COAT CHARACTERS OF CATTLE IN RELATION TO ADAPTATION

(Invited Paper)

H. G. TURNER*

I. COAT TYPE AND ADAPTATION

It is a familiar observation that different ecotypes of cattle, whether they are distinguished as species, breeds, or strains, show marked contrasts in coat cover. These differences follow the principle, dignified by Wright (1954) as "Wilson's Rule", of a gradient from thick, woolly coats in cold climates to short coats with bristly hairs lying sleekly against the skin in hot climates. The contrasts between British Highland cattle or Scottish beef breeds and the Zebus of India or Bantengs of south-east Asia clearly represent adaptations to cold and to heat. Within breeds, also, climate modifies both phenotype and genotype of coat characters. For instance, progeny of a N.S.W. strain of Herefords, born and reared in Central Queensland, had longer coats than progeny of a Central Queensland strain (Turner and Schleger 1960). The fact that coat genotype seems to have changed fairly rapidly in breeds introduced to the tropics confirms the importance of this trait to adaptation. Individual animals also grow shorter coats when transferred from a cold to a hot environment, even at the same latitude (Berman and Volcani 1961), unless their limits of general adaptation are exceeded, when physiological degeneration sets in and a woolly, non-shedding coat is produced.

The effect of coat cover on body temperature regulation has been shown by clipping (Yeates 1955, Berman and Kibler 1959, Bianca 1959, Dowling 1958, 1959b, Turner 1962). This kind of demonstration is only a first step. It does not put in perspective the importance of inherent differences in coat type, and it also leaves one to assume how much a difference in body temperature control under test conditions affects total physiological and economic performance in the field. Bonsma (1949) showed the direct relationship between inherent coat type and capacity to thrive in the Northern Transvaal. Dowling (1956) associated the heat tolerance and performance of different strains of cattle with their coat characters, and Turner and Schleger (1958, 1960) measured the degree of variability of coat type within herds, and assessed the proportion of the variation in growth rate that is accounted for by variation in coat type.

We found that, within herds of Herefords or Shorthorns, variation in coat type accounted for about one third of the variation in growth rate. The correlation between coat type and gain was higher than the repeatability of gain so that assessment of coat type was superior to a record of gain as an estimate of growth

*Cattle Research Laboratory, Division of Animal Genetics, C.S.I.R.O., Rockhampton, Queensland.

capacity. Heritability of coat type (0·63) and the genetic correlation between coat type and gain were high. Selection of parents on coat type would give the same improvement in gain of progeny as would be given by selection on gain if the heritability of gain in this environment were 0·46.

Differences in adaptation between members of a group assume increasing significance as the discrepancy between the environment and the mean level of adaptation of the group grows wider. Coat type of calves on Belmont was most closely related to growth rate during the difficult post-weaning phase. Among Zebu-cross calves, at the other extreme, there was little evidence of association between coat type and performance. An association between coat type and fertility of cows was strongly expressed in the most stressed group of cows on Belmont, i.e. lactating Shorthorns. This association with fertility has been found more generally in British-breed herds under very stressful conditions in New Guinea. As stress increases coat type can be expected to show relationships firstly with growth of young stock, then in mature cows with birth weight of their calves and ultimately with fertility. "Stress" in this connection may mean solely heat stress, but adaptation to other stresses may be reflected in coat type.

II. COMPONENTS OF EFFECT OF COAT TYPE

By distinguishing between the effects of coat cover, which can be experimentally varied by clipping, and of inherent coat type which differs between animals whether they are clipped or unclipped, we have ascribed the association between coat type and performance to several causes (Turner 1962). The first two of these represent effects of coat cover, the others attributes correlated with inherent coat type.

(i) Insulation—the effect of coat cover in reducing dissipation of heat by conduction, convection, and radiation.

(ii) Efficiency of evaporative cooling. Yeates (1955) showed that clipping of calves improved their tolerance of an environment at 40·6°C, when the only means of heat loss would be by vaporization. As there is no reason to believe that clipping increased surface water loss, it appears that coat cover affects efficiency of evaporative cooling, i.e. the extent to which latent heat of vaporization is drawn from the skin or from the ambient air.

While the effect of clipping on summer growth rate shows these effects of coat cover to be significant, they account for one third or less of the total relationship between growth rate and natural coat type. The remaining avenues of association are functions of inherent coat type, not of coat cover.

(iii) Correlated thermoregulatory attributes. Sleek-coated calves tolerate heat better than woolly-coated calves even when all are clipped and equated in respect of coat cover (Yeates 1955, Turner 1962). A major cause of this phenomenon is the association between coat type and sweat gland size and level of sweat gland activity (Nay and Dowling 1957, Dowling 1958, Schleger and Turner 1964). It would be speculative at present to suggest that coat type may also be associated with level of endogenous heat load.

(iv) Correlated non-thermoregulatory attributes. In the Rockhampton winter, clipping had if anything a deleterious effect on growth rate and, comparing individual animals, ability to keep skin temperature low was not advantageous, and yet sleek-coated calves still grew better than woolly-coated. It appears that calves with sleek coats have some physiological merits that are relevant even in the absence of heat stress.

These considerations raise various questions and point to gaps in our knowledge. Though present evidence (Berman and Kibler 1959) indicates that clipping does not affect surface water loss, this should be checked under various conditions. It is linked with the problem of the effect of humidity on sweating and insensible water loss. The conclusion that a significant and variable part of latent heat of vaporization does not serve to cool the animal needs experimental testing. The physics of translocation of moisture through the coat and associated heat exchanges may be fairly complex.

Various aspects of the relationship between coat type and sweat glands remain to be clarified. There is an association between sweat gland size and hair type (notably hair diameter) in various contexts: between different follicles within a skin section (Nay 1959), between different regions of the body (Pan 1963, 1964), between breeds, between strains (Nay and Dowling 1957), and probably between animals within breeds. However, sweat gland size is only a component of sweat gland function, and stronger associations, in most of the same contexts, are found between coat type and sweating rates (Dowling 1958, Schleger and Turner 1965). Coat type, although normally highly heritable, is quite labile under nutritional or pathological influences. Sweat gland function has not been shown to be similarly influenced, but I suspect that it is. The total picture is that the quality of function of the hair follicle and of the sweat gland are closely linked and subject to a common physiological control. The common factor remains to be defined, whether in terms of energy or nitrogen metabolism of the skin, of blood supply to the skin or mobilization of nutrients to the skin, or in endocrine terms.

The concept that metabolic factors underlie the association between coat type and sweat gland activity is extended by the evidence that coat type is associated with factors which affect growth rate even in the absence of heat stress. In other words, the physiological correlates of coat type are of fairly general significance. The problem of defining the physiological basis of differences in coat type therefore assumes greater importance.

III. PHYSIOLOGICAL CORRELATES OF COAT TYPE

There is some basis for speculating on the nature of the difference, in broad animal-production terms. An observation which provides a starting point is the familiar contrast between the sleek coats of Jerseys and Friesians and the woolly coats of the British beef breeds. The same contrast is found between dairy-type and beef-type Shorthorns. Steers of dairy breeds are increasingly being recognized as quite efficient producers of beef. The one outstanding feature is that their carcases have a lower ratio of fat to lean and therefore grade lower in a market which demands high finish (fatness), but meet the modern trend in demand for leaner beef. The fact that Brahmans and Brahman cross-breds also do not reach the levels of finish attainable by British beef breeds is well known. For example, Cole et *al.* (1964) recorded the following proportions of separable fat in carcases: British beef breeds 32·8%, Zebu 26·1%, Dairy breeds 24.2%. There is probably an interaction in degree of fatness between breeds and nutritional environment. When Hereford and Brahman x Hereford steers were raised on low-concentrate or high-concentrate rations, the Herefords had less superficial and internal fat than the crossbreds on the low ration, but much higher levels of these and of marbling and total fat on the high ration (Cartwright, Butler and Cover 1958). Hewetson (personal communication) found a lower degree of carcase finish in British than in Zebu-cross steers which had been raised together to the same weight under relatively slow-growing pastoral conditions, in contrast to the comparisons found under feed-lot conditions in U.S.A. The apparent bias towards deposition of lean in Zebu cattle may derive partly from their more efficient digestion of nitrogen (Ashton 1962), but obviously other metabolic factors would also be involved.

The same association between coat type and tendency to fatten is found in comparison of sexes. Bulls have much sleeker coats than heifers or steers and also produce a much higher ratio of lean to fat.

These comparisons suggest that coat type reflects differences in metabolic type, soft coats being associated with a tendency to fatten under favourable conditions, sleek coats with a more protein-biased metabolism. An extreme expression of the latter type of metabolism is shown by African game animals adapted to arid conditions, in which the fat content of carcases is extremely low (Ledger, personal communication). The contrast in metabolic type may have something in common with the contrast between so-called early-maturing and late-maturing strains as distinguished particularly in pigs.

The generality of this association receives support from the opinion of commercial cattle breeders and fatteners as to the relative performance of sleek-coated and woolly-coated animals within the orthodox beef breeds. The belief is that "hard" cattle, characterized by short coats, withstand heat and also other hardships of nutritional environment, drought, diseases, and parasities, but are slow to fatten and finish under favourable conditions. "Soft" cattle, with woolly coats, are believed to fatten more readily and produce beef with higher finish, provided conditions for growth are favourable.

While a sleek coat has manifold significance in relation to adaptation to a hot environment, it seems that factors normally associated with it may be relevant to adaptation to other stresses and also to that broader environmental factor to which animals need to be "adapted", namely, market preference for a particular type of product. The existence of correlated attributes of hardiness and carcase type could be more critically tested in a cool climate, possibly with all experimental animals clipped, so that any effects would not be confounded by differential reactions to heat or by effects of insulation on reactions to heat or cold.

In a cold climate, an insulating cover is adaptive (Yeates and Southcott 1958). This discussion raises the possibility that some coat characters and metabolic characters, normally correlated with insulation, may be widely relevant to cattle production and might be manipulated, if necessary, by breaking down their genetic correlation with insulation.

The critical characters responsible for the association between coat type and performance need to be defined. Definition can be at various levels: in terms of coat characters, of skin structures and functions which control hair follicle and sweat gland activity, or in terms of systemic factors which influence both skin function and growth rate.

Varying emphasis has been placed on different characters in assessments of coat type. Bonsma (1949) stressed felting properties, Dowling (1959a, 1959b) degree of medullation, and Turner and Schleger (1960) primarily depth and "handle". Within a herd, different characters tend strongly to vary together. Length, diameter, medullation, and curvature of hairs and the angle the follicle makes with the skin, were all found to be correlated with skin temperature and growth rate, but were all so interrelated that taking account of diameter alone left the others with little independent effect (Schleger and Turner 1960). All these characters, and others such as aspects of shedding (Hayman and Nay 1961) and of hair composition (Springell, unpublished data), and shade of colour (Schleger 1962), are apparently influenced by one underlying factor broadly described as the vigour of the hair follicle. Depth of coat or length of hair is the most obvious character. It is normally inversely correlated with hair diameter, but diameter may be useful as an index of vigour, potentially independent of depth of coat.

These are characters of the coat viewed as a static entity. The coat is dynamic, and studies of the processes of initiation, growth, and shedding of hairs could improve understanding of the determinants of coat type (Dowling and Nay 1960, Hayman and Nay 1961, Turner and Schleger unpublished data). Briefly, it has been shown that at any time some hairs are being shed and replaced by new hairs but there are marked peaks in spring and summer. The total number of new hairs initiated during a year equals twice the number of follicles. There are marked seasonal variations in lengths of growth phase and static phase of hairs. While extremes of coat type have been found associated with differences in size of peaks of initiation and in relative lengths of growth and static phases, this approach has not provided more sensitive means of discrimination between animals, partly because techniques of measurement are fairly crude.

Many reports have been published on histological structures of the skin, particularly hair follicles, sweat glands, and thickness of layers. In Australia, at least, work on function is seriously deficient in relation to the amount of work on morphology. Patterns of sweat gland activity, variations in blood supply to the skin (Schleger, unpublished observations), and the metabolism of skin (Springell, unpublished observations) are some subjects for study.

The endocrines should provide a key to systemic factors affecting both coat type and performance. On the endocrine control of hair growth in cattle there is a wealth of suggestive clues but a lack of experimental information and perspective. The striking seasonal variations in coat are photoperiodically controlled (Yeates 1955, 1957) and this suggests the possibility of association with gonadotrophic activity. The differences in coat type between males, females, and castrates imply association with sex hormones. Cowie et *al.* (1964) have shown that the hypophysectomized goat develops a coat strikingly similar to that of ill-adapted cattle. Berman (1960) reported evidence that thyroxine affects some aspects of hair growth in cattle, and Post (unpublished observations) has found thyroid activity well correlated with both coat type and growth rate. We have found that a glucocorticoid profoundly depresses the initiation of new hairs and this implicates the adrenal at least in the development of the non-shedding coat of the badly stressed animal. The effects of stress and of lactation on coat colour (Schleger 1962) may be mediated by the adrenal. In general these relationships are analogous to the multitude of endocrine effects on hair growth in the rat (Mohn 1958), where various hormones act principally on the conversion of resting to growing follicles, and to some extent on hair diameter. In the context of the relationship between coat type and performance in cattle, the problem is to place these various activities in perspective, to determine which endocrines affecting hair growth show greatest variation between animals and covariation with coat type and performance.

IV. CONCLUSION

While the obvious role of coat type as an insulating cover affecting climatic adaptation has been confirmed and is important, it is considered that the evidence of physiological correlates of coat type in cattle raises questions of greater scientific interest and potentially of equal, or even broader, practical importance.

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