GROWTH OF THE MOUSE COAT

VIII. CHANGES IN THE COAT AND BODY WEIGHT UNDER HEAT STRESS

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Summary

Observations were made on the hair growth and body weight of mice subjected to high temperature stress. It was found that:

(1) The critical temperature at which the influence of the high temperature becomes noticeable is about 34°C.

(2) At 38°C the effect is pronounced, the eruption of adult coat is delayed, and the body weight depressed as compared with controls.

(3) All hairs were finer and shorter in treated animals.

(4) The structure of the coat becomes affected in the sense that the number of zigzags is increased and the number of auchenes decreased, as compared with controls.

I. INTRODUCTION

Bonsma (1949) and Turner and Schleger (1960) have shown a close association between hair growth and body growth in cattle. The causal relations between the two are far from clear. Cattle which have a short flat coat increase in body weight at a faster rate, particularly in hot unfavourable environments, than cattle with long silky coats. A short flat coat indicates, at least in hot climates, general thrift and fertility. As mice are more easily handled experimentally than cattle, an exploration in mice of the association between coat and body growth rate in hot environments may help to explain the association in cattle, though the physiology of the two species is different in many respects. This paper describes an investigation into the effect of heat on growth rate in mice and on associated changes in the growth of the coat. This investigation was undertaken prior to an examination of the growth of mice with different types of coat in order to determine the temperature at which effects of heat are marked and the types of changes in coat which take place. These observations may help in classifying mice according to coat type.

The mouse coat is replaced by new hairs at intervals which in early life are rather regular. The first coat is initiated before birth and completes its growth by the time the mouse is $18\frac{1}{2}$ days old (Fraser 1951). This coat is the baby coat and will be referred to as G_1 or the first hair generation. The second coat completely replaces the first and will be referred to as G_2. The replacement is complete insofar as the shafts of the hairs of G_1 lose contact with the follicle bulbs; these grow new hairs

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belonging to G_2. Both hairs, one G_1 and one G_2, usually remain in the same hair canal of each follicle, however. Initiation of G_2 is not simultaneous all over the body but starts at the head and in most cases spreads rapidly towards the tail. As G_2 is initiated between 30 and 40 days after birth and as weaning to 40 days is a period during which weight increases rapidly, this period was chosen to test the effect of heat on body and hair growth. The eruption of hairs of G_2 has been described by Dry (1926), Borum (1945), and Fraser and Nay (1955).

The effect of heat on the composition of the coat, the dimensions of the hairs composing it, and the rate of growth of the coat was also observed. Dry (1926) classified the coat into hairs of four kinds: *A*, guard hairs; *B*, awls; *C*, auchenes;

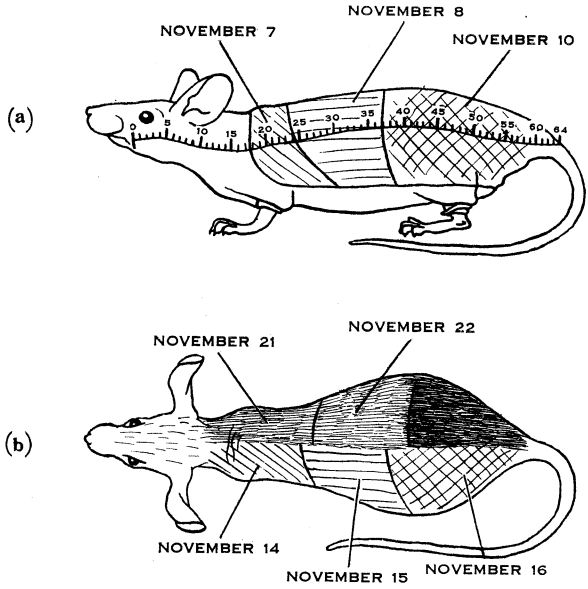

Fig. 1.—(*a*) Method of recording the eruption of G_2 hairs; (*b*) method of recording growth rate of G_2 hairs.

and *D*, zigzags. This classification is followed here, the composition of the coat being expressed as the proportion of hairs of type *B*, *C*, and *D*. *A* has been ignored, as guard hairs form a very small proportion of the total.

II. Material

Two stocks of mice were used. One is a non-inbred stock of albino mice kept in the laboratory, and which was founded by crossing several different lines. The second stock, also made by crossing several stocks together, and maintained non-inbred, is of recent origin and is segregating for many different colour genes including albino. This stock was used to determine the time taken to complete G_2. The albino stock was used in all other experiments.

III. Experimental

(*a*) *The Timing of G_2 at 20°C*

Forty male and 40 female mice were clipped shortly after weaning, close to the skin on the left side of the body. Mice were weaned at 21 days in this and all subsequent experiments. The eruption of G_2 hairs could be seen clearly on the clipped side and the date at which hairs appear on different areas was recorded on the silhouettes as shown in Figure 1(*a*). The method is described in more detail by Fraser and Nay (1955). G_2 was considered complete when hairs had appeared on all areas

Table 1

Average age (in days) at the eruption of G_2 in 40 male and 40 female crossbred mice

Position	Males	Females
20	30·92	33·50
30	31·92	37·25
40	32·77	38·17
50	33·30	38·50

of skin. The average age at which G_2 hairs appear in positions 20, 30, 40, and 50 is given in Table 1. It will be seen that in males the process starts on about the 31st day of life and takes about 2·5 days, passing from head to tail. Females start when a few days older and the process takes 5 days to complete. Males and females must, therefore, be considered separately.

Table 2

Average weaning weight and average weight and age at the eruption of G_2 of male albino mice kept at 20, 34, and 38°C from time of weaning

Group	Temp. (°C)	No. of Animals	Average Weaning Weight (g)	Average Weight at Eruption of G_2 (g)	Average Age at Eruption of G_2 (days)
Control	20	19	9·40	17·33	33·31
Hot room	34	19	9·67	16·56	34·78
Control	20	10	8·73	17·37	34·4
Hot room	38	10	9·07	15·10	48·9

(*b*) *Temperature at which Heat Stress becomes Evident*

Thirty-eight males from seven litters were divided into two groups. One was kept in the mouse house at 20°C. The other was put into a 1500-egg capacity commercial egg incubator in cages. The temperature was kept at 34°C and the humidity was not controlled. A second lot of 20 males was divided into two groups,

the first being kept at 20°C, and the second being kept in the incubator at 38°C. All mice were weighed at weaning and at intervals thereafter. The completion of G_2 was recorded for both sets of controls and both treated groups. The results are set out in Table 2 and Figure 2. At 34°C the body weight increases are a little less and the completion of G_2 is slightly later than at 20°C. The weights were recorded at weaning and at completion of G_2 so that the treated group was growing a little longer than the control. It seems probable that though the effect of 34°C is not marked there is some retardation of growth. At 38°C the effect was more noticeable. The completion of G_2 took 14 days longer and at 7 weeks of age the control group

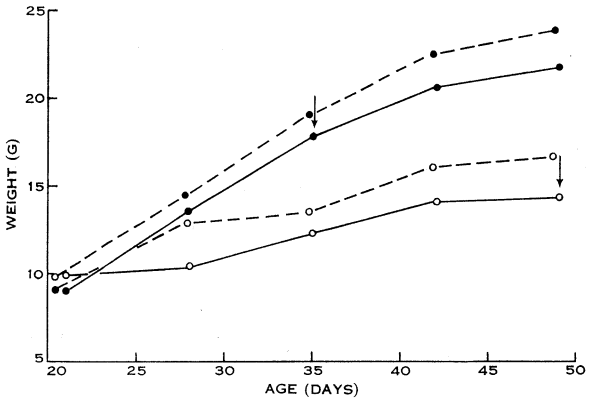

Fig. 2.—Effect of heat stress (38°C) on body weight and the eruption of G_2 hairs (○). Arrows mark the eruption of G_2 over the whole back of the animal. The dotted lines refer to a second experiment in which the eruption of G_2 was not observed. ● Controls.

weighed 22 g whereas the treated group weighed only 14 g. At the stage when G_2 is completed the controls weighed more than the treated even though the treated took 2 weeks longer to reach this stage. It appears, therefore, that 34°C is very near the critical temperature above which growth is seriously interfered with, and at 38°C the effect is more pronounced. Further experiments were carried out at 38°C. The first of these was a repeat of the effect of temperature on growth rate of males. Twenty-two males from four litters were divided into two groups, control and treated, and weighed at weaning and at weekly intervals to 7 weeks. The results are shown graphically in Figure 2 as dotted lines. Both treated and controls were heavier than similar groups in the first run at 38°C but the difference due to treatment was much the same.

(c) *Effect of Heat on Hair Growth Rate and on Coat Composition*

The third experiment was carried out with 46 mice from nine litters, 23 mice being kept as controls and 23 being kept at 38°C. There were 12 females and 11 males in each group. In addition to being clipped at weaning on the left side, the hair on the right side of these animals was dyed with commercial hair dye. When the hair

of G_2 reaches a length almost the same as G_1 the white hairs of the albino coat can be seen through the dyed G_1 coat (Fig. 1(*b*)). The time at which the coat changes colour in this way can be recorded to the nearest day. This time was taken as the time required for G_2 to reach a length just short of G_1 and is used as a measure of hair growth rate. The change in coat colour was recorded on silhouettes in the same way as the appearance of G_2 hairs. The difference in days between the two events in each area is taken as an index of hair growth rate. The results are shown in Table 3. The rate of growth of hairs of treated males is slightly less than that of controls, the rate of growth of hairs of females is more than 10% less. The method has limitations, nevertheless it is fair to say that hair growth rate is probably retarded and not accelerated by heat. In treated females the difference in rate of hair growth was significant (at the 5% level) but in treated males it was not significant.

TABLE 3

TIME TAKEN FOR HAIRS OF ALBINO MICE TO REACH A GIVEN LENGTH

Group	Temp. (°C)	Males		Females	
		No. of Animals	No. of Days	No. of Animals	No. of Days
Control	20	11	7·27	12	7·33
Hot room	38	11	7·72	12	8·75

Samples of hair were plucked from all mice in the last experiment and classified into types *B*, *C*, and *D*. Their length and diameter were then measured. One sample was plucked from each mouse at position 40 on the clipped side so all hairs belonged to G_2. One hundred hairs were picked from the lower end of the sample to avoid discrimination. Only hairs with a club intact were taken to avoid measuring broken hairs. Classification was made in cedar-wood oil under a dissection microscope. Lengths were measured against a graticule and hairs were straightened against the measuring edge. Diameters were measured under a microscope at a magnification of ×350. The broadest part of the *B* hairs, the broadest part of the second segment from the tip of the *C* hairs, and the broadest part of the "stalk" of the *D* hairs were measured. The results, set out in Table 4, show that the composition of the coat differed after heat treatment. The number of *D* hairs was higher and of *C* lower than in the controls. The difference in the number of *D* hairs between treated and non-treated groups was significant at the 1% level, and in the number of *C* hairs at the 0·1% level. There was no significant difference in the number of *B* hairs. All hairs were shorter and finer after treatment. The effect on males and females was not very different. Ten mice were sampled 12 days after the first sample to check that growth had ceased at the time of first sampling. As the measurements

TABLE 4

EFFECT OF TEMPERATURE ON COAT COMPOSITION OF ALBINO MICE

Group	Temp. (°C)	Sex	Hair Generation	Type *B*			Type *C*			Type *D*		
				%	Length (mm)	Dia. (μ)	%	Length (mm)	Dia. (μ)	%	Length (mm)	Dia. (μ)
Control	20	Male	G_2	19·63	8·36	48·84	16·80	7·83	27·78	60·27	6·95	19·99
Hot room	38	Male	G_2	18·18	6·54	40·08	10·27	6·32	22·25	68·90	5·81	17·19
Control	20	Female	G_2	17·16	7·95	48·25	16·75	7·90	27·99	63·41	7·06	19·99
Hot room	38	Female	G_2	19·41	6·40	41·69	9·66	6·30	22·12	68·33	5·82	16·97
Control	20	Male	G_1	11·30	7·07	33·65	10·80	6·98	22·84	76·00	6·23	15·00

did not differ they have not been included. The length of the G_2 coat at 38°C was in fact shorter than the G_1 coat. Measurements of G_1 coats of males are shown in Table 4 for comparison.

IV. Discussion

Temperatures over 34°C affect the growth of mice. At 38°C their increase in weight is slow and their hair grows more slowly and to a smaller size than at lower temperatures; the appearance of G_2 is delayed and the percentage of different types of hair is different from that of mice kept at 20°C. Dry (1926) and Fraser (1951) have calculated the percentage of hairs of different types seen in G_1. Dry found 83% of *D* and 14% of *B* and *C* combined. Fraser, in four different strains of mice, found 69–75% of *D*, 26–28% of *B*, and 1–3% of *C*. The G_1 coats scored in this experiment lie somewhere between Dry's and Fraser's counts. Dry observed that a follicle which produces a certain type of hair in G_1 may produce the same type in G_2 but may produce one of a larger type and only very rarely one of a smaller type. Comparing G_1 to G_2 in this experiment, it appears that retardation of hair growth by heat has resulted in fewer follicles increasing their activity so as to grow type *C* rather than type *D* hairs, and about the same number producing type *B* rather than type *C* though the *B* hairs are shorter, not longer, than those in G_1 and the increase in diameter over G_1 is less in the heat than at normal temperatures. The interpretation of hair type being related to follicle activity is in accord with work on sheep (Fraser and Short 1960). It is possible that all changes observed were due to a lowering of follicle activity, in which case time of origin of G_2 which is the most sensitive measure, is the best index of the effect of heat on hair growth in mice.

Rensh (1929) observed that animals living in hot climates were smaller and had shorter coats than their relatives living in temperate climates. If the changes observed in this experiment can be considered adaptive, then the fact that animals in hot climates have similar characters genetically fixed in them may be an example of the way a physiological response becomes fixed by selection as a genetic trait. If mice were selected, some for early and some for late appearance of G_2, one might expect differences between the two groups in response to a hot environment.

V. Acknowledgments

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