GROWTH OF THE MOUSE COAT

III. PATTERNS OF HAIR GROWTH

By T. Nay and A. S. Fraser*

[*Manuscript received January* 15, 1954]

Summary

Hair growth cycles were observed for a period of 60 days in 10 Naked mice of different ages. The duration of the total hair cycle varied according to position and increased from head to tail. Within each position over all ages the duration was constant. These facts explain the pattern of growth cycles in Naked mice.

I. Introduction

The cyclical replacement of the mouse coat is a well-established fact, and has been studied in detail by Dry (1926), Dannel and Kahls (1947), Fraser (1951), Fraser and Nay (1953), and several others. Dry examined microscope preparations of hair samples from different sites and deduced the position of bands of hair growth from the stages of development of these samples. He achieved very exact information but his analysis suffered from (*a*) the heterogeneity of the mice which he used, (*b*) the necessity of killing each animal to obtain the hair samples, and (*c*) the short range of the analysis, which extended only to the fourth hair cycle. Dannel and Kahls (1947) made drawings of the internal surface and so could also make only one observation per animal. Fraser (1947) measured the rate of growth in length of the different types of hairs which occur in the first coat. He obtained accurate estimates of the ages of initiation and cessation of growth of the first coat in four genetically defined stocks of mice. However, his observations were again limited to one per individual, and to the first hair cycle. He suggested that these difficulties could be avoided by utilizing the Naked gene (Lebedevsky and Dauvert 1927; see also Grüneberg 1952) which causes ordinary coat hairs to break and be shed just before the completion of their growth. Such mice differ from normal mice in exhibiting a covering of coat hairs only on those regions which are actively in the growth phase. The advantages of using Naked mice are that observation of the position of hair bands is very simple and fast (Fraser and Nay 1953), and that repeated observations can be made on the same individual.

II. Methods and Material

Dannel and Kahls (1947) traced the positions of hair bands on a silhouette representing the whole outstretched skin of an animal. They did not transform

* Animal Genetics Section, C.S.I.R.O., University of Sydney.

their observations onto a numerical scale. Fraser and Nay (1953) also used standard silhouettes to record positions of hair bands in Naked mice. They used a top and a side view, and it was found by Turner (appendix to Fraser and Nay 1953) that positions of hair bands could be estimated equally from the top or side silhouettes. The top view has therefore been discarded.

The position of a hair band is determined along a line running from head to tail, along the side, which is divided into 64 segments, and position is measured from the head (0) to the root of the tail (64).

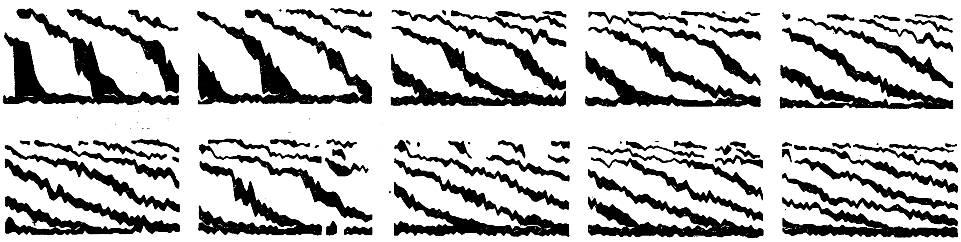


Fig. 1.—Hair growth cycles plotted against age and position separately for each of the 10 mice. Each graph extends over 60 days, from the ages given in the text.

The stock of mice used was the NA stock, which is a highly inbred subline of the Strong A strain kept segregating for the *Na* gene (Fraser and Nay 1953). Ten adult male mice, selected at random, were drawn daily for a period of 60 days. The ages and weights of these mice at the beginning of observations were:

(1)	73 days	20·7 g	(6)	181 days	24·5 g
(2)	78 days	23·6 g	(7)	195 days	20·9 g
(3)	123 days	26·5 g	(8)	217 days	24·6 g
(4)	140 days	22·5 g	(9)	227 days	25·4 g
(5)	150 days	23·1 g	(10)	340 days	24·9 g

The drawings (600) were scored for positions of the hair bands, and these were then plotted against age, to allow study of the changes of position (Fig. 1). Two measurements were extracted from these graphs.

(i) *Duration of Total Cycle* (A-B).—This is the interval between the successive initiations of hair growth phases in a specified region. On our diagrams this is the interval between the passage of two successive anterior (advancing) edges of hair bands over a specified region. The measurement (*A-B*) includes both the growth and the rest phases.

(ii) *Duration of the Growth Phase* (C-D).—The interval between initiation and cessation of hair growth, on a specified region. Both *A-B* and *C-D* were measured to ± ½ day. They are illustrated in Figure 2.

Since observations were made of different mice at the same age, their graphs overlap; they were therefore superimposed, and the advancing (anterior) edge of hair cycles traced onto a single diagram (Fig. 3). A mean value of the positions of the anterior edge of successive hair cycles was determined and plotted in Figure 4.

III. Results

(a) A-B. *Duration of Total Cycle*

A-B was measured for several positions and the age at each measurement taken as the position of *A* (Fig. 2). No change of *A-B* with age was found over the range of ages included in our data. This is illustrated in Figure 5. The duration of a total cycle does vary with position, increasing from head to tail. This is shown in Figure 6.

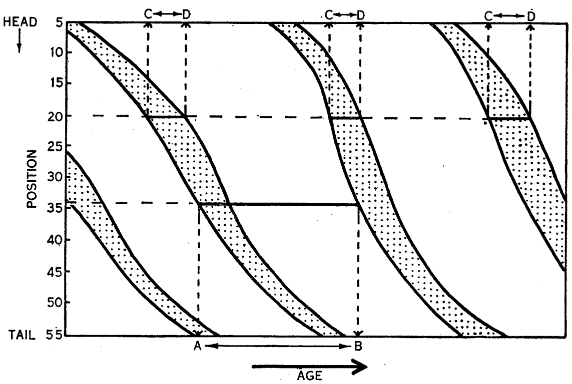


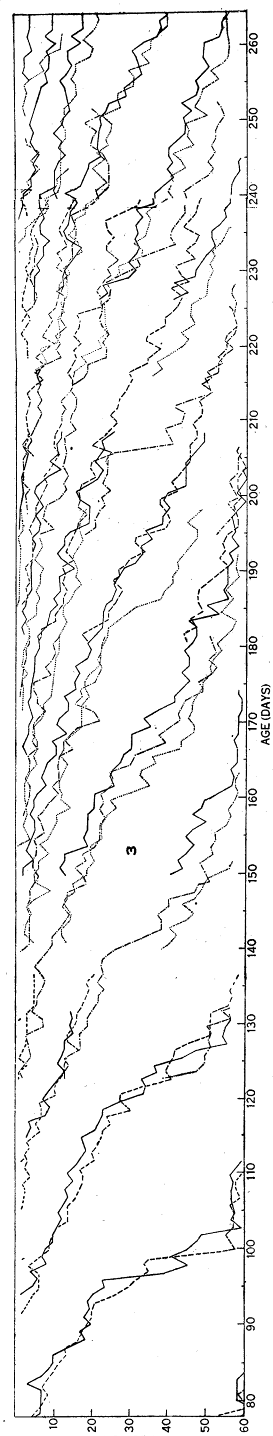
Fig. 2.—A schematic pattern of hair growth cycles to show how *A-B* and *C-D* are obtained from the data in Figure 7.

(b) C-D. *Duration of Growth Phase*

Measurements of *C-D* were made in the same way as for *A-B*. Again no change of *C-D* with age and a marked increase from head to tail were found (Figs. 7 and 8).

The average values of *A-B* and *C-D* for different positions are given in Figure 9. A feature of this diagram is the demonstration that the duration of the resting phase also increases from head to tail.

The diagram (Fig. 3) in which data from the different mice were superimposed shows a surprising uniformity of the total pattern. This can be explained by the genetical uniformity of the stock and by the environmental variation of the pattern being low. Only one mouse (7) is out of step, showing a more juvenile pattern than would be expected. This mouse became sick and emaciated towards the end of the observation period, and died shortly afterwards. Results obtained from this mouse were not included in the average diagram (Fig. 4). The diagram in which the positions of hair bands were averaged (Fig. 4) illustrates several features of the total pattern which require



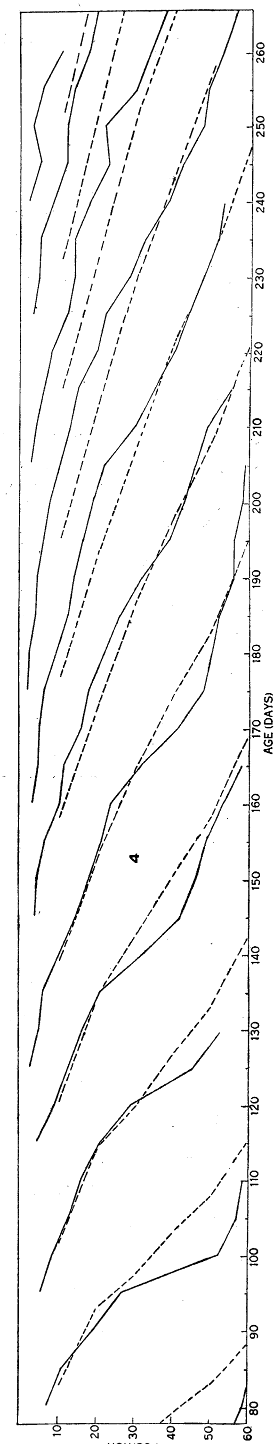


Fig. 3.—Plots of the position of the advancing (anterior) edge of the hair bands, overlapped for each of the 10 mice.

Fig. 4.—Plot of the position of the advancing (anterior) edge of hair bands, averaged over all mice, and superimposed on the theoretical pattern (broken line).

explanation. The slope of the movement of hair bands decreases markedly with age. The width of a hair band decreases markedly with age. The number of hair bands occurring simultaneously on a single animal increases with age. This is very well marked in the comparisons of animals 1 and 8 (Fig. 1).

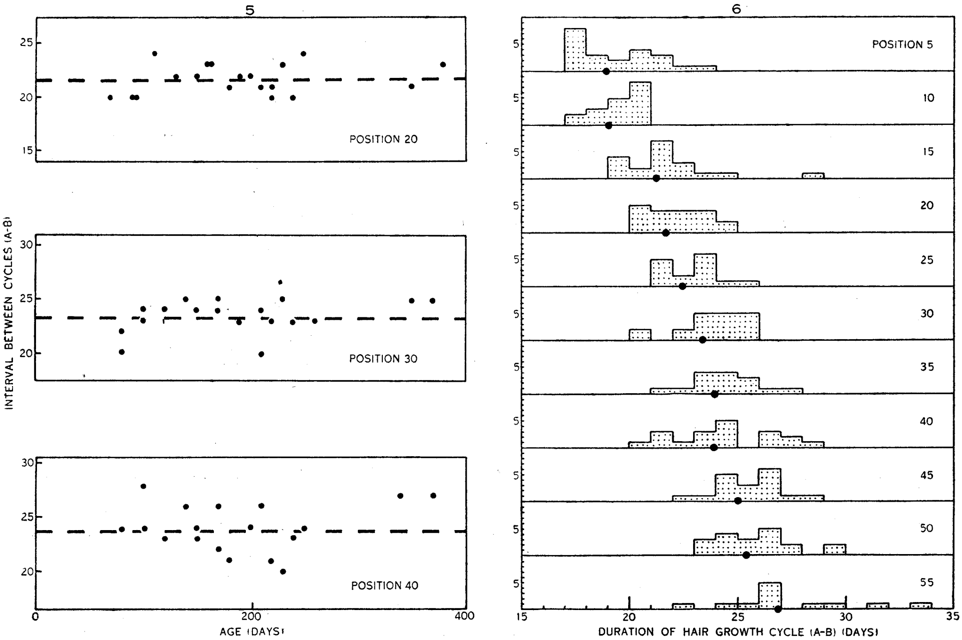


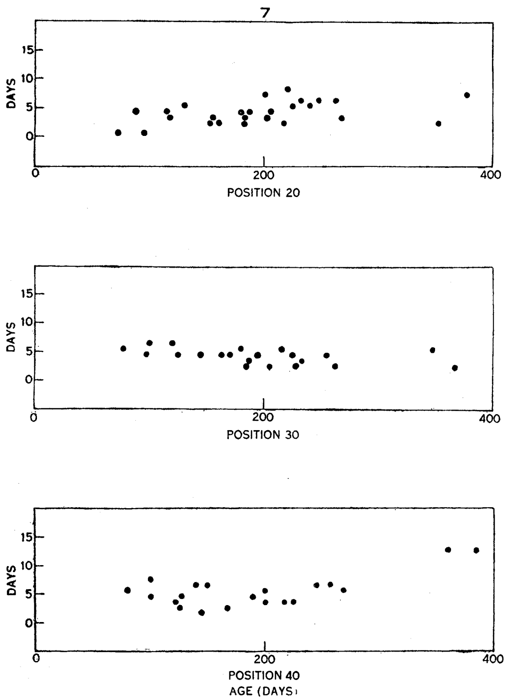
Fig. 5.—Duration of total cycle (*A-B*) plotted against age for positions 20, 30, and 40.

Fig. 6.—Frequency histograms of *A-B* for different positions, taken over all mice and ages.

IV. Discussion

It has been shown that although the duration of the resting and growth phases increases from head to tail, yet they are invariant with age. These two facts supply the explanation of all the features of the pattern of hair cycles, and this is clearly demonstrated by calculating a theoretical pattern of hair cycles derived solely from our estimates of the values of *A-B* which were given in Figure 6. The construction of such a theoretical pattern has been made for the anterior (advancing) edge in order that comparison can be made with the average values of the pattern, which are given in Figure 4.

Growth of the first coat begins about 8 days after birth (Grüneberg 1952) and although initiation on the head is earlier than initiation on the tail, the interval is only 1-2 days. We therefore assume that growth of the first coat commences simultaneously all over the body at 8 days after birth. The mean value of *A-B* at a given point gives the time of initiation of the second hair cycle at that position. By adding *A-B* for each position successively, the time of initiation of the third, fourth, fifth, and later periods of growth at each



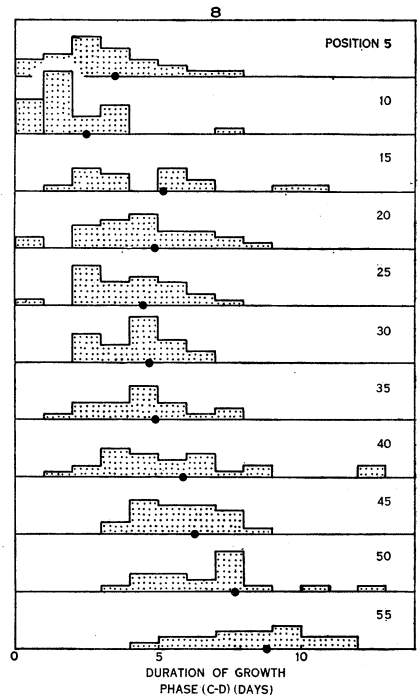


Fig. 7.—Duration of growth phase *C-D,* plotted against age for positions 20, 30, and 40 over all mice.

Fig. 8.—Frequency histograms of duration of growth phase *C-D,* for a series of positions, over all mice and ages.

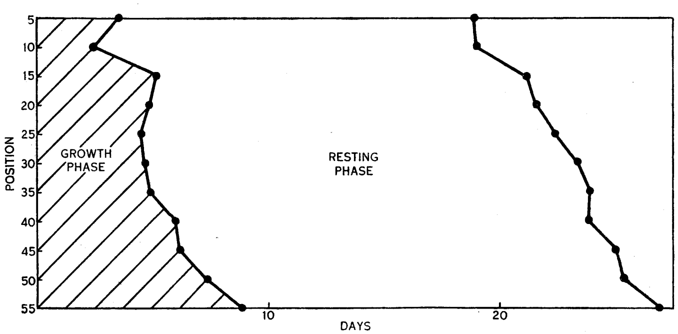


Fig. 9.—Average values of *A-B* and *C-D* for different positions to show the increase with position, from head to tail.

position can be found, and so a theoretical pattern of the hair cycles can be built up. This is shown by the broken lines in Figure 4. The agreement between actual and observed values is reasonable, and shows the validity of our assumption that the various features of the pattern can be explained (*a*) by the constancy of duration of hair cycles at each position, and (*b*) by the increase in duration of hair cycles in a gradient from head to tail.

There must be an early, probably pre-natal, determination of the constants of hair cycles. Each region follows its own pattern of growth and rest in slightly more time than the adjoining region cranial to it, and slightly less time than the adjoining region caudal to it. The mechanism can be analogized to a row of alarm clocks in which each clock runs at a slightly slower rate than the preceding one. After the first cycle the alarms will go off in an almost continuous sequence. However, as more and more cycles are run through, the alarms will go off in greater and greater disagreement.

It must be emphasized that although in adult males and unmated females the basis of the pattern of hair growth cycles is invariant with age, yet in pregnant females this pattern is consistently and characteristically disrupted (Lebedevsky and Dauvert 1927; Dannel and Kahls 1947; Fraser and Nay 1953).

V. References

Dannel, R. L., and Kahls, Liselotte (1947).—*Z. Naturf.* (2*b*) **516**: 215-22.
Dry, F. W. (1926).—*J. Genet.* **16**: 287-340.
Fraser, A. S. (1951).—*J. Exp. Zool.* **117**: 15-29.
Fraser, A. S., and Nay, T. (1953).—*Aust. J. Biol. Sci.* **6**: 645-56.
Grüneberg, H. (1952).—"Genetics of the Mouse." (Nijhoff: The Hague.)
Lebedevsky, N. G., and Dauvert, A. (1927).—*Biol. Zbl.* **47**: 748-52.