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THE ANALYSIS AND INTERPRETATION OF DATA ON THE BODY WEIGHT OF THE TWO-TOOTH EWE

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SUMMARY

The analysis of data relating fertility and body weight in the two-tooth ewe is discussed. An outline is given of possible components of a relationship between these two traits in terms of the growth periods or the proportion of fat contributing to two-tooth body weight. Methods of analysis of these components are considered in relation to the interpretation of data on them.

It was considered that insufficient information was available for the inclusion of body weight in selection plans for sheep except for the culling of obviously poorly grown animals.

INTRODUCTION

THE PURPOSE of this paper is to discuss analysis and interpretation problems associated with the possible use of the body weight of the two-tooth (18-month-old) ewe in selection plans based on this trait. Such plans would be based on the thesis that body weight "affects" productive characters of importance such as fertility and ovulation rate (Quinlivan, 1963, 1964) and fleece weight (Coop, 1964).

This discussion will be based on the general thesis that body weight *per se* is unlikely to have any direct effect on other traits and that relationships which do exist arise from common underlying causes.

The first section will consider evidence from the analysis of data relevant to relationships between a two-tooth ewe's pre-mating weight and its lambing performance. The second section will consider the possible components of this weight in terms of the previous growth of the animal, while the third section will consider the components in terms of body tissues with particular emphasis on fat.

As the main aspect to be considered is that of the possible use of relationships with body weight for selection purposes, the two main results of selection should be defined:

(1) Phenotypic selection, which may improve the productivity of a flock for the lifetime of the selected animals.

(2) Genetic selection by which, if the traits are heritable and the appropriate genetic correlations exist, more productive offspring are produced.

These two selection effects may be quite independent; for example, in the Merino body weight and fleece weight are phenotypically but not genetically correlated (Morley, 1955). Selection for body weight would not, therefore, increase the fleece weight of the offspring but would probably mean that they were less efficient producers of the same amount of wool.

Genetic relationships in the Romney have been discussed by Rae (1958, 1962 and 1964) while nutritional aspects of body weight in the sheep have been reviewed by Schinckel (1963). Except for data from mouse selection experiments, the relationships discussed in this present paper will be phenotypic ones of which the relative genetic contribution is at present unknown.

BODY WEIGHT AND FERTILITY

The main published evidence for a relationship between body weight and fertility in New Zealand ewes is in papers by Coop (1962, 1964) and Quinlivan (1963). The data of Coop have been analysed in detail by Coop and Hayman (1962) and they are used here to illustrate some disadvantages of analysis solely by weight range groupings and percentages. It should be emphasized that Coop's conclusions (1962, 1964) are based on consideration of some of these disadvantages and on alternative analyses, while Quinlivan (1963). This method of presentation follows a weight range groups alone.

The purpose of this section is to use published and unpublished data to illustrate difficulties in their analysis. The final conclusions from these data may depend on re-analysis or on further data and are, therefore, still open to discussion.

The method of analysis to be discussed is illustrated in Fig. 1 which shows the percentage of dry ewes by weight range groupings for data from Coop (1962) and from Quinliven (1963). This method of presentation follows a diagram of Coop's and a table of Quinlivan's. In both analyses the populations were heterogeneous and consisted of about 2,000 two-tooth ewes in Coop's data and 2,000 or 3,000 two-tooth ewes in Quinlivan's data. Coop's original figure included lines for the percentage of twin-bearing ewes in each weight range from data for two-tooth and from older ewes. The lines for these two age groups coincided.

The two sets of data in Fig. 1 show that, within any one weight range, there is a wide possible range of per cent. dry ewes. This range cannot be estimated from only two

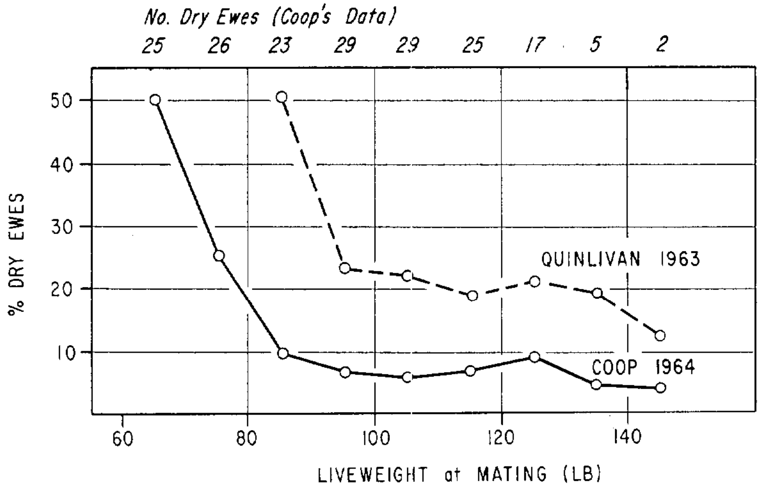

Fig. 1: The percentage of barren ewes plotted against the body weight range (10 lb ranges). (From data of Coop (1964) and Quinlivan (1963).)

sets of data, but as each set is based on both between- and within-flock observations, the between-flock component could have been estimated. As it stands, it is impossible to tell whether the higher probability of dry ewes in the lower weight ranges results from management practices and other environmental effects or from effects operating within one flock. Knowledge of the latter is essential for a culling policy while knowledge of the former gives some assessment of the importance of management practices. This method of analysis gives neither information.

However, if it is assumed that the data come from an homogeneous population, further misinterpretations can still arise from the use of percentages. The actual number of dry ewes is shown for each weight range from Coop's data in Fig. 1. These have been computed from the total ewe figures given by Coop (1962). Although a high percentage of ewes under 90 lb are dry, these comprise only about 40% of all the dry ewes, so that 60% of the dry ewes are in the higher weight ranges. To confirm a relationship between weight and fertility, it is necessary to ask the additional question of whether it is characteristic of dry ewes to differ in average weight from the wet ewes. This analysis problem arises because it is not possible to calculate a correlation or regression between a classification of nil or one or two lambs as the dependent variable and a continuous variable

TABLE 1: AVERAGE PRE-MATING BODY WEIGHTS (LB) CLASSIFIED BY SUBSEQUENT LAMBING PERFORMANCE (Estimated from the data of Coop, 1962)

Age of Sheep	*Dry*	*Subsequent Lambing* *Single*	*Twin*
Two-tooths	96	104	113
Older ewes	123	121	130

such as weight. However, if the covariance term is real, then a difference should exist between the average weights of the classification. Table 1 shows the average pre-mating body weights estimated from Coop's data for two-tooth and for older ewes. For the two-tooth ewes the weight differences are probably real so that it is a characteristic of dry ewes in this population that they are of lower body weight. This is supplementary to the conclusion from Fig. 1 — that there is a higher probability of a ewe in the low weight ranges being barren. If differences were significant and the population homogeneous, then some relationship between body weight and fertility would exist.

However, on two points the method of analysis in Table 1 would lead to different conclusions from those based on Fig. 1. First, the dry two-tooth ewes have an average weight above 90 lb so it seems unlikely that 90 lb (below which per cent. dry ewes increases) is a critical weight determining whether a ewe is dry or not. Secondly, within each lambing group the older ewes are heavier than the two-tooth ewes. Coop's conclusion (based on the coincidence of lines in grouped body weight data) that the increase of fertility with age is the result of liveweight increases, does not appear to be validated by this alternative method of presentation. This is the result of the different distributions amongst body weight ranges of the two-tooth and the older ewes, which are not allowed for in the percentage method of analysis.

Because the actual numbers are not allowed for, culling policies cannot be assessed from percentages calculated within liveweight ranges. In Table 2 the effects of culling have been calculated from Coop's data. The results of a policy of culling two-tooths below 90 lb and older ewes below 100 lb have been used as an example — that is, 18% and 10% of total sheep in each age grouping, respectively. For the two-tooth ewes, a high *percentage* of dry ewes in the culled group does not represent a large *number* of dry ewes while, conversely, in both the two-tooth and older

TABLE 2: THE NUMBERS AND PERCENTAGES OF EWES CULLED CLASSIFIED BY LAMBING STATUS WITH A POLICY OF CULLING ON BODY WEIGHT
(Estimated from the data of Coop, 1962)

Lambing	*Two-tooths under 90 lb*			*Older Ewes under 100 lb*		
	Dry	*Single*	*Twin*	*Dry*	*Single*	*Twin*
No. culled	74	266	22	32	356	64
Total ewes	181	1,453	396	277	2,705	1,679
% culled	41	18	6	12	13	4

TABLE 3: THE EFFECT ON LAMBING AND DRY EWE PERCENTAGE OF THE CULLING POLICY SHOWN IN TABLE 2.

	Dry Ewes as % of All Ewes		*Lambing Percentage*	
	Before Culling	*After Culling*	*Before Culling*	*After Culling*
Two-tooths	9	6	105	111
Older ewes	5.7	5.6	125	128

ewes, a large *number* of single-bearing ewes represents quite a small *percentage*. Because of this, the actual improvements in lambing percentage (Table 3) are small, although the curves shown in Fig. 1 could suggest that culling on body weight might overcome the dry ewe problem.

As has been stated above, between- and within-flock effects are confounded in the data in Tables 2 and 3; however, the analyses of Coop and Hayman (1962) would suggest that the within-flock component is less and more variable than the between-flock one. In this case a culling

TABLE 4: PRE-MATING BODY WEIGHT BETWEEN AND WITHIN GROUPS OF DIFFERENT FACE COVER IN RELATION TO LAMBING PERFORMANCE
(Two-tooth ewes)

BETWEEN GROUPS	*n*	*Mean Weight (lb)*	*Dry Ewes %*
Open faced	40	89	45
Woolly faced	80	80	56
MEAN WEIGHTS WITHIN GROUPS (LB)		*Wet Ewes*	*Dry Ewes*
Open faced		88	89
Woolly faced		79	80

policy for a single flock, based on body weight, might not improve lambing by more than a few per cent.

The possible misleading nature of conclusions based on between-group differences is shown in Table 4. In this case the groups are those based on face cover in one flock. *Between groups,* the heavier open-faced sheep had less dry ewes as two-tooths, suggesting a body weight-fertility relationship. However, the mean weight *within the groups* show that wet and dry ewes had the same body weights so these weights do not explain the fertility differences.

TABLE 5: PRE-MATING BODY WEIGHTS AND WEIGHT GAINS FOR TWO-TOOTH EWES BORN AS SINGLES OR AS TWINS CLASSIFIED BY SUBSEQUENT LAMBING PERFORMANCE
(Data from Massey Face Cover Experimental Flock.)

Birth Rank	*Lambing Performance* *Dry* *(n=20)*	*Wet* *(n=29)*	*Total* *(N=49)*
	PRE-MATING BODY WEIGHT (LB)		
Single	107	109	108
Twin	97	103	100
Total	103	107	105
	WEIGHT GAINS FROM WEANING TO OCTOBER		
Single	30	39	35
Twin	33	37	35
Total	31	38	35

In Table 5 is shown a similar situation for another group of sheep classified according to whether they were born as singles or twins. The numbers are too small for definite conclusions but they illustrate the point of the analysis. If the overall mean weight of dry ewes, not allowing for birth rank, was used as a basis for a culling policy, then the wet ewes born as twins would be culled as heavily as dry ewes born as singles if a normal distribution of weight within groups is assumed. As the subsequent lambing of the twins over the next three years was 20% higher than that of the singles, this would lower rather than increase production.

The discussion so far does not disprove a relationship between two-tooth body weight and fertility but it does suggest that a more rigorous approach to the collection and analysis of data is required if the importance of the possible relationship is to be assessed.

However, body weight is the sum total of previous weight gains and the second half of Table 5 shows the gains between weaning and October which contributed to the body weights in the top half of the table. The differences between ewes which were wet or dry as two-tooths were greater, both for all ewes and for those born as singles and twins. Furthermore, the gains for singles and twins were the same. Thus relationships between pre-mating body weight and fertility could reflect differences in weight gain over earlier periods which are themselves critical for subsequent fertility. In turn, this could reflect differences such as "general fitness" which would show both in growth over critical periods and in fertility. It is likely that concentration of work on relationships over those periods and the reasons for them is more likely to lead to better selection policies, carried out earlier and not penalizing twins, than are attempts to cull on pre-mating body weight. In particular, suitable criteria might be developed for selecting rams for factors which increase "general fitness" in their ewe offspring. However, on present knowledge the selection methods for fertility suggested by Rae (1963) would appear to be the most practical approach until further research results become available.

THE ANALYSIS OF GROWTH PERIODS

If body weights have been taken at various times between birth and two-tooth mating, it is possible to estimate the mean weights at each time of weighing of singles and twins, and of any other groupings required and carry out analyses of variance on these estimates by least squares (Cockrem and Rae, 1959). Variables such as birth date or previous weights can be included to give analyses of covariance. If only the sheep surviving to two-tooth mating are analysed, then all the numbers in each sub-class remain the same and a standard analysis form can be used for all the weighing dates. This form of least squares analysis enables the critical periods to be identified when any differences between groups arise. For large amounts of data or for many groups, an electronic computer is necessary for the matrix inversions which are required.

The result is not a growth curve but a series of estimated weights. However, the important conclusions are likely to be the same as those obtained by attempting the difficult task of trying to fit curves to the rather erratic growth of Romney lambs.

Figure 2 shows a series of weights estimated in this way for lambs of three grades of face cover. Adjustments were

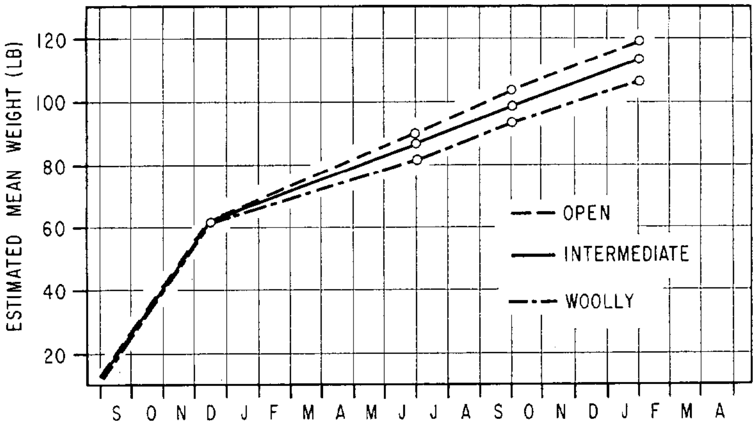

Fig. 2: The estimated mean weights of lambs born in 1958, 1960 and 1961 classified by face cover and plotted against weighing date.

made for the lamb's sex, its birth rank and its year of birth (three years' data). The critical period where open-faced lambs gained more than the woolly-faced ones was between weaning in December and the following October. It is growth over this period which led to differences in two-tooth body weight. (The significance of these results will be assessed by analyses of variance when a computer becomes available.)

There are two important points in the interpretation of results obtained in this way:

(1) Where differences arise gradually over a long period, the successive analyses of variance may show gradually-decreasing probabilities of differences arising by chance. This will depend on the size of the differences and on the variability of the weights. If the 5% level is taken as an absolute point — *i.e.*, such that 4% is interpreted as a real difference, while 6% is interpreted as a chance difference, then a false interpretation could arise. This interpretation is that the difference had arisen in the period prior to the 4% result only, whereas in fact it was a gradual change over a number of periods.

This error can be avoided by common sense and also by adjusting for the previous weight by a covariance analysis. This covariance analysis is equivalent to one obtained by adjusting weight gains for the initial weight (Cockrem, 1956).

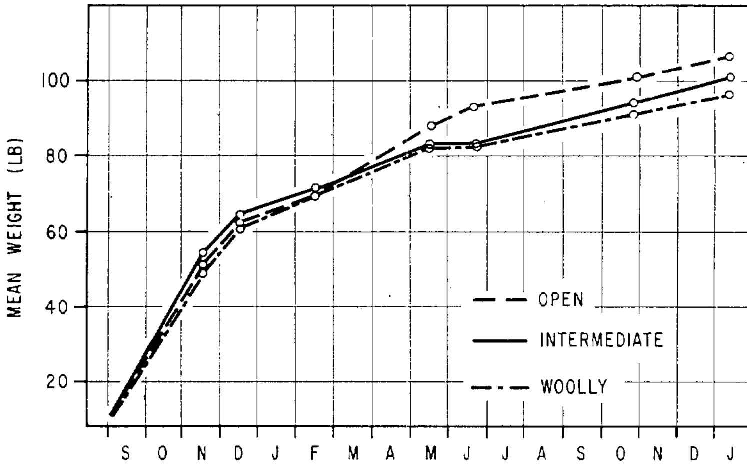

Fig. 3: The mean weights of the ewe single lambs born in 1960. This is a sub-group of means in Fig. 2.

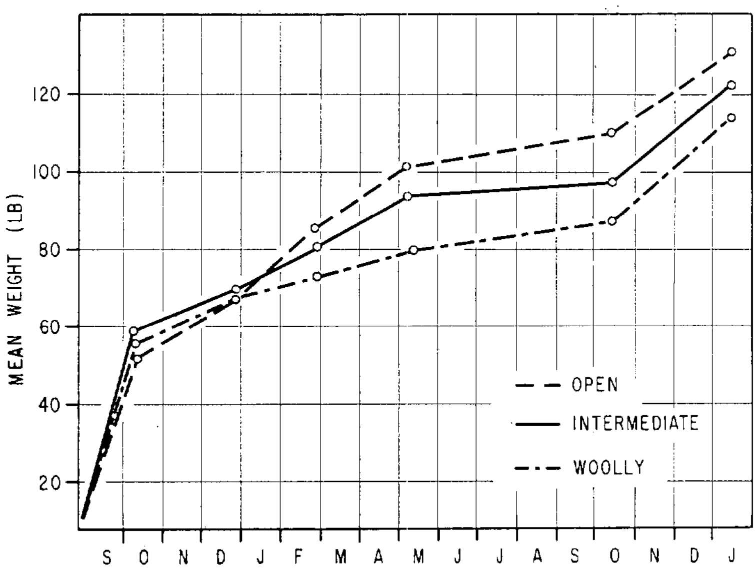

Fig. 4: The mean weights of wether single lambs born in 1958. A sub-group of Fig. 2.

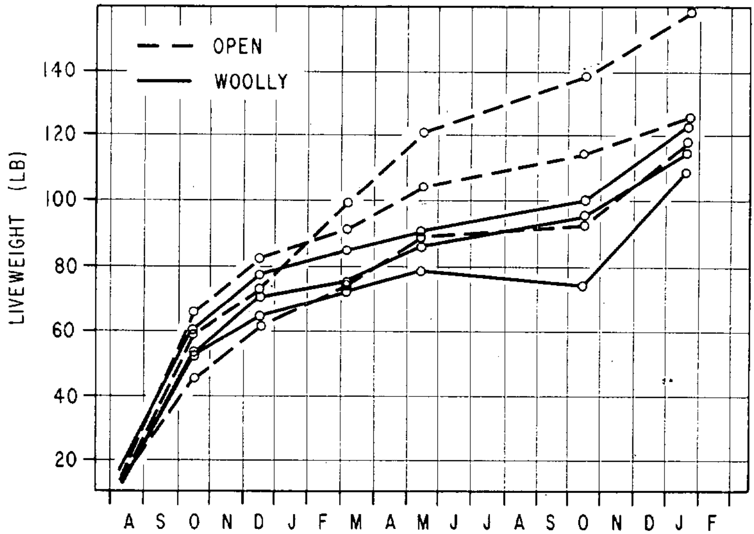

Fig. 5: The weights of some individual lambs on which the means of Fig. 4 are based.

(2) The graphs obtained are of estimated mean weights and not growth curves. Changes in gradient for individuals and sub-groups may have been smoothed out by the averaging. Thus a short critical period could be missed both by this process and by the choice of intervals for weighing. Therefore, plotting of curves for sub-groups or individuals may help in the final interpretation.

This point is illustrated in the next three figures based on the sub-groups and individuals contributing to the estimates in Fig. 2.

Figure 3 shows the sub-group of ewe single lambs in one year with some extra weighings included: the critical period for the woolly-faced sheep was between February and October but in particular over the period May-June.

Figure 4 shows wether single lambs in an earlier year: weaning to October is still the important period but weaning to February also appears to be critical for this group.

Figure 5 shows the curves for some of the individual sheep contributing to the averages in Fig. 4; the curves are somewhat different from those in the original weighted averages, but the conclusion that the lower two-tooth weight of woolly-faced lambs results from differences in gain between weaning and October would still stand. However, the results from the breakdown of these estimates suggest that the slowing of growth in woolly-faced lambs can be fairly abrupt and can occur at different times in different years.

The individual growth diagrams in Fig. 5 show that a particular two-tooth body weight can be arrived at in a number of different ways and also that there is considerable variation in growth over the winter of animals which were run as one flock under the same management system.

If only a few of these growth components of two-tooth body weight contribute to the possible relationship with fertility, then for phenotypic selection it would be of considerable interest to know which periods are important. If the genetic relationships were also known, then a genetic selection policy could also be defined.

THE FAT COMPONENT OF BODY WEIGHT

The alternative method of considering factors making up body weight is to analyse the contribution of the tissue components. The most variable of these components is fat which, besides being a problem in meat production, could also be a problem in that it is inefficient to have an animal laying down surplus fat.

The two aspects to be discussed here are, first, the selection of sires which will produce lambs with the required proportions of fat and, secondly, the possible contribution of the fatty tissues to any relationships of body weight with other traits.

FAT PROPORTIONS IN MEAT PRODUCTION

Most studies of fat in sheep have been concerned with carcass quality and its prediction. As long as animals have to be slaughtered to obtain results, then a progeny test is the main method of selection available. This will result in a number of groups of animals which can be compared for fat weight and for proportions of fat.

The proportion of fat is likely to be the variable of interest in meat production and this will depend on the nutritional treatment, particularly over the period immediately before slaughter, and also the stage of growth and the genotype of the animal. Indirect effects can occur; for example, a genetically slow-growing animal might reach a stage of accelerated fat formation at a greater age than a fast-growing animal.

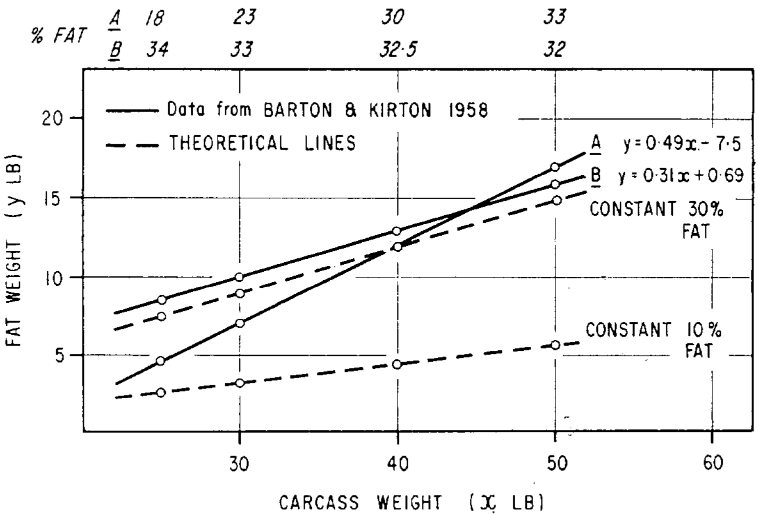

Fig. 6: A comparison of observed and theoretical regression lines of fat weight on carcass weight to illustrate relationships with fat proportions.

This type of effect can be detected only by killing animals over a series of ages. However, for meat-production studies, animals are usually killed at a given time or age (weight variable) or at a given weight (age variable). Both these methods can lead to difficulties of interpretation. However, determination of fat at a constant body or carcass weight has the disadvantage that the time of killing will be spread so that, unless the later killed lambs are stall fed, they will have had a different nutritional treatment prior to slaughter. Environmental temperatures, which also affect fat metabolism (Blaxter, 1962), may also have been different. Further confounding of the required information — that is, the potential of the animal to lay down fat — will also occur with age and maturity effects.

The alternative of killing animals at one time removes the different environmental effects, but will mean that animals of weights not normally killed commercially will be included. However, a regression of fat weight on carcass weight can be calculated for each progeny (or treatment) group and some useful information obtained.

Figure 6 shows two such regression lines (A and B) from two groups of wether lambs from the data of Barton and Kirton (1958). Above the diagram are shown the proportions of fat represented by various points on the lines. For Group A the proportion increases with carcass weight while the slope of line B is such that the fat proportion remains nearly constant. If one requirement is a uniform product over a range of carcass weights, then the Group B lambs are the better ones. If less fat is also required, then a group which had a line below either of these would be the best. Such a group might be one shown by the theoretical line for a constant 10% fat if this were a desirable proportion.

Thus, for a progeny test (or a treatment), selection could be made for the sire which gave a group of progeny (or a treatment group) which fell the closest to a theoretical, desired line both in slope and in mean fat and carcass weights.

This possibility of variation in the slope and the position of regression lines also illustrates the importance of considering these parameters when assessing possible indices of carcass components. An index may show a very high correlation but still be inapplicable because the slope of the regression line varies between groups. More important, the use of an index for estimating a carcass component automatically negates the possibility of selecting for changes in the relationship involved. For example, if in Fig. 6 the relationship of Group B was used to estimate fat weight from carcass weight, then the lower fat proportion of Group A at 30 lb carcass weight would have been missed.

While this regression approach at a point in time might be useful for a progeny test, or nutritional treatment, it does not give information on the rate at which animals are laying down fat relative to other tissues. This is illustrated in Fig. 7 where it can be seen that the individual rates of growth (dotted lines) of y relative to x are quite different from the slope of the regression line of y on x between the individuals at one point in time.

Fat as a Component of Body Weight Growth

The contribution of fat to growth over a period can be obtained only by killing random samples of animals at intervals or by estimating fat in the live animal. This has yet to be done for the Romney lamb in the field, but the potential of such information can be illustrated from the results from various workers who have used mice as the experimental animal.

Figure 8 shows data from two strains of mice for fat weight and fat-free carcass weight up to maturity (Fenton,

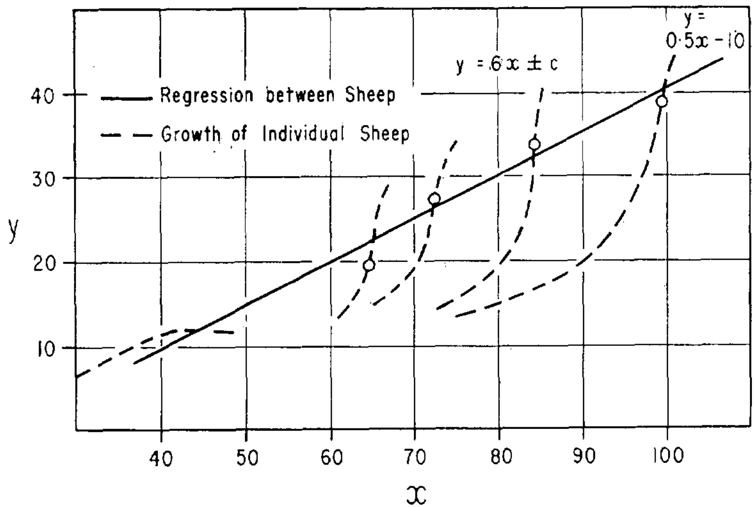

Fig. 7: Theoretical lines to illustrate the difference between growth rate of y *relative to* x *and the regression of* y *on* x *at a point in time.*

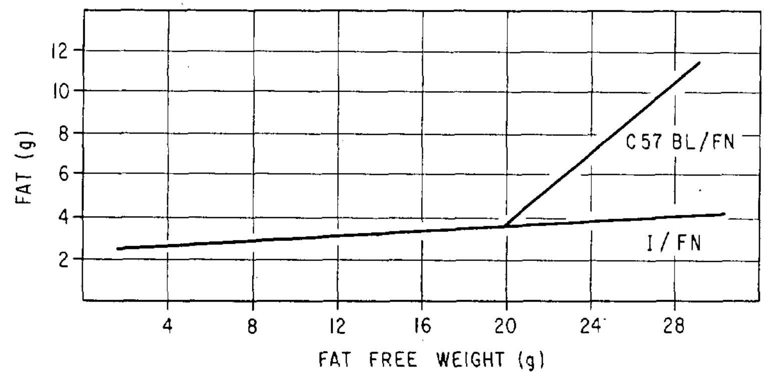

Fig. 8: The growth of fat in two strains of mice (after Fenton, 1956).

1956). Up to about six weeks of age (20 g fat-free weight) both strains laid down fat at a similar rate but at this age the C.57.Bl strain shifted abruptly to a fat-biased metabolism which resulted in a mature mouse which was considerably fatter than the I strain of mice. This illustrates that marked strain differences can occur in the changes in fat metabolism and in this particular case there is ideal material for investigating the underlying physiology leading to the abrupt change.

TABLE 6: THE FAT PROPORTIONS OF MICE RESULTING FROM SELECTION FOR BODY WEIGHT UNDER DIFFERENT CONDITIONS (Data of Falconer, 1960; Fowler, 1958; Hull, 1960.)

Selection Method			*Data at Six Weeks of Age Normal Diet*	
Age Selected	*Strain*	*Diet*	*Body Weight (g)*	*Abdominal Fat (%)*
Six weeks	N	Normal	29.8	15.1*
Six weeks	C	Normal	30.3	9.0*
Six weeks	C	High plane	32.5	1.36
Six weeks	C	Low plane	33.8	1.24
Three wks.	Outbred	Normal	29.0	1.1
Six weeks	Outbred	Normal	25.0	0.7

* Total fat.

Table 6 summarizes the results of a number of experiments by Falconer (1960) and his associates on the effects of selecting for body weight in mice. The first two lines show the result of selecting two different base stocks for six-week body weight (Fowler, 1958). The increase in body weight was correlated with an increase in proportion of fat in strain N but not in strain C. Fowler and Edwards (1960) have also examined fertility and ovulation rates in these selected strains which included low body weight selection and control lines. They found a higher ovulation rate for strain C than for strain N, while within the groups, the only line showing a body weight-ovulation rate correlation was the C strain selected for small size. That was the line in which fat contributed least to the body weight, the correlation being virtually with a fat-free weight. From all their analyses they concluded that the ability to lay down protein was the important aspect of body weight which might be related to ovulation rate.

The second group in Table 6 (Falconer, 1960) shows the result of selecting for six-week body weight under high and low planes of nutrition. The test for fat proportion was made with all mice under a high plane. Abdominal fat was closely correlated with total fat in these animals with similar regression relationships. Selection under a high plane led to a fatter animal than selection under a low plane, although selection progress for body weight was essentially similar. If this is true for sheep the implications are clear.

The third result (Hull, 1960) shows the result of selecting for body weight at two different ages. There was a difference in fat according to the age at which selection was made. Again the implications for sheep are clear.

A final point on the use of Romney sheep for fat lambs: selection for an animal which will start laying down fat at an age suitable for production of a "Prime Lamb" carcass may be incompatible with selecting for an older sheep which lays down the minimum of fat.

DISCUSSION

The possible factors and relationships discussed in this paper are presented in diagrammatic form in Fig. 9. This figure is complementary to Fig. 3 in a paper by Cockrem (1962). The possible relationship, within flocks, between fertility and two-tooth body weight has been broken down according to some of its possible underlying causes. Thus body weight has the growth components and the fat-protein components. The inter-relationship of these is at present unknown as is the possible relationship of the latter with fertility. However, the control of metabolism is likely to affect the fat/protein balance and fertility, particularly through common endocrine control. Metabolic control is also likely to be a common factor affecting growth over the component periods. Other common factors in fertility and

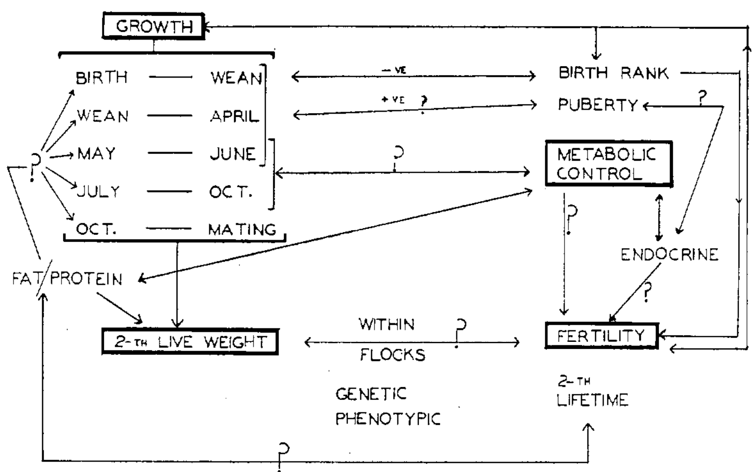

Fig. 9: A diagram to illustrate the possible inter-relationships underlying body weight and fertility.

early growth may be puberty and the lamb's birth rank. A feedback maternal effect will also exist, in that the more fertile ewes will be more likely to produce twins.

Before two-tooth or other body weights are used for selection, it would seem desirable to have answers to at least some of the following unknowns:

(1) Whether a worthwhile relationship exists between two-tooth pre-mating body weight and subsequent two-tooth and later fertility *within* flocks.

(2) The relative importance of the growth periods from birth to two-tooth and their possible relationships with subsequent fertility.

(3) The possible common physiological or other causes which underlie any relationships and their possible genetic bases so they could be directly selected.

(4) Relationships with other productive traits, in particular with efficient wool growth.

(5) The genetic and environmental components of any relationships which might be used for selection.

(6) The contribution of fat to two-tooth body weight and to the body weights in contributing growth periods.

(7) The factors determining fat metabolism in the sheep, in particular information on possible changes from a protein-biased to a fat-biased metabolism and the relationship of these to fertility and efficient production.

(8) The related changes which occur when sheep are selected for body weight at different ages and under different conditions.

Selection experiments to answer this last question could not only answer some of the others but also provide experimental material to answer the remainder. This would be essentially a long-term research approach but a number of these questions could be answered from the analysis of field data.

The conclusion is that, with our present facilities and knowledge, any attempt to improve production by selection for two-tooth pre-mating body weight, except for culling the obvious runts, could lead to unpredictable results.

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DISCUSSION

PROF. I. E. COOP: I can agree with much that Dr Cockrem has said on the need for a careful interpretation and appraisal of liveweight effects, a search for the fundamental operative factors by which liveweight exerts its influence, and a search for an even better measure than pre-mating liveweight. But in his criticism of the mode of presentation of my data (Coop, 1962) and the misinterpretations which can be made, I find myself not in agreement with all he says.

The fundamental point of disagreement is over the question of whether the situation within a flock can be derived from the graphs in which the percentage of barren or twin-bearing ewes is plotted against a sequence of liveweight intervals. My graph of the relationship between barrenness and two-tooth liveweight is reproduced in his Fig. 1. This graph is derived from data from many flocks and represents a predominantly between-flock situation. Dr Cockrem argues that it is not legitimate to conclude, because the graph shows increasing barrenness with decreasing liveweight, that a similar situation would necessarily occur within a single flock, and then gives Table 4 as an example of data from two small flocks of 40 and 80 ewes showing no relationship within the flocks. I agree that such a deduction cannot be made without other confirmatory evidence.

Dr Hayman and I (Coop and Hayman, 1962) studied the influence of liveweight on a number of characters such as fleece weight, lamb weaning weight, and twinning within flocks. We did not study the barrenness character but it would be reasonable to look at the analogy of liveweight-twinning relationships. It was found that the mean within-flock regression was slightly lower than that deduced from the graphs of twinning against liveweight, but as explained in that paper there are reasons why this should be so, and similar reasons could well be used in a barrenness-liveweight relationships. Further, in the 36 flocks studied there was considerable variation in the regression coefficient from flock to flock — a range from +0.015 to −0.008 with a mean of +0.046. 20% of the flocks had a zero or negative regression although the mean was positive (+0.046). There is no reason to doubt that in barrenness-liveweight relationships similar variations would not exist. This shows that there could be flocks in which barrenness actually decreased with decreasing liveweight.

Dr Cockrem's example in Table 4 is, therefore, not beyond possibility. But this also needs to be examined very carefully. Are these apparent anomalies real or are they the result of pure chance through using flocks of inadequate size. I incline to the view that the number of sheep involved have been too small and chance has had too big an influence. For example, in Coop and Hayman (1962), in the 16 flocks with more than 100 ewes there was only one with a negative regression as compared with four in the 20 flocks of fewer than 100 ewes. In the nine flocks each of over 400 ewes (Coop, 1964), only one had a within-flock regression significantly different from the mean between-flock regression. In my opinion, meaningful results require flocks of several hundred ewes, even thousands. In biological terms it would be necessary to postulate that those factors which cause differences in liveweight between flocks were largely inoperative within flocks. This is not inconceivable, though improbable. In short, therefore, I do not regard it as proven that some flocks do not obey the general rule that barrenness increases with decreasing liveweight below 90 lb. Dr Cockrem believes that it is unwise to believe that all flocks do obey the rule.

Dr Cockrem then points out what he considers to be dangers of culling on liveweight. I agree with him that it depends on the within-flock regression. This point has already been discussed. He then argues (from Table 5) that culling on liveweight would prejudice twin-born two-tooths, with which I would agree. This would be important in stud flocks, but in my opinion would be of minor significance in hill flocks where the great majority of two-tooths are reared. Here the problem is lack of size and barrenness, not the absence of twinning. In this environment where ewes are poorly grown, twins are not identified and early and late born lambs not identified, the reproductive situation is dominated by lack of size and a culling policy based on size is important even though it may operate against the twin-born ewe. Dr Cockrem has calculated from my 1962 data that, if all two-tooths below 90 lb were culled, 18% would be culled and lambing percentage would increase by only 6%. However, I suggest that this is a very worthwhile improvement, at least as good as and I think better than one would get from culling 18% on face cover, or as great an improvement in fleece weight from culling out 18% of the lowest producers.

My conclusion (Coop, 1962) that the increase in fertility with age results from liveweight increases, Dr Cockrem says does not appear to be validated. I postulated this and would agree that it is not proven. It would, in fact, be extremely difficult to design a trial to prove it. But, likewise, I cannot agree that Dr Cockrem's analysis disproves it. In my 1962 paper, I said the results were consistent with the age effect being a liveweight effect. Since then, in our analysis of high country flocks (Coop, 1964), I have been unable to prove that there are differences between two-tooths, four-tooths and six-tooths which cannot be explained in terms of liveweight. Finally, Dr Cockrem makes two statements which cannot reasonably be inferred from my graphs. The first is "that 90 lb (below which percentage of dry ewes increases) is a critical weight, determining whether a ewe is dry or not". The second is "Fig. 1 could suggest that culling on liveweight might overcome the dry ewe problem".

Dr Cockrem's method of analysis used in conjunction with mine certainly makes the situation clearer and to this extent it is to be welcomed, but on its own I believe it to be much less informative than the method of analysis and presentation originally used. In my opinion, the main value of liveweight-fertility relationships is in connection with husbandry and management aimed at increasing the liveweight of young sheep. Its value in culling is of rather less value.

DR F. COCKREM: Professor Coop's comments are mainly concerned with final conclusions from analyses largely dependent on percentages. My paper points out certain ways in which such analyses could be misleading and suggests additional (rather than alternative) approaches. The ideal analysis, which can relate a discrete variable such as 0, 1 or 2 lambs to continuous variables, has yet to be arrived at, if indeed it is possible. Until then a form of analysis which takes variability and actual numbers of animals into account is desirable as an adjunct to percentage methods, if reasonable predictions are to be made for practical use. Until this information is available, disagreements between Professor Coop and myself on the correct conclusions must be mainly matters of opinion, for which the arguments are available in my paper and in his papers and comments.

DR A. H. CARTER: *The important finding of apparent lack of genetic relationship between liveweight and fleece weight in the Australian Merino clearly warrants investigation under New Zealand conditions. In respect of growth studies, is there not a danger that the method described of analysing consecutive weight records of animals surviving to some specified stage may be liable to biased interpretation in that animals not surviving, which will frequently have different growth patterns, are ignored?*

DR COCKREM: I agree that this requires investigation in New Zealand, in particular as selection experiments with the Merino have shown that the lack of correlated response of body weight, when fleece weight is selected for, results in increased efficiency of wool production.

On the second point: deaths are liable to bias any method of analysis of growth. If animals which die are included in the analysis until the time of death, then if, for example, a number of the lightest animals die, there will be an increase in subsequent mean weights. This could lead to a false interpretation of an increase in growth rate. It is probably simpler to analyse the weights of dead animals separately and include the conclusions in the final interpretation of the experiment.