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THE EFFECT OF TEMPERATURE ON BODY GROWTH AND OTHER TRAITS OF OPEN- AND WOOLLY-FACED ROMNEY LAMBS

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SUMMARY

The effects of different temperatures (45°F and 65°F) and of face cover on body growth and other variables were examined in 14 Romney wether single lambs using controlled temperature rooms. The treatment period was between 7 and 12 months of age and the animals were shorn when 11 months old. They were fed *ad lib.* on pellets containing lucerne and barley meals and wheat husk.

A control group in the field showed body growth differences of 9 lb in favour of open-faced lambs but no differences associated with face cover occurred under the controlled temperature treatments. The 45° treatment increased body growth, wool growth and feed intake compared with the 65° treatment.

Differences between the face cover groups were as follows: At 45° open-faced sheep grew more wool on the side and less on the face than woolly-faced sheep; they also had a lower food intake at the warmer temperature. At 65° open-faced sheep grew as much wool on the face as the woolly-faced sheep on either treatment. Body temperatures of woolly-faced sheep were higher than those of open-faced sheep at 65°, but were similar or lower after shearing and at 45°.

Sheep kept at 65° showed a greater drop of body temperature after shearing than those kept at 45°, although both groups were still kept at the pre-shearing ambient temperatures.

The significance of the results are discussed in relation to an hypothesis to account for the relationships of face cover with productive characters.

STUDIES of the growth of lambs under field conditions have shown that open-faced (O-F) lambs gain more weight over the winter than woolly-faced (W-F) lambs. Cockrem (1962a) has suggested that these growth differences could result from a lesser ability of W-F lambs to adjust to cold stress. Cockrem (1960) also suggested that changes in the blood supply to the face have resulted from selection for more wool growth in this position.

The critical testing of an hypothesis of this type requires the collection of data from animals in a known temperature environment. Controlled temperature rooms are available

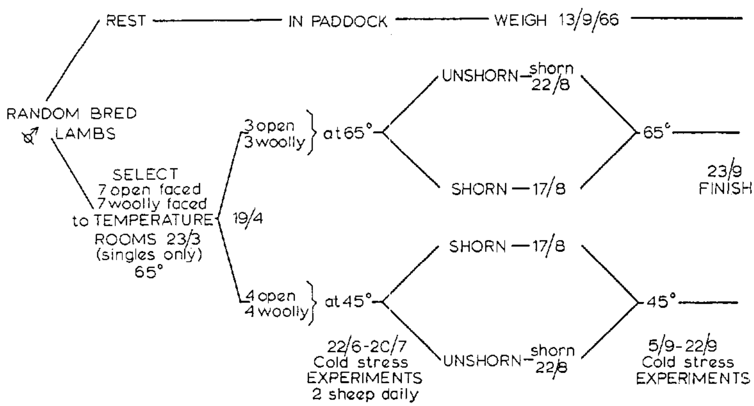

Fig. 1: Plan of the experiment.

at Massey University and the purpose of this paper is to describe initial experiments carried out both to test these rooms and for obtaining further information on face cover relationships.

THE PLAN OF EXPERIMENT AND THE COLLECTION AND ANALYSIS OF DATA

The general plan of experiment is shown in Fig. 1. Single wether Romney lambs were selected at six months of age from the Massey University random-bred flocks (Rae, 1958) for extremes of face cover. The unselected lambs continued on pasture or crop until weighing in August. On March 23, the selected lambs were randomized into two groups, each with the same proportion of O-F and W-F animals and placed into controlled temperature rooms at 65°. On April 19, one room with the group of eight lambs was lowered to 45° and both rooms were maintained at these temperatures until the end of the experiment on September 23. One half of the animals in each room were shorn on August 17 and the remaining animals on August 22.

During late June and early July and also after shearing, animals were taken two at a time and subjected to cold stress for a period of five hours. This occurred twice during each period for each animal in order to measure physiological responses. Any effects of this extra cold stress treatment on the body growth and other data presented in this paper are assumed to be random.

In the two main rooms, temperature can be set between 40° and 90°F and, apart from power cuts, control is within ± 1°F. Lighting is controlled by an external photo-electric cell giving the actual seasonal daylight cycles. Humidity is not controlled so the 45° room (cold treatment) was at about 95% R.H. and the 65° room (warm treatment) was at 75% R.H. except after the rooms had been washed daily.

The pens are on raised slatted boards and arranged so that the animals can see one another. All cleaning is by high-pressure hose. Each room will hold ten pens and can be divided in half for different light treatments (photo-cell or time-clock controlled). There were no indications that the conditions in the rooms caused any stress to the sheep.

The animals were dosed with thiabendazole on arrival and injected against lungworm. There was no sickness during the experiment. They were fed *ad lib.* on sheep pellets of which intake was determined daily to the nearest 0.1 lb. The composition of these pellets was: 60% lucerne meal, 20% barley meal, 20% wheat husks, together with a commercial vitamin additive, sodium molybdate (3.6 g/ 2,000 lb) and sodium sulphate (anhydrous, 4 kg/2,000 lb).

THE DATA COLLECTED AND THE FORM OF PRESENTATION

(1) *Body-weights:* Weekly at 9 a.m. Presented as weight every third week.
(2) *Weight gains:* For the three weekly periods.
(3) *Feed intake:* As lb/day averaged over the three weeks prior to presentation.
(4) *Wool growth:* As clean weight/sq. cm/day (mg × 10) from measured patches on the mid-side and on the left side of the nose. The same patch was sampled throughout the experiment at approximately monthly intervals. The initial sample represented wool growth from shearing in December, 1965, until arrival at the controlled temperature rooms.
(5) *Fleece weights:* Weighed at shearing and yield determined from a right mid-side sample for estimation of clean fleece weight. Character, number of crimps per inch, length, and mean fibre diameter were also determined.

(6) *Body temperature:* Measured by a thermistor in a probe at a depth of 10 cm in the rectum. Each of the measurements presented is the mean of measurements at 11 a.m. and 2 p.m. on two successive days—*i.e.*, around the maximum of the diurnal curve. At each time two measurements were taken, followed by a third if these differed by more than 0.3°F which indicated a possible artifact.

The measurements of the response to the separate cold stress periods will be presented elsewhere.

Analysis of Data

A programme for analyses of variance and covariance was written for the IBM 1620 computer and all analyses are by this standard programme. The two basic analyses were by the method of weighted means to allow for the unequal sub-class numbers between the two rooms. The two models were (a and b fixed effects):

Variance: $y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk}$

Covariance: $y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + \beta x_{ij} + e_{ijk}$

where a_1 and a_2 were the warm and cold environments
b_1 and b_2 were open and woolly face cover groups
$(ab)_{ij}$ are the interactions (sub-classes between the groups
β is the regression coefficient of y on x within the classes.

Probabilities given in the results are based on the appropriate F tests derived from these analyses. Estimated means refer to estimates in the equations above, while adjusted means refer to the means of y adjusted to the overall mean of x by the within sub-classes regression coefficient.

Analyses of variance were made at each point in time shown on the graphs. Analyses of covariance were made adjusting for previous differences or for those from the initial control period. Further analyses of covariance were made in order to examine relationships between variables at a particular time. Conclusions on the reality of differences or relationships may therefore be based on a number of analyses and probabilities which cannnot all be presented in this paper.

TABLE 1: PADDOCK LAMBS' BODY-WEIGHT, (LB) SEPTEMBER 13, 1966

	Singles		Twins	
	n	Mean	*n*	Mean
Open	16	95.9	22	93.5
Woolly	22	85.4	35	87.4
F	8.85		6.56	
P	0.001–0.01		0.01–0.05	

RESULTS

BODY-WEIGHTS

In Table 1 are shown the body-weights in September of those wethers which remained in the paddock. For both singles and twins there were significant body-weight differences in favour of the O-F group.

For the treated animals, the estimated means for temperature and face cover effects are shown in Fig. 2 for body-weights and in Fig. 3 for the corresponding weight gains. The main conclusions from the analyses of these results were:

(a) There were no body-weight differences between face cover groups at either temperature, although W-F lambs showed greater gains over one period in July.

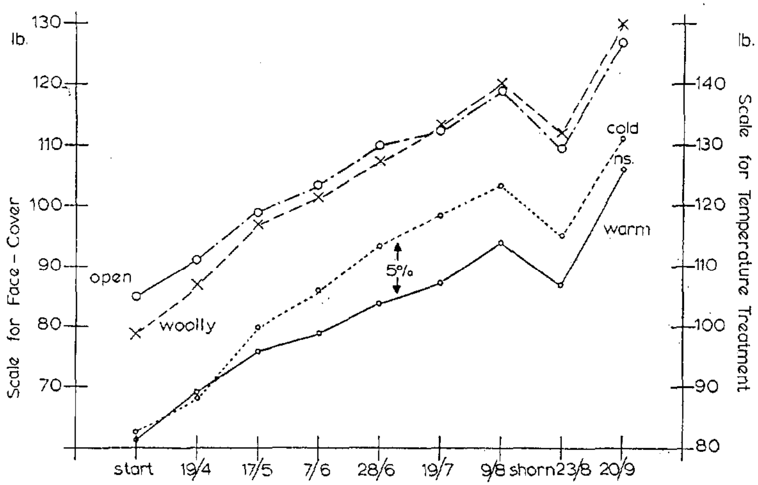

Fig. 2: The estimated mean body-weights at three-weekly intervals.

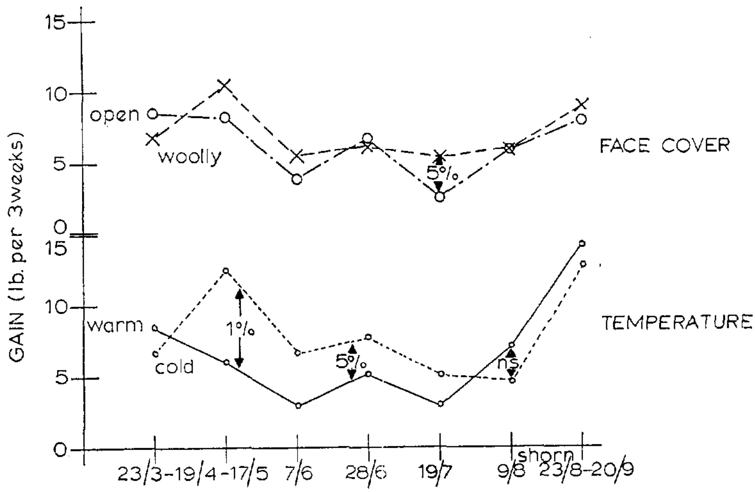

Fig. 3: The estimated weight gains during three-weekly periods.

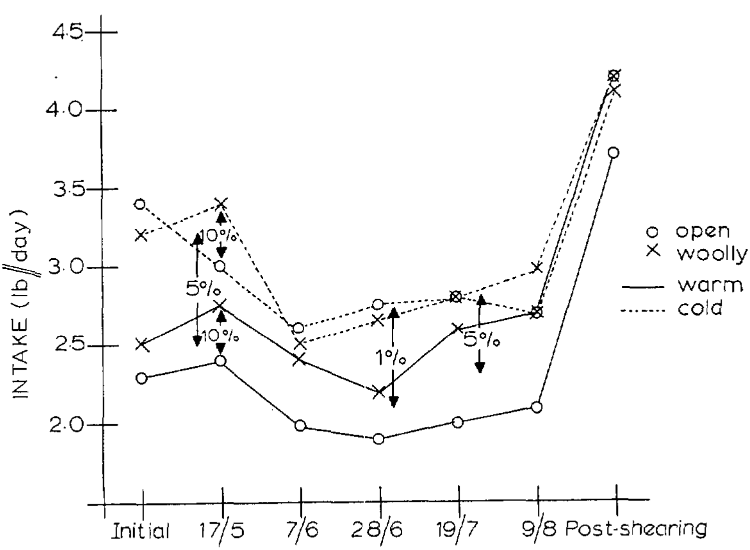

Fig. 4: The estimated mean intakes calculated over three-weekly periods.

(b) By July, lambs in the cold room had greater bodyweights than those in the warm room. This resulted from greater weight gains, particularly in the first period after the start of the treatment. For the period prior to shearing, and after shearing, there were no major differences in gain. However, gains in all groups increased after shearing.

(c) The lack of weight gain over June and July which is usually found for lambs in the field did not occur.

Feed Intake

Estimated sub-group means (not main effects because of interaction) are shown in Fig. 4. Differences occurred during the latter part of the control (initial) period (both rooms at the same temperature) when the intake of warm room animals decreased. As a result of this it is not clear to what extent cold increased appetite or the warm treatment decreased it. However, there was a significant difference between rooms over the treatment period. This difference was not maintained after shearing when all groups increased their intake, to similar levels—*i.e.*, a greater relative increase for the warm room.

Woolly-faced sheep had a greater intake than O-F sheep in both rooms during May and in the warm room in June and July. The intakes over successive periods showed a significant ($P < 0.05$) relationship within groups.

Wool Growth

Clean fleece weights were greater from the cold than from the warm room ($P < 0.01$). This probably resulted from both greater diameter and length, although neither of these variables was *significantly* different taken individually. Other fleece characters showed no differences.

Wool growth per unit area for the two sampled positions is shown in Fig. 5 for the different sampling times. For the mid-side position, O-F lambs showed a greater growth during the control period. Within the groups, growth in this period was unrelated to that in subsequent periods. During treatment there was an interaction such that O-F grew more wool on the side than W-F under the cold treatment only ($P < 0.05$, 26/5–26/6). Overall it appeared that the cold treatment increased wool growth on the side but that the major effect was in the O-F lambs.

For wool growth on the face position, the reverse was true. Open-faced sheep in the cold grew less than the three other groups. Overall, it appeared that, compared with the control period, the warm treatment increased wool growth on the face of O-F sheep and possibly to a lesser extent on the W-F sheep relative to their growth on the side. Seasonal variations were still apparent.

After shearing there were no significant differences in either position although the direction of differences was similar to that before shearing.

Body Temperatures

Repeatabilities assessed as the percentage of sums of squares due to regressions on temperatures taken at the start (April 6), were 73% on April 19 and 43% just prior to shearing in August. The estimated mean body temperatures are shown in Fig. 6.

Three major effects were found:

(a) Woolly-faced lambs had a higher body temperature during the control period and subsequently in the warm room. These differences were more marked in the afternoon.

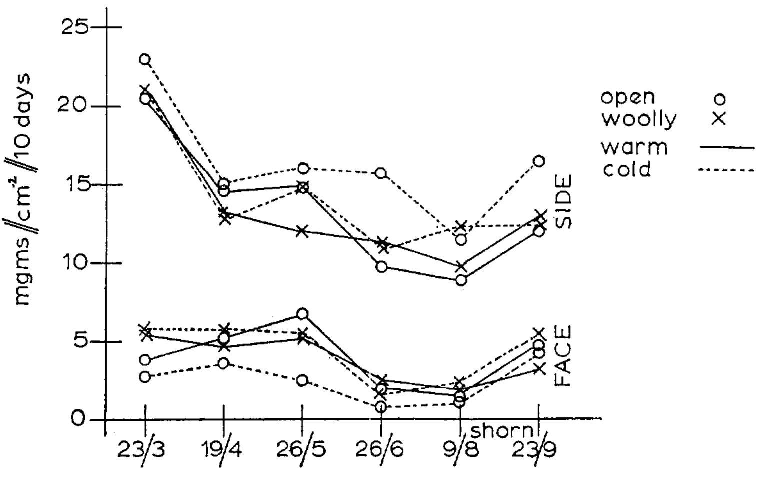

Fig. 5: Wool growth per unit area at monthly intervals for the mid-side and face positions.

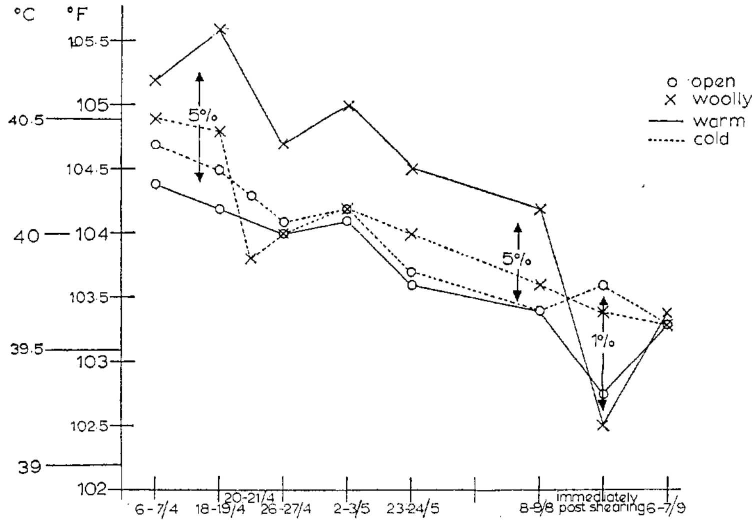

Fig. 6: The estimated mean body temperatures.

(b) At the start of the cold treatment, the body temperatures of W-F sheep dropped to a level at or below those of the O-F group. Subsequently body temperatures increased slightly but remained below the warm room level. Open-faced lambs had similar body temperatures under both treatments. After shearing, W-F dropped below O-F under both treatments. (A significant difference prior to shearing became non-significant.) A similar effect was found for the individual cold stress treatments for both shorn and unshorn lambs.

(c) Acclimation had a marked effect on the shearing response. Those lambs acclimated to 45°F showed no drop in body temperature, while both O-F and W-F acclimated to 65°F showed marked drops, even although they were kept at the same temperature after shearing. Four weeks after shearing all groups showed similar body temperatures.

Relationships with Feed Intake

With *ad lib.* feeding, any relationship between intake and a productive variable implies that those animals with

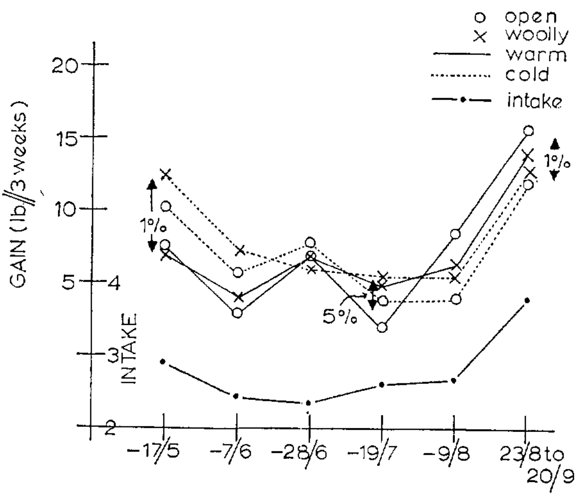

Fig. 7: The mean body-weight gains adjusted for intake.

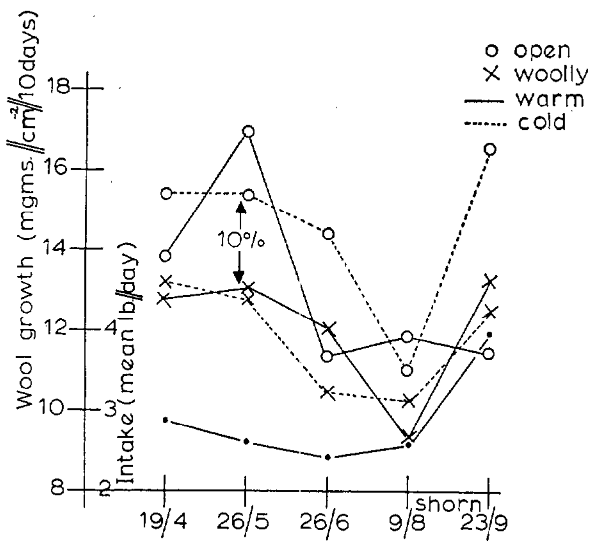

Fig. 8: The mean mid-side wool growth adjusted for intake.

greater appetite have a greater production. It is a relationship between sheep and could be different from one obtained by feeding groups at various levels. If no relationship exists, then presumably factors other than appetite are determining the differences in production between sheep. In these circumstances, corrections to production per unit feed as a ratio could be misleading.

For this reason, results in this section are presented as means adjusted by the within-group regression to the mean intake for the period. If the relationship was small, then the adjusted mean differences will be similar to those between the unadjusted means—*i.e.*, if appetite and production were independent for the period, then productive differences between groups would still be in the same order even if appetite was the same, as other factors must be more important than appetite.

(a) *Relationships*

Feed intake was not related to body weight at the beginning or end of a period at any stage of the experiment. Weight gains were related to intake for the initial cold treatment period and after shearing ($P < 0.05$)—*i.e.*, within each group sheep with greater appetite grew faster. This was true for only one of the other four periods. For wool growth on the mid-side, the reverse was true. Within groups, sheep with greater appetite grew more wool *except* for the initial cold treatment and after shearing.

Body temperature was related to intake within the groups, for the first three periods after the temperature treatment started. The relationship was such that those sheep with a higher body temperature (x) had a higher intake (y). The relationships were similar for the three periods ($b_{yx} = 0.06 \pm 0.025$, 0.04 ± 0.019, 0.03 ± 0.02 lb/day/0.1°F).

(b) *Adjusted Means*

The means of weight gains adjusted for intake are shown in Fig. 7 together with the overall mean intake for the period. Animals on the cold treatment still had greater weight gains even when differences in appetite were allowed for, except after shearing when this may have been true for the sheep at 65° ($P < 0.01$). This implies that factors other than intake were also important in determining the differences in weight gain between the temperature treatments.

The means for wool growth adjusted in a similar way are shown in Fig. 8. The main effect for this variable was that O-F sheep at 45° and for one period at 65° (26/5) had a greater adjusted wool production —*i.e.*, other factors than appetite must have contributed to the unadjusted difference.

For body temperature, the between-group adjusted means showed that the cold treatment lambs had a higher intake at a given body temperature.

DISCUSSION

The data presented here confirm the feasibility, suggested by Cockrem (1962a) of investigating strain differences in physiological characters by means of treatments involving environmental temperature differences. In addition, breed differences in vasoconstriction points and tissue insulation have also been demonstrated by Slee (1964) and Joyce and Blaxter (1965). Variation between sheep in heat tolerance has also been shown by Wodzicka (1960). The present results indicate the importance of acclimation in experiments of this kind.

Apart from the results on face cover, there are a number of points of general interest. Differences between species in their control of variability in body temperature have been reviewed by Hart (1962) and Johansen (1962). Bligh *et al.* (1965) measured body temperature in the shoulder muscle of a single sheep in the field over one year by the use of telemetry. They found lower temperatures over the winter and after shearing. Rectal temperatures were lower than, but related to, the muscle temperatures. These authors suggest as a result of this experiment, and also those of Bligh and Harthoorn (1965), that sheep have a higher degree of thermostability than some other species. The present results for sheep and those of McLaren (1961) and Bigham (1965) for mice show that such differences can occur within a species. The question remains as to the importance of such differences to productive processes.

The greater wool growth on the mid-side of open-faced sheep associated with no difference in voluntary intake is contrary to previous observations for the merino—*i.e.*, Schinckel (1960), Williams (1966), where high wool growth strains had a greater voluntary intake. This suggests that other factors as well as intake are of importance in the Romney in affecting the genetic expression of wool growth. The importance of possible environmental interactions is indicated by the lack of relationship within groups for the cold treatment period and after shearing only. This was in contrast for the relationships for weight gain and feed intake which were strongest over these periods of cold stress and suggests that the causal mechanisms of wool growth and weight gain relationships with intake are different. The effect of cold or shearing appears to produce a greater increase in body growth than would be expected from the increase in intake. This suggests that greater changes in metabolism occur than those required for the necessary increase in heat production alone.

The results obtained for body temperature after shearing illustrate the importance of acclimation. Thus, those acclimated at 65° showed greater relative increases in weight gain and intake but a greater drop in body temperature. If both groups had been at 45° after shearing, then the warm acclimated animals could well have shown cold stress effects. Clearly, if similar effects occur in the field, then previous temperature may be as important as that at the time of shearing..

Further studies making use of calorimetry and of information obtained by telemetry from animals in the field should make possible definition of those physiological traits which are associated with production in particular environments.

The differences between O-F and W-F sheep have confirmed a number of points and also added some information. The fall in body temperature after shearing or cold treatment confirms results reported by Cockrem (1962a). The higher body temperatures of W-F sheep at ambient temperatures of 65° indicate that these animals have comparatively incomplete body temperature control even over a narrow range of environmental temperatures. Further evidence on the suggestion that blood supply and skin temperature are related to facial wool growth

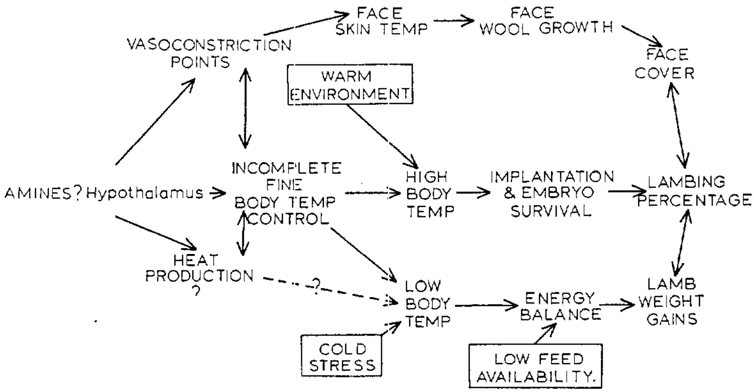

Fig. 9: A working hypothesis for the causes of observed face cover relationships.

(Cockrem 1960) comes from the fact that O-F sheep at 65° grew as much face wool as W-F animals at either 45° or 65°.

The increase in wool growth on the side but the decrease on the face of O-F lambs at 45° confirms the suggestion of Cockrem (1966) that a different gradient of wool growth, and not a general increase over the whole body, is an important factor in face cover differences.

As a result of the additional information from this present experiment, it is possible to suggest a general hypothesis to explain the various observed associations with face cover. This is shown in Fig. 9. The evidence for the various steps can be summarized as follows:

The suggestion that the basic genetic effects are in the secretion or release of the amines, nor-adrenaline, adrenaline or 5 hydroxy-tryptamine, is based on theoretical considerations at this stage. Evidence for their importance in body temperature control in the hypothalamus of the cat and dog has been presented by Feldberg and Myers (1964). The general field of thermo-regulation in mammals in relation to Feldberg's work has been reviewed by Bligh (1966). Evidence for the effects of catecholamines on metabolism and vaso-constriction apart from their effects in the hypothalamus and for the role of nor-adrenaline in cold acclimation is discussed by Smith and Hoijer (1962) and Leblanc (1964).

Evidence that skin temperature and wool growth on the face are related was given by Cockrem (1960, 1962b) and is further suggested by the present results. Relationships between facial skin temperature and blood supply are suggested by the experiments of Cockrem and Wickham (1961) and this aspect is reviewed by Hertzman (1953). Increased wool growth (to a lesser extent than that found in the present experiment) has been found following sympathectomy of nerves serving facial blood vessels (Cockrem, 1962b).

The possible chain of events leading to a lower fertility assumes that the differences in body temperature found for wethers at 65° will also apply to unshorn ewes in autumn when ambient temperatures are at about this level. Evidence that differences in rectal temperature of the order found can lead to a difference in implantation rate and in embryonic deaths has been presented by Ryle (1961) for merino ewes. Cumming (1965) has found differences in implantation rate of a similar order to those of Ryle (1961) between O-F and W-F Romney ewes. The differences in these various experiments are such that a greater rectal temperature of about 1.5°F would lead to about 20% less lambs. This is similar to the lambing percentage differences reported by Cockrem and Rae (1966) for selected O-F and W-F groups. If these postulated relationships exist, then fertility differences between O-F and W-F sheep should be lessened by shearing. Inkster (1959) reported increased implantation rate after pre-mating shearing and Cockrem *et al.* (1956, Table 3, Flock C) found no difference in lambing percentage associated with face cover in a flock which had been shorn in March.

Possible relationships between the body growth of lambs over the winter and their body temperature variation have been discussed by Cockrem (1962a). The additional evidence in the present paper was that a constant environmental temperature and *ad lib.* feed conditions prevented the usual growth differences associated with face cover. Thus, either fluctuations in environmental temperature or the availability of feed are important in causing these growth differences. Wind and rain may be an important additional cold stress outside. If, as a result of greater heat loss or a lower efficiency of heat production, W-F sheep require more feed to maintain a given body temperature, then the additional effects on weight gain may show only when feed is restricted. Differences in digestive processes may also occur, as indicated by a lower weight of stomach contents after 12 to 20 hours' starvation in a separate experiment (Hight *et al.* 1962).

While this overall hypothesis would account for the majority of observed results on face cover, a number of steps still require experimental verification. It does, however, provide a working framework for the design of such experiments and it also has a number of implications for sheep breeding and sheep research in general. For example, the low fertility of Romney ewes in Northland might be associated with an inability to adjust to the warm climate, while poor hogget growth in, for example, the Gisborne district might be associated with the extensive fluctuations of environmental temperature in that district. If so, appropriate selection methods could be of great practical importance.

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