

A NOTE ON THE GROWTH OF THE REX AND ANGORA COATS

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(With Plate 5 and Five Text-figures)

In rabbits, as in most mammals, the skin follicles form a succession of complete hairs, each growth period alternating with a rest period. After forming a hair a follicle may immediately shed it, or retain it passively for some time, thus retaining continual cover. Except during the growth of the first pelage, it is not usual for more than a small region of skin to be in the growth phase at any one time. Dry (1926), working on the mouse, and Haddow, Elson, Roc, Rudall & Timmis (1945), on the rat, have shown that the growth phase passed like a wave in an antero-posterior direction over the main trunk. Examination of new-born mice and rabbits indicates that the commencement of growth of the first pelage also spreads in a wave from head to tail. The cessation of growth of the first pelage presumably also occurs in a similar manner (Fraser, 1951*a*). The existence of definite periods of growth implies that variation of the length of the coat can be caused by alterations in either of two factors: the fibre growth rate and the duration of the growth phase.

Two genes occur in the rabbit which affect the length of the coat. In Rex rabbits the coat is shorter, and in Angora rabbits the coat is markedly longer than in normals. Both the rex (*r*) and the angora (*l*) genes are recessive, and they show independent segregations indicative of independence, or a very loose linkage.

Preliminary observations were made of the effects of these genes on animals from crosses segregating for both Rex and Angora. The rex gene, in addition to the shortening of the coat, also causes a curling of the whiskers by which litters can be separated into Rex and non-Rex soon after birth, before growth of the coat has commenced. Once the coat has commenced growing it becomes increasingly obvious that the Rex coat grows more slowly than the non-Rex coat. Within the non-Rex group, no differences could be seen either in the age of commencement or rate of growth, until 3–4 weeks after birth, when it becomes apparent that the growth of the angora coat continues for a longer time than the normal coat. This is first noticeable around the head, and later on the rest of the body. The growth of the Angora coat continues until about 8 weeks after birth at least, when observations were discontinued.

It can therefore be adopted as a working hypothesis that the rex gene causes a decrease of the rate of growth of the coat without affecting the duration of the growth phase, and the angora gene causes an increase of the duration of the growth phase without affecting the rate of growth. The latter conclusion has already been reached by Iljin (1936) from results of thallium treatment. If an animal is treated with a thallium compound the coat ceases to grow and after a few days it is shed, leaving the skin naked. This occurs only in those regions which are actively in the growth phase, no effect being discernible in regions in which the follicles are in the resting phase. Iljin found that thallium treatment of Angoras always results in complete shedding all over the body, whereas the same treatment of normals results in only small regions shedding their hairs. Thus in normals the growth

of hair may be interrupted in various regions by thallium treatment, depending on age at treatment, but in Angoras the growth phase occurs continually all over the animal.

These observations indicate two methods by which useful data could be collected on the modes of action of the rex and angora genes: (1) thallium treatment of Rex, Angora and normal sibs made at a sequence of ages, which should allow the duration of the growth phase to be estimated, since if animals of a certain age shed their coat after treatment one can conclude that they were in the growth phase at that time, whereas if they show no effect of treatment they must have been in the resting phase; (2) comparison of the lengths of the coat at a sequence of ages. This will allow measurement of rate of growth, and estimation of the duration of the growth phase.

These two methods have been used in studies of a limited number of Rex, Angora, Rex-Angora and normal rabbits. Only the growth of the first pelage is considered.

TREATMENT WITH THALLIUM

Throughout the experiments involving thallium treatment, thallos acetate was used, at a concentration of 1 mg./c.c. of distilled water, to give a dosage of 10 mg./kg. body weight. The intraperitoneal route was used.

In the first experiment a litter of two Angoras and two normals was injected 28 days after birth. After a lag of about 6 days the Angoras completely shed their coats. No effect was discernible in the normals; thus at some age before 28 days, growth of the first coat has ceased in normals, but not in the Angoras.

The second experiment was designed to test whether the growth phase ceased at the same age in the Rex and normal types. A series of sib pairs of Rex and normal rabbits were treated at ages ranging from 8 to 30 days. In all the pairs injected before 16 days the coat was completely shed in both Rex and normal. There was a lag between treatment and shedding of about 7-9 days in the normals and 8-10 days in the Rexes, as reported by Ijijn. Shedding commenced on the face. The effect of treatment of two pairs injected at 17 days is interesting, since in both Rex and normal only the coat of the posterior trunk was shed, that on the head and shoulders showing no effect of treatment (see Pl. 5). This can be interpreted as showing that the coat had ceased to grow on the head and on the shoulder at 17 days, but was still growing on the back and rump. The pairs of animals injected at later ages (23, 25 and 30 days) showed no effect of treatment. Therefore the coat ceases to grow on the back between 18 and 22 days.

These results allow an estimate of the age of cessation of growth of the first pelage, but it is not certain whether the day of treatment or of effect is the pertinent age; on the former assumption growth ceases on the back soon after 17 days, and on the latter soon after 24 days. Considering all the results, it can be said that growth of the coat on the back ceases either at 18-22 or 24-28 days. The growth data given below clarify this. However, regardless of the actual date of cessation it is certain that in both Rex and normal the duration of the growth phase is similar or identical.

STRUCTURE OF THE COAT

Cursory inspection of the coats of normal rabbits shows that two types of hairs occur: guard-hairs which project above the rest of the coat, and down-hairs which form the bulk of the coat. If samples of the coat are separated into their individual hairs, this heterogeneity is very obvious, and it can be seen that guard-hairs, in addition to their greater

length, have a coarse tip, and are less markedly crimped, or not crimped at all. The down-hairs lack this coarse tip, and are markedly crimped throughout their length.

No differences can be seen, either macroscopically or microscopically, between Angoras and normals till after 30 days from birth, when it becomes increasingly apparent that the angora coat continues to grow whereas the normal coat ceases to grow.

The Rex coat grows at a slower rate than the normal coat, and further there is an absence of the guard-hairs which are so noticeable a feature of the normal coat. However, if samples of Rex coats are separated into their individual hairs, two types can be seen which correspond to the guard-hairs and down-hairs of the normal coat, although not differing in length. The Rex guard-hairs are only slightly longer than the longest down-hairs, but can be easily distinguished by the occurrence of a coarse tip. This tip is not as coarse or as long as in normal guard-hairs and the crimping of the basal part of the Rex guard-hairs is more marked than in normal guard-hairs.

Two Rex-Angora rabbits have occurred in one of our crosses. These were initially scored as Rexes, since they seemed identical with Rex rabbits, having the curled whiskers, short coat, and apparent lack of guard-hairs which are diagnostic of the rex gene. However, after 30 days from birth their coats continued to increase in length until it became obvious that they had coats of the Rex-Angora type. The length of their coats is intermediate between normal and Angora, and there is a lack of the coarse guard-hairs which are a feature of the Angora coat; instead the shorter, less coarse guard-hairs occur, as in the Rex coat. In Text-fig. 1 are shown two samples of the coats, taken at 21 and 53 days, of normal, Rex, Angora, and Rex-Angora rabbits.

The structure of the different types of coats corroborates the suggestions that the angora gene affects only the duration of the growth phase, and the rex gene affects only the rate of growth of the coat. The identity of normal and Angora, and of Rex and Rex-Angora coats before 30 days, the continuing of growth of the Angora and Rex-Angora coats after this age, and the difference of length of normal and Rex, and Angora and Rex-Angora coats all support this suggestion.

RATE OF GROWTH OF THE COAT

Measurements were made of the lengths of a number of hairs from samples taken at various ages from 7 to 60 days. All the samples were taken at or near the standard back sampling region which is located at the point of attachment of the last rib. The measurements were made by the same method as that used for the analysis of the growth of the mouse coat (Fraser, 1951*a*).

Several rabbits were sampled sequentially, around the same region, at ages from 7 to 60 days, and in Text-fig. 2 are given the average lengths of guard-hairs and down-hairs plotted against age. These show that growth ceases at or before 21 days, since no further increase of length occurs after that age. The average lengths of the samples taken before 25 days lie on reasonably straight lines, showing that for each type of hair, within a rabbit, the rate of increase of length is constant. This has also been found for mouse hairs (Fraser, 1951*a*). As expected, the guard-hairs grow faster than the down-hairs, both in Rex and normal, the difference being less in Rex.

The results of thallium treatment gave an estimate of the cessation of growth of the coat as at 17+ or 24+ days, depending on whether the day of treatment or of effect is pertinent. The measurement of the rate of growth of the coat shown in Text-fig. 2 indicates that the

coat ceases growing before 21 days, and therefore considering the results from both methods it appears that the growth of the first pelage ceases on the back at about 18–21 days.

These comparisons of Rex and normal can be extended by including all the various rabbits which were sampled in the analysis. In Text-fig. 3 are shown the growth rates, separately for guard-hairs and down-hairs, for all four types of coat.

These data show that the normal and Angora coats grow at the same rate, and that the growth of the normal coat ceases at about 21 days, whereas that of the Angora continues at

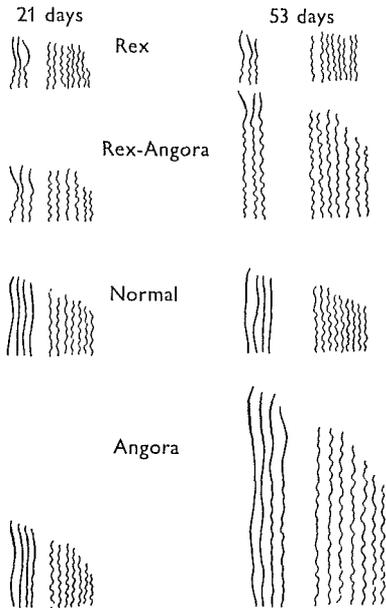


Fig. 1.

Text-fig. 1. Drawings of hairs from the various coat types, to illustrate the separation of down-hairs from guard-hairs, and to show similarity of Rex to Rex-Angora, and normal to Angora in samples taken at 21 days, and the differences in samples taken at 53 days.

Text-fig. 2. Length of coat plotted against age to show the cessation of growth at about 20 days. Three rabbits were sampled, and in each the increases of length of guard-hairs and down-hairs are plotted separately. The pairs of solid and dotted lines are from two normal rabbits, the pair of broken lines are from a Rex rabbit.

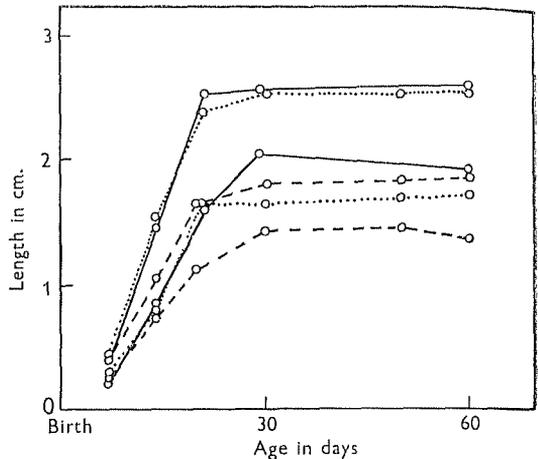


Fig. 2.

the same rate at least until 60 days, after which no further measurements were made. Similarly, the Rex and Rex-Angora coats grow at the same rate, and the growth of the Rex coat ceases at about 21 days, whereas that of the Rex-Angora continues again at least until 60 days, after which no further measurements were taken. This fully corroborates the hypothesis of the different bases of effect of the rex and angora genes.

HISTOLOGY

The next step in the description of the Rex and Angora coats is to examine the effects of the *r* and *l* genes on the development of the hair-follicle population. Samples of skin were taken from a number of Rex, Rex-Angora, Angora and normal rabbits at about 20–30 days after birth. All of the samples, as nearly as possible, were taken from the standard back sampling position. These samples were sectioned, using standard histological methods, both in the plane of the skin surface and in a plane running along the length of the follicles.

Not enough of these sections were successful to allow rigorous descriptions of the effects of the *r* and *l* genes, and therefore the following descriptions can only be taken as preliminary.

In Text-fig. 4 are shown camera lucida drawings of + and *r* skin sections cut in the plane of the skin surface. The + section shows clearly the division of the follicle population into groups, and how these groups consist of one large, primary hair follicle, and several small, secondary hair follicles. Almost certainly the primaries form the guard-hairs and the secondaries form the down-hairs. The ratio of *P/S* follicles is 1/18 (two samples examined),

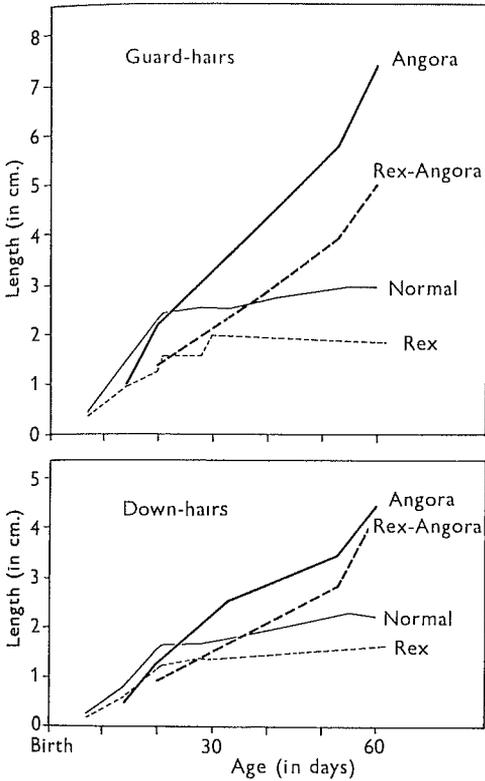


Fig. 3.

Text-fig. 3. Rates of increase of length of the coats averaged over all the available data (several rabbits of each type) for all four types of coat.

Text-fig. 4. Camera lucida drawings of sections through the plane of the skin surface of a normal (left) and a Rex (right) rabbit.



Fig. 4.

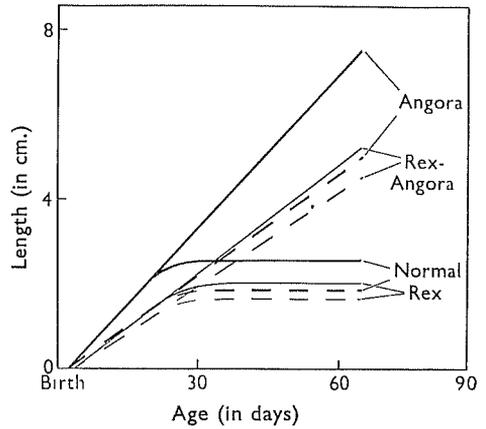


Fig. 5.

Text-fig. 5. Simplification of Text-fig. 3 to remove variation due to sampling and illustrate the effects of the *r* and *l* genes on the growth of the coat. Solid lines are the rates of growth of guard-hairs, broken lines are rates of growth of down-hairs.

which agrees with the ratio of guard-hairs to down-hairs, which is of the same order. In the *r* section, there is no clear division into groups of follicles, and it is not possible clearly to distinguish primaries from secondaries. Further, although examination of a larger number of samples may prove this to be incorrect as a generalization, the follicle population is noticeably more dense in the two *r* samples studied than in the three + samples. This suggests that the decrease of the rate of growth of the coat caused by the *r* gene is due to an increase of density of hair follicles, which would result in a decrease of the amount of hair

substrate available to each follicle. This has been suggested to occur in sheep (see Fraser, 1951*b*, Fraser & Hamada, 1952), where an increase of follicle density is also correlated with a decrease of the length of the fleece. Critical studies are needed to check this point in the rabbit.

In Pl. 5 are shown micro-photographs of longitudinal sections of skin from rabbits with all types of coat (+, r, l and rl). It is possible, as expected, to distinguish primary from secondary follicles in + and l, and in r and rl, again as expected, this distinction is difficult; the primary follicles in these types are only occasionally sufficiently larger than the secondary follicles to allow a clear distinction between the two types. There are no marked differences between + and r, and + and l in the depth to which follicles extend into the skin.

The histological studies, to be rigorous, need to be based on controlled sampling procedures to obviate differences due to shrinkage, etc. (Burns, 1949), and should be carried out at a series of ages from pre-natal to advanced post-natal stages. The results described above may only be taken as indications that an increase of follicle density may be caused by the r gene, and that no obvious changes of the follicle population appear to be caused by the l gene.

SUMMARY

It has been shown that the normal coat of rabbits is composed of two types of hairs: long guard-hairs and short down-hairs. The growth of the coat ceases at about 18–21 days. The gene rex causes the hairs to grow at a slower rate, but does not affect the duration of the growth phase. The angora gene causes no change in the rate of growth of the hairs, but causes an increase of the duration of the growth phase, the hairs continuing to grow until at least 8 weeks after birth. This is illustrated in Text-fig. 4.

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EXPLANATION OF PLATE 5

- A, B. Rabbits injected with thallium acetate at 17 days showing the incomplete shedding of the coat. A, Rex; B, normal.
 C, D, E, and F. Sections cut through length of hair follicles. C, normal; D, Rex; E, Angora; F, Rex-Angora.