wool samples collected are presented.

7. A discussion of the facts emerging from the data is given, including a survey of the results obtained by other workers.

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(t.t. = translated title)

APPENDIX TABLE I.

Kemp Analysis Figures of Ewes.

No. of sheep	Per cent. wt. of kemp. Left side.	Per cent. wt. of kemp. Right side.	Mean per cent. wt. of kemp.	No. of sheep	Per cent. wt. of kemp. Left side.	Per cent. wt. of kemp. Right side.	Mean per cent. wt. of kemp.
780	<1	<1	<1	A405	22.00	25.40	23.70
781	<1	<1	<1	A406	<1	2.13	<1.32
822	15.00	12.50	13.75	A407	<1	<1	<1
842	10.77	11.43	11.10	A415	<1	<1	<1
895	16.98	18.18	17.58	A444	24.32	22.22	23.27
A 29	25.00	25.45	25.23	A476	2.21	1	1.36
A 63	4.26	5.49	4.88	A496	10.45	12.82	11.64
A 99	<1	<1	<1	A528	12.96	14.42	15.87
A152	6.90	6.67	6.79	A600	<1	<1	<1
A217	25.00	22.22	23.61	A624	13.51	17.54	15.53
A253	14.06	18.52	16.29	A632	10.71	9.09	9.90
A255	39.22	38.63	38.93	A635	11.11	11.11	11.11
A258	5.88	3.03	4.46	A649	13.75	18.42	16.08
A261	14.66	16.42	15.54	A660	<1	<1	<1
A265	20.37	15.79	18.08	A666	32.43	31.25	31.84
A276	12.96	13.56	13.26	A667	18.18	15.22	16.70
A289	13.57	14.28	13.93	A669	10.64	12.77	11.71
A290	4.29	4.29	4.29	A670	22.73	20.00	21.37
A292	5.88	6.06	5.97	A671	<1	<1	<1
A294	1.41	1.97	1.69	A674	12.16	13.33	12.75
A303	22.22	22.22	22.22	A683	1.21	1.87	1.54
A319	<1	<1	<1	A688	10.26	11.36	10.81
A344	2.44	1.25	1.85	A690	1.82	1.69	1.76
A346	<1	<1	<1	A692	<1	3.92	2.21
A373	4.76	4.76	4.76	A696	10.00	7.14	8.57

APPENDIX TABLE I. (Contd.)

A699	1.56	1.54	1.55	A872	1.64	1.79	1.72
A700	7.14	8.90	8.04	A880	<1	<1	<1
A703	7.32	2.67	4.99	A948	<1	<1	<1
A705	19.35	19.64	19.50	A955	<1	<1	<1
A709	<1	<1	<1	A956	7.46	7.84	7.65
A710	<1	<1	<1	A958	16.42	16.67	16.55
A719	12.82	13.51	13.17	B 11	10.26	6.52	8.39
A724	11.67	10.81	11.24	B 12	10.81	8.69	9.75
A725	17.07	16.67	16.87	B 15	15.62	18.52	17.07
A726	10.81	10.71	10.76	B 20	<1	<1	<1
A734	13.73	12.50	13.12	B 21	7.69	10.91	9.30
A765	11.11	15.38	13.25	B 24	1	2.04	1.27
A766	<1	<1	<1	B 26	11.59	15.38	13.49
A769	18.64	18.42	18.53	B 28	13.79	16.36	15.08
A773	8.57	13.21	10.89	B 30	<1	<1	<1
A775	2.78	3.37	3.08	B 34	6.82	6.90	6.86
A779	17.78	17.95	17.87	B 35	9.80	13.04	11.42
A790	5.08	9.62	7.04	B 38	16.44	20.55	18.50
A797	17.24	18.97	18.11	B 41	12.07	10.64	11.36
A800	11.63	14.29	12.96	B 42	<1	4.65	2.58
A814	10.94	12.33	11.64	B 48	18.33	17.50	17.92
A815	12.82	17.19	15.01	B 54	6.33	7.41	6.87
A817	31.91	30.77	31.34	B 56	<1	<1	<1

APPENDIX TABLE I (Contd.)

B 58	13.33	16.00	14.67	B302	9.57	8.24	8.91
B 69	15.79	15.52	15.66	B306	10.0	9.68	9.84
B 73	<1	1.72	1.11	B311	<1	<1	<1
B 74	9.59	7.02	8.31	B312	3.45	4.44	3.95
B 91	<1	<1	<1	B331	4.08	6.98	5.53
B120	<1	<1	<1	B345	<1	<1	<1
B121	21.74	22.00	21.87	B361	14.00	16.28	15.14
B127	<1	<1	<1	B372	12.82	16.67	14.75
B137	11.11	11.63	11.37	B398	14.58	13.21	13.90
B147	7.41	2.44	4.93	B401	9.44	10.53	9.99
B150	13.21	13.79	13.50	B404	7.55	10.87	9.21
B155	<1	2.17	1.34	B406	1.85	<1	1.18
B156	18.75	21.88	20.32	B410	10.53	10.34	10.44
B166	14.81	17.24	16.03	B413	2.33	4.48	3.41
B168	11.63	14.58	13.11	B416	4.62	3.13	3.88
B178	12.90	15.63	14.27	B421	4.90	8.42	6.66
B215	14.89	14.00	14.45	B427	8.62	9.80	9.21
B219	11.11	9.38	10.25	B429	11.86	13.56	12.71
B241	<1	1	<1	B434	17.15	12.28	14.72
B242	5.56	3.51	4.54	B440	7.50	3.45	5.48
B244	17.02	18.18	17.60	B441	7.94	9.09	8.52
B256	4.65	6.12	5.39	B444	6.67	10.00	8.34
B271	4.93	7.94	6.44	B446	8.20	7.27	7.74
B285	13.95	16.33	15.14	B447	17.65	15.11	16.38
B287	<1	<1	<1	B449	13.95	15.55	14.75
B292	3.64	5.41	4.53	B451	1.92	1.96	1.94

APPENDIX TABLE I (Contd.)

B453	2.22	<1	1.36	B548	8.47	11.54	10.01
B456	8.33	12.77	10.55	B550	<1	<1	<1
B457	<1	<1	<1	B555	5.88	3.38	4.61
B465	<1	<1	<1	B560	8.33	10.64	9.49
B468	17.39	16.67	17.03	B563	9.44	9.62	9.53
B469	7.14	10.34	8.74	B589	9.33	11.39	10.36
B470	14.63	16.67	15.65	B594	2.56	5.32	3.94
B476	<1	1.93	1.22	B597	14.55	14.29	14.42
B479	18.18	19.67	18.93	B598	2.56	5.19	3.88
B480	12.24	11.67	11.97	B601	18.31	21.43	19.87
B484	<1	<1	<1	B603	7.94	6.94	7.44
B487	5.88	6.76	6.32	B652	11.90	13.89	12.90
B488	2.04	5.26	3.65	B653	<1	<1	<1
B489	10.00	12.00	11.00	B664	2.18	<1	1.34
B491	10.14	11.46	10.80	B685	1.91	<1	1.21
B492	2.00	1.72	1.86	B698	<1	<1	<1
B501	17.39	17.54	17.47	B731	17.95	18.75	18.35
B504	13.16	14.04	13.60	B734	14.29	16.67	15.48
B505	<1	<1	<1	B735	4.55	6.67	5.61
B506	<1	1.87	1.19	B738	14.29	17.40	15.85
B521	7.14	10.00	8.57	B739	5.56	5.88	5.72
B525	7.14	10.42	8.78	B745	4.76	4.26	4.51
B528	6.98	3.95	5.47	B747	5.08	5.77	5.43
B537	6.78	5.00	5.89	B749	9.26	9.62	9.44
B542	<1	<1	<1	B755	14.29	16.13	15.21
B543	5.13	7.69	6.41	B756	8.51	8.89	8.70
B546	13.16	13.64	13.40	B758	3.39	7.94	5.67

APPENDIX TABLE I (Contd.)

B759	3.90	3.08	3.49	B860	4.84	4.84	4.84
B762	22.78	21.43	22.11	B862	1.49	1.59	1.54
B765	5.63	5.88	5.75	B864	9.44	12.07	10.76
B767	7.14	3.85	5.50	B879	4.26	7.69	5.98
B774	13.80	13.21	13.51	B884	<1	<1	<1
B776	7.69	6.33	7.01	B888	<1	<1	<1
B779	6.38	7.69	7.04	B889	13.11	15.38	14.25
B780	3.51	4.26	3.89	B890	16.44	16.07	16.26
B782	9.80	14.00	11.90	B896	6.65	6.98	6.82
B794	10.71	14.00	12.36	B899	12.50	10.00	11.25
B810	1.56	4.55	3.06	B900	14.29	17.65	15.97
B818	8.51	8.89	8.70	B901	4.76	3.39	4.08
B820	11.11	12.77	11.94	B907	12.50	12.82	12.66
B822	18.91	17.65	18.28	B915	12.28	12.00	12.14
B824	4.55	5.26	4.91	B917	8.47	7.02	7.75
B825	<1	1.74	1.12	B919	9.09	13.24	11.17
B830	1.64	2.70	2.17	B931	9.68	8.00	8.84
B832	8.69	9.38	9.04	B979	6.52	7.50	7.01
B833	6.76	9.37	8.07	B984	2.21	<1	1.36
B842	10.00	11.11	10.56	B986	20.00	18.75	19.38
B843	13.16	11.90	12.53	C 1	<1	<1	<1
B845	<1	<1	<1	C 2	<1	<1	<1
B846	3.95	6.35	5.15	C 4	1.75	2.04	1.90
B855	11.54	11.90	11.72	C 6	9.44	4.76	7.10
B856	<1	2.23	1.37	C 11	6.25	4.55	5.40
B857	8.93	5.56	7.25	C 12	5.26	9.44	7.35
B858	<1	1.19	<1	C 15	4.55	5.88	5.22
B859	12.50	13.72	13.11	C 16	18.64	18.87	18.76
				C 18	15.58	15.52	15.55

APPENDIX TABLE I (Contd)

C 19	12.70	9.30	11.00	C 77	12.28	14.63	13.46
C 20	7.41	6.78	7.10	C 78	15.15	13.04	14.10
C 21	20.46	17.65	19.06	C 82	22.22	22.00	22.11
C 22	20.34	17.33	18.84	C 85	<1	1.76	1.13
C 24	5.97	3.85	4.91	C100	9.26	7.32	8.29
C 25	5.00	5.00	5.00	C102	6.67	8.62	7.65
C 31	<1	<1	<1	C103	9.44	8.33	8.89
C 32	<1	<1	<1	C104	3.23	5.88	4.56
C 33	14.10	17.57	15.84	C106	9.62	5.88	7.75
C 35	11.29	10.00	10.65	C108	11.76	8.16	9.96
C 36	6.90	8.57	7.74	C112	11.11	10.00	10.56
C 45	17.78	16.13	16.96	C119	17.02	12.50	14.76
C 46	12.24	12.77	12.51	C120	7.14	8.70	7.92
C 47	10.34	8.96	9.65	C124	<1	2.13	1.32
C 50	5.17	5.13	5.15	C125	3.85	3.45	3.65
C 54	5.56	5.48	5.52	C126	25.00	23.40	24.20
C 59	6.78	5.77	6.28	C128	5.88	6.00	5.94
C 61	5.80	4.76	5.28	C129	5.00	2.94	3.97
C 64	7.55	8.16	7.86	C131	<1	<1	<1
C 69	14.71	15.22	14.97	C133	<1	<1	<1
C 70	16.95	13.46	15.21	C139	13.04	9.38	11.21
C 72	<1	<1	<1	C145	10.29	11.29	10.79
C 73	<1	<1	<1	C146	7.04	9.59	8.32
C 76	7.94	7.14	7.54	C153	7.46	3.08	5.27

APPENDIX TABLE I (Contd)

C155	13.33	10.00	11.67
C161	15.00	13.72	14.36
C162	12.31	14.49	13.40
C164	16.33	13.65	14.99
C165	15.92	19.23	17.58
C173	14.12	12.77	13.45
C181	16.07	17.65	16.86
C184	<1	2.86	1.68
C185	11.69	16.00	13.85
C187	18.03	14.12	16.08
C189	17.50	14.89	16.20
C192	1.95	<1	1.23
C257	10.53	12.73	11.63

APPENDIX TABLE II.

Kemp Analysis Figures of Stud Rams.

No. of sheep	Per cent. wt. of kemp. Left side.	Per cent. wt. of kemp. Right side.	Mean per cent. wt. of kemp.	No. of sheep	Per cent. wt. of kemp. Left side	Per cent. wt. of kemp. Right side.	Mean per cent. wt of kemp.
1	<1	1.37	<1	66	<1	<1	<1
2	4.67	4.29	4.48	67	15.17	12.24	13.71
3	12.30	12.07	12.19	82	5.81	6.54	6.18
4	2.63	3.73	3.18	91	6.67	7.77	7.22
21	<1	<1	<1	92	15.79	14.29	15.04
22	18.60	19.18	18.89	93	21.28	24.56	22.92
23	5.88	3.91	4.90	94	11.83	11.24	11.54
25	23.53	18.89	21.21	95	6.38	4.88	5.63
26	8.57	3.64	6.11	96	12.28	12.28	12.28
27	<1	<1	<1	97	<1	<1	<1
28	11.11	15.48	13.30	119	2.38	3.64	3.01
29	18.31	17.50	17.91	122	24.10	24.37	24.24
30	37.33	40.74	39.04	123	7.69	8.33	8.01
44	11.11	11.63	11.37	124	18.64	22.81	20.73
45	17.31	19.10	18.21	125	19.10	16.79	17.95
46	9.88	11.01	10.45	126	6.10	5.00	5.55
47	<1	1.92	1.21	136	10.00	5.17	7.59
52	14.20	17.22	15.71	137	1.19	1.54	1.37
53	4.13	8.16	6.15	138	2.27	1.30	1.79
54	14.67	15.66	15.17	147	<1	<1	<1
61	2.68	4.90	3.79	148	12.50	13.10	12.80
62	13.87	11.43	12.65	151	3.17	5.19	4.18

APPENDIX TABLE II (Contd.)

152	18.28	18.87	18.58
157	<1	<1	<1
158	<1	<1	<1
159	6.67	3.03	4.85
162	4.55	5.55	5.05
166	25.76	26.58	26.17
167	4.65	2.38	3.52
175	10.34	7.92	9.13
180	<1	2.17	1.34
181	<1	<1	<1
188	14.04	16.67	15.36
189	<1	<1	<1
199	5.04	6.90	5.97
200	1.45	1.72	1.59
201	<1	<1	<1
207	21.67	16.87	19.27
208	8.33	11.70	10.02
210	10.81	11.32	11.07

Note:- In all cases where the figures for percentage weights of kemp in the two samples removed from an individual sheep differed by more than five, the samples were discarded and no use was made of the figures. It was thought that mistakes in locating the sampling areas, or in the subsequent classification of the samples, were most probably responsible for such discrepancies. This occurred in 10% of cases.