THE EFFECTS OF DAY LENGTH ON THE COAT-SHEDDING CYCLES, BODY WEIGHT, AND REPRODUCTION OF THE FERRET

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Summary

The effect of light on the coat of the ferret has been measured during the annual cycle of seasons. Two groups of ferrets were kept in the same environment except for the daily duration of light, which comprised the normal seasonal day length of Brisbane for the control group, and a complete and exaggerated reversal of seasonal light trend for the experimental group.

The growth of hair was shown to be controlled by day length. In both control and experimental groups, as the daily light decreased, there was an extensive shedding of hair, stimulation of new hair growth, and a subsequent increase in coat thickness. As days became shorter, body weight increased significantly, sebum secretion declined, and both males and females became reproductively inactive.

When day length increased, on the other hand, hair growth ceased and minor shedding of some of the fine hair decreased the density of the coat. This resulted in a relatively coarse coat, which became very greasy with sebaceous secretion. There was a significant fall in body weight and the ferrets rapidly assumed reproductive activity as days lengthened, irrespective of ambient temperature.

The effects of pregnancy and other factors which may be associated with these changes are discussed.

I. INTRODUCTION

That light is an important factor in regulating the breeding season of ferrets has frequently been demonstrated since the initial studies made by Bissonnette (1932). He showed that electric light added after dusk caused the onset of oestrus in the ferret during the non-breeding season of the year, from September to March (northern hemisphere) or from March to September (southern hemisphere).

Later it was reported that changes in the pelts of ferrets and fitch (Bissonnette 1935) and mink (Bissonnette and Wilson 1939) were conditioned by changes in the duration of daily exposures to light irrespective of the environmental temperature and colour of surroundings. A more detailed account is given by Bissonnette and Bailey (1944) of studies on the weasel, an animal closely related to the ferret. They found that reduction of the daily periods of light induced moulting and growth of new fur, together with a colour change from brown to white (Bonaparte weasels) or from dark brown to light brown (New York weasels). Increase of the daily light periods caused moulting and a change to dark brown in both species. It was also found that a latent or adjustment period intervened between the time of increase of light ration and the shedding and regrowth of hair. In the weasel the latency appeared to be about 3 months. It was noted by Hammond Jr. (1953) that mink laid down thick subcutaneous fat during the period of decreasing light but the deposition was not measured. This adaptation to cold appeared to be unaffected by temperature since it occurred when day temperatures were over 90°F if the photoperiod were reversed.

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Photostimulation passes through the eyes, as has been shown by Bissonnette, and the fact that hypophysectomy abolishes the cyclic moulting and regrowth of hair in ferrets (Bissonnette 1935) indicates that this gland is involved in the reaction. Recent studies by Donovan and Harris (1954) have demonstrated that the effect of light on oestrus in the female ferret depends upon the integrity of the hypophysial portal blood vessels. It seems likely, therefore, that the seasonal light change acts as a stimulus which is translated into a seasonal release of hormones from the anterior pituitary, and that this controls the breeding cycle, and probably the hair cycle also.

Cattle shed their coats under the influence of changes of day length (Yeates 1955) and the ferret has been studied as a laboratory animal in order to investigate the control of the shedding process.

II. Experimental Methods

Five male and five female adult ferrets, including four albino ferrets, were kept in large wire cages in a room open to natural daylight. They were therefore exposed to the normal light duration for the latitude of Brisbane, 27°30′S. These formed the control group.

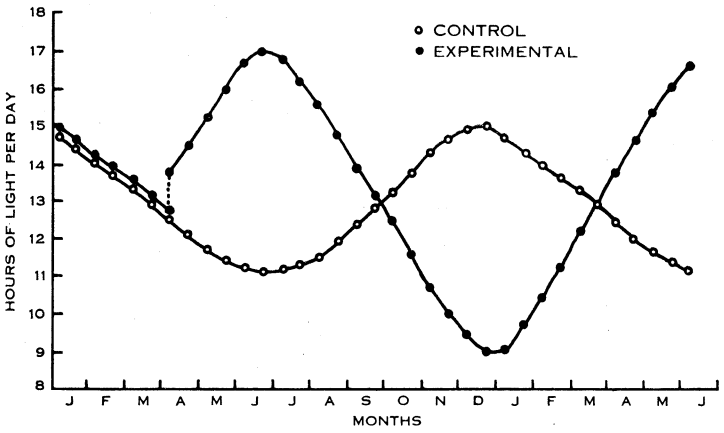

Fig. 1.—Lighting conditions to which the control and experimental groups were subjected.

A similar group of ferrets was placed in a box 6 by 4 by 3 ft in which the duration of light could be decreased by blackout arrangements, or increased by switching on four 100-W electric lights in the early morning and evening. A pattern of light duration similar to that used by Yeates (1955) was adopted for the experimental group. From Figure 1 it is seen that while the control animals were experiencing their shortest day in June, the experimental ferrets through the addition of artificial light were experiencing their longest days. The summer-to-winter light changes in the experimental group were exaggerated beyond the normal range for Brisbane, so that they amounted to 17 hr of light in midwinter and 9 in midsummer. This was done to emphasize any effects which light might have. Apart from reversal of the light trend for the experimental group, the environments and treatments of both groups were the same. The animals were exposed to the normal temperature fluctuations for Brisbane's

climate, ranging from a winter mean monthly minimum of 49°F, to a summer mean monthly maximum of 86°F. To prevent any excessive rise in temperature within the light box, fresh cool air was circulated and maximum–minimum thermometers showed that the temperatures of the control room and light box did not differ by more than 3°F.

A diet of raw meat, bread, and water supplemented with bran mash, salt, and vitamins was provided *ad libitum*. Satisfactory weight records and freedom from disease indicated that there was no nutritional deficiency.

TABLE 1

CHANGE IN AVERAGE LENGTH OF COARSE AND FINE HAIR (CALCULATED FROM THE LENGTHS OF ABOUT 20 HAIRS FROM CLIPPINGS OF FOUR CONTROL AND FIVE EXPERIMENTAL MALES) AFTER SHEDDING INDUCED BY DECREASING DAILY PHOTOPERIOD

	Control		Experimental	
	Coarse Hair	Fine Hair	Coarse Hair	Fine Hair
Average maximum length (mm) before shedding period	48±5	28±5	46±5	33±5
Average maximum length (mm) after 4–6 weeks of major coat-shedding period	33±3	21±1	31±3	23±3
Significance of difference	$P<0{\cdot}001$	$P<0{\cdot}05$	$P<0{\cdot}001$	$P<0{\cdot}01$

During 12 months, observations were made on the reproductive state of the animals, and weekly records of weight were kept. In particular, measurements were made on the coat. The shedding tendency was estimated by the amount of hair which could be pulled from the coat by gently plucking. A scoring system was used by which increasing degrees of shedding were represented by numbers up to 4. Hair density was calculated by shaving a measured area of skin and weighing the hair so removed. This sample of hair was analysed by measuring the lengths and diameters of about 200 individual hairs from each sample. The growth rate of hair was measured directly on the shaved areas as millimeters increment per week. The activity of the sebaceous glands was assessed roughly by the greasiness of the coat.

During the course of the year's experiment two animals died from causes unknown. The results given below are therefore averages from four male and five female control ferrets, and from five male and four female experimental ferrets.

III. RESULTS

(*a*) *Hair*

(i) *Type of Hair*

Diameter.—Two distinct types of hair occur in the coat of ferrets—coarse hairs with a diameter of 95±20 μ and fine hairs with a diameter of 23±9 μ. The changing proportions of fine and coarse hairs of male ferrets are shown in Figure 2. There was relatively more coarse hair in the long light period, while the fine hair correspondingly

decreased. In the short light period there was a decrease in the relative amount of coarse hair and an increase of fine hair. The differences within each group and between the two groups are significant at the $P<0{\cdot}001$ level.

Some of the females were allowed to mate, and the ensuing pregnancy or pseudo-pregnancy had pronounced effects on the coat. The females were therefore excluded from the analysis of the effect of light on the coarseness of the coat. The effects of pregnancy will be discussed later on in more detail.

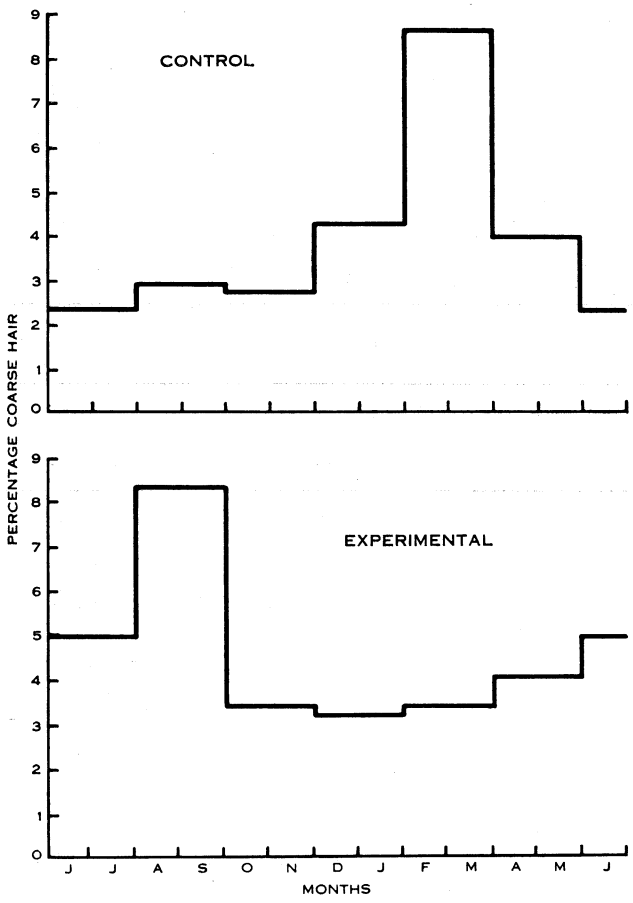

Fig. 2.—Percentage of coarse hairs (diameter $\simeq 95\,\mu$) in coats of male ferrets.

Length.—The changes in hair length were less obvious. The maximum lengths of hair in midsummer and midwinter were not significantly different for either group of ferrets. There was, however, a significant decrease in average coat length at the beginning of the major shedding period (Table 1). Since rapid growth also occurred in this period, the hair quickly became thick and long again within 4–6 weeks.

Greasiness.—The coat appeared oily and the hairs became adherent to each other as the light increased, and the coat was greasy to touch in contrast with the soft, non-greasy coat of the short light season.

Pigmentation.—Pigmentation, when present, occurred only in the distal portion of the coase hairs, which varied in colour from light brown to black. Fine hairs of all the ferrets remained unpigmented, although sebum secretion tended to turn them yellowish in the "summer" season.

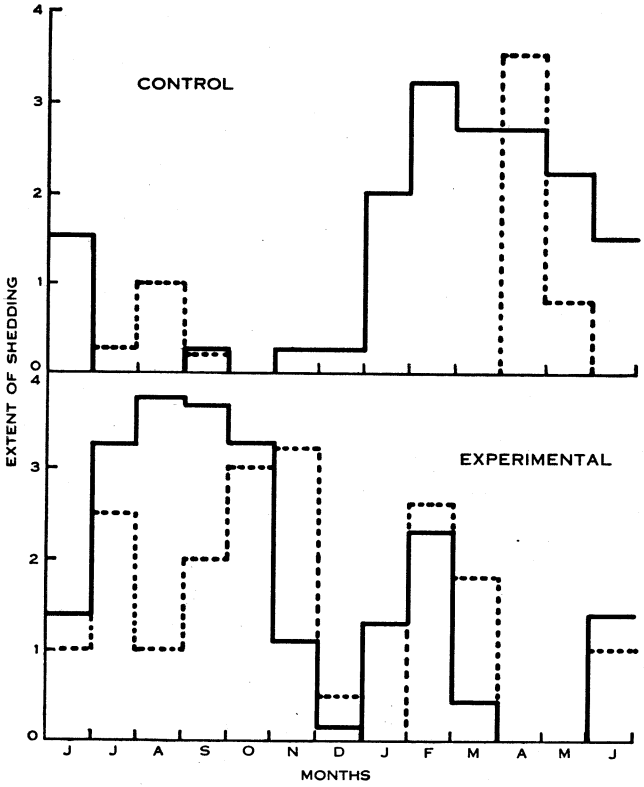

Fig. 3.—Extent of shedding in male (———) and female (– – – –) ferrets. Increasing degrees of shedding are represented by figures up to a maximum of 4.

(ii) *Shedding*

For each group of ferrets there were two distinct moults during the year—a major shed during the decreasing light period and a minor shed during the increasing light period. The major shed for the control males lasted from January to June with a peak in February, so that the response to the change in light trend occurred after 1 month of shortening day length. The major shed for females, excluding the two which were pregnant at this time, was much shorter, lasting for only 2 months (April and May) with a peak in April. The latent period for females was about 3 months.

The minor shed for the control males occurred from September to December, 3 months after the light began to increase. From July to September there was minor shedding among the females after a latent period of 1 month.

The experimental animals showed the same shedding pattern as the controls, except that it was 6 months out of phase. The major shed lasted from June to November with a peak in August–September for the males and in October–November

for the females. The latent period for the males, therefore, was less than 1 month, whereas for the females it was about 3 months.

The lesser shed in the males occurred from January to March and from February to March in the females. Shedding reached a peak in February for both groups, i.e. after 1 month's latency.

The major shed involved a loss of the entire coat of old hair in a wavelike fashion, starting at the head and proceeding in roughly transverse bands towards the tail.

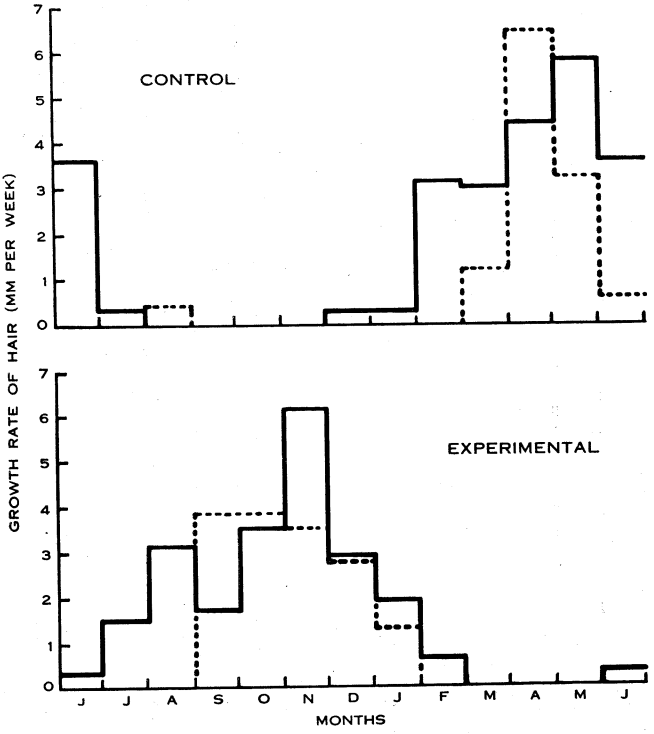

Fig. 4.—Growth rate of hair (mm per week) of male (————) and female (– – – –) ferrets.

New hair, already partly grown, took the place of the old coat, and although the animals were never actually bare at any time, the coat became short during this moulting process. The process was particularly clear in the white ferrets whose "summer light" coat was coarse, and yellow with grease. As shedding proceeded, the yellow hair was replaced, band after band, by soft white hair. The minor shed appeared to involve only the loss of some of the underfur, while the thicker hairs became coated with sebum. The extent of shedding, averaged over the groups, is shown in Figure 3. The prolific shedding which followed in the two pregnant control animals is not included in the histogram.

(iii) *Growth Rate of Hair*

The average rate of growth of hair for each group of animals is shown in Figure 4. There was virtually no growth during the period of increasing daily light so the

clipped patches remained bare for nearly 6 months of the year. Growth was stimulated within 4 weeks of decreasing the daily light and the greatest rate of growth (6 mm/week) was reached 4 or 5 months later. The graph for the control females does not include the rapid growth of hair which occurred in two ferrets in December and early January as a result of pregnancy.

The hair reached its maximum length (Table 1) before it was fully pigmented, so that clipped patches were easy to identify for measuring purposes. Full pigmentation of the coarse hair occurred 3 or 4 weeks after the hairs had grown to their maximum length.

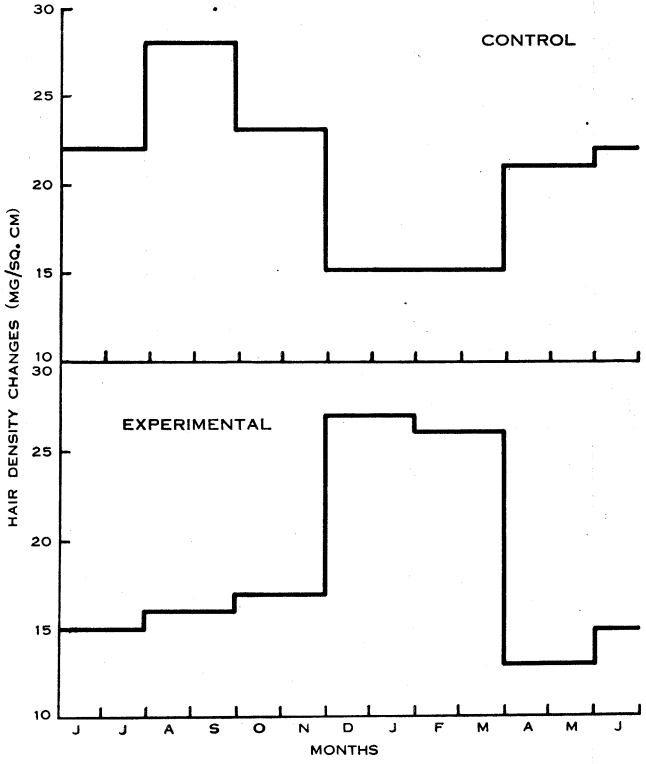

Fig. 5.—Changes in density of hair (mg/sq. cm.) among male ferrets.

(iv) *Density of Hair*

Changes in coat density with the seasonal light changes were analysed on the male ferrets of each group (Fig. 5). In the long day period the coat became less dense as the minor shedding process brought about loss of fine underfur. After a latent period of about 2 months, shortening day length was associated with an increase in coat density, which reached its maximum 2 or 3 weeks after the shortest day. The difference in coat density between the groups for "summer" and "winter" was highly significant ($P<0{\cdot}001$).

The females are excluded from this analysis again owing to the effects of pregnancy.

(*b*) *Breeding Season*

The breeding season of both male and female ferrets was recorded in terms of the size of the testes or vulva, and its incidence is represented in Figure 6. The histograms show that the females were in full oestrus for about 6 months of the year and completely anoestrous for the other 6 months. The sexual activity of the males, on the other hand, reached a peak for only about 4 months, but it was sustained at a much reduced level during most of the rest of the year.

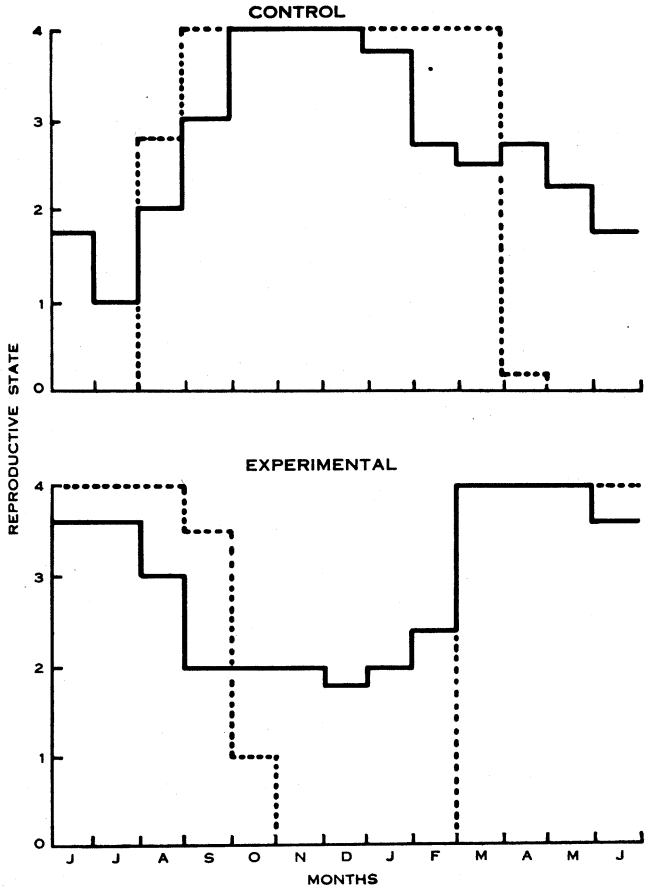

Fig. 6.—Reproductive state of male (———) and female (– – – –) ferrets. The size of the testes or vulval turgor is indicated by an arbitrary scale of 0 (small) to 4 (large, active).

The relationship of breeding cycles and light changes is in accord with the many previous experiments reported since 1932. It is presented here to show its correlation with the hair cycle.

(*c*) *Body Weight*

Weight gain or loss in fully grown ferrets was found to be a light-controlled seasonal phenomenon (Figs. 7 and 8). As the daily light period increased there was a gradual loss of weight amounting to 22–28 per cent. of the initial weight. The weight cycle was reversed by reduction of day length but it was independent of ambient tem-

perature. Hence the animals were lighter in weight during long days and heavier during short days. The differences between the summer and winter values (January and July) in each curve are highly significant ($P<0{\cdot}001$), as are the differences between the two January and two July peaks (controls and experimentals).

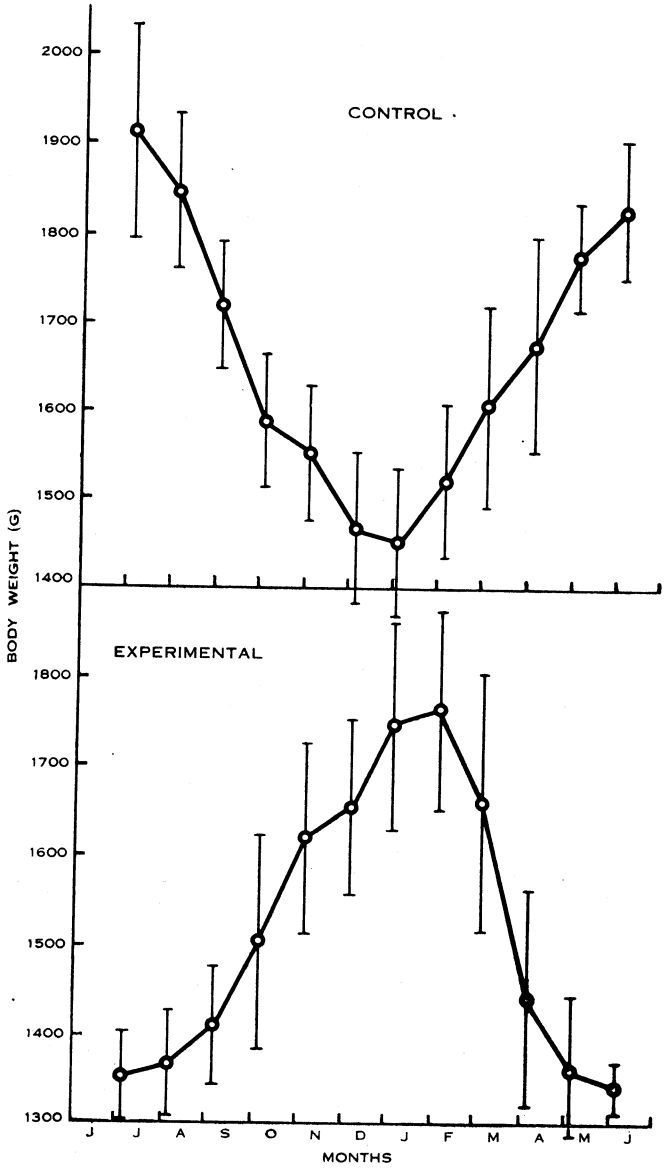

Fig. 7.—Body weight (in grams) of fully grown male ferrets, showing the standard deviation for each month.

(*d*) *Pregnancy*

The effect of pregnancy on the coat of the ferret was similar to that produced by reducing the daily photoperiod. About 2 weeks after mating, the vulva subsided,

indicating an anoestrous state, and at this time coat shedding commenced. Hair growth was rapid, and the coat became sleek and free from excess grease, despite the season of the year. Parturition occurred 6 weeks after mating. In the absence of

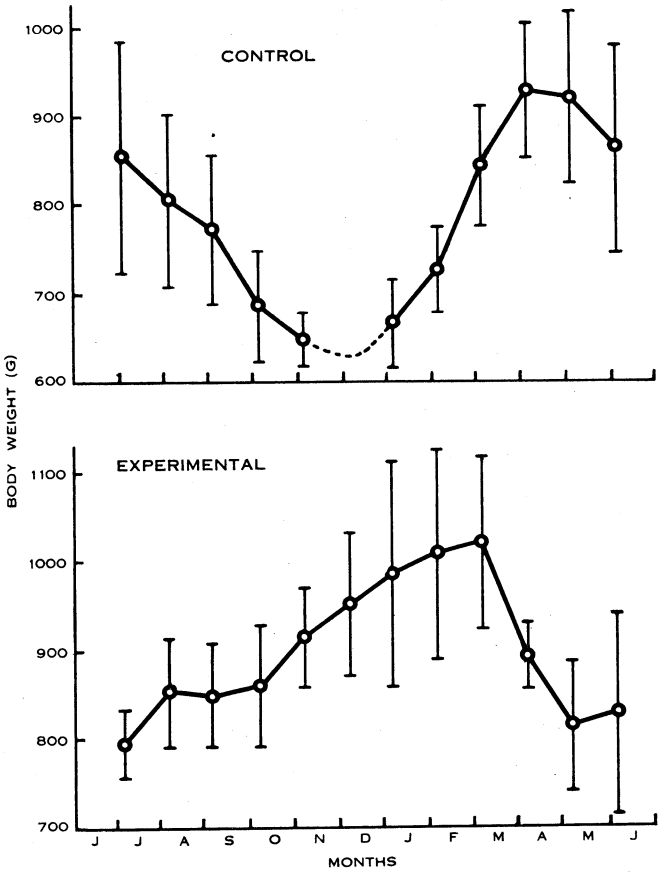

Fig. 8.—Body weight (in grams) of adult female ferrets showing the standard deviation for each month.

lactation, the vulva swelled to the oestrous condition again within 1 week. Shedding, however, continued about 4 weeks after parturition, and hair growth was rapid during this post-partum period. Eventually this activity ceased, and the animals returned to the condition typical of the increasing daylight period. When lactation followed parturition, there was a longer post-partum period (about 6 or 7 weeks), during which there was no vulval turgor, while hair growth and shedding continued.

(*e*) *Sequence of Events*

From a composite diagram representing the average behaviour of four male control ferrets (Fig. 9) it appears that slight shedding during the increasing photoperiod ("spring") caused the density of hair to fall, since there was no compensatory

hair growth at this time. After the change over to a decreasing photoperiod, although growth of hair was stimulated, the effect was counteracted by massive shedding, so that for about 2 months the density of hair remained low. Eventually the hair growth

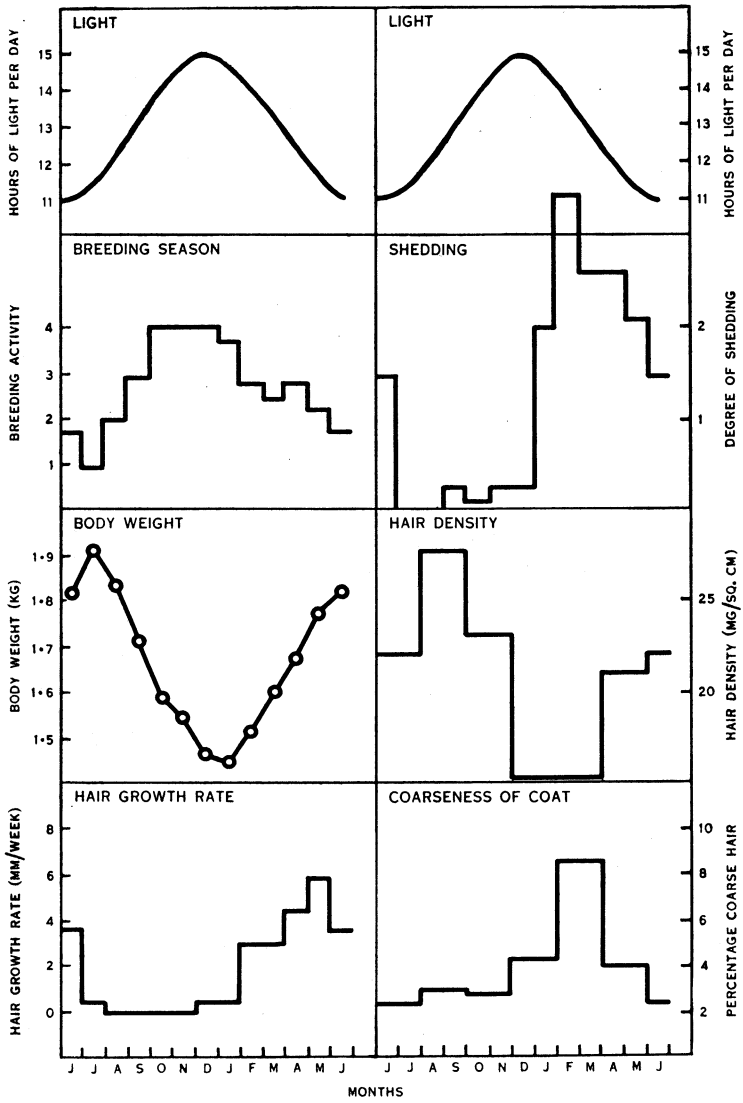

Fig. 9.—Correlation of light changes with breeding season, body weight, hair growth, shedding, hair density, and coarseness of coat of the control male ferrets.

rate exceeded the shedding rate so that the coat became thicker by "winter". It is apparent, too, that the minor shed involved mainly fine hair since the relative amount of coarse hair in the coat increased. This coarse hair was lost in the next (major) shedding process.

The curves for the time course of breeding season and body weight were almost exactly 180° out of phase. Body weight increased only as breeding activity declined, and growth of hair occurred only as body weight increased.

IV. Discussion

The coat of the ferret consists of two distinct types of hair—coarse overhair and fine woolly underfur. In the normal summer, i.e. when daylight is longest, the coarse hairs number about 8 per cent. of the coat, and the fine hair is relatively short. The coat is sparse and greasy with sebum so that air circulates into the coat, which offers little insulation. There is no new growth of hair, and the shedding, if any, is slight and comprises fine underfur only. As day length decreases, hair growth is quickly stimulated and the major shedding process involving the entire coat of summer hair begins. This keeps the density of the coat low until the growth rate of hair exceeds the shedding rate. Like mouse hair patterns (Nay and Fraser 1954), the hair follicles of the ferret appear to become activated in waves passing towards the tail. Shedding and hair growth occur first on the head, and then proceed gradually in bands from the head, so that the tail is the last part to lose the old coat and the last to grow the new one. The new coat has only 2 or 3 per cent of coarse hairs and, by midwinter, the hair has grown to its maximum length. The sebum secretion is reduced, and the normal winter coat is, therefore, a soft, thick insulator.

If there is a hormonal stimulus to growth or shedding, it must be assumed that there are many different types of follicle with different latencies and degrees of response. Growth of some hairs occurs at the same time as loss of other hairs. This suggests a life cycle of individual follicles in which the endocrine background may stop follicular proliferation of hair cells in one, while encouraging growth in another. There remains the possibility of local action, in which a shedding follicle could release a stimulating substance to increase the growth of neighbouring follicles.

The breeding season is brought on by the increasing photoperiod. The males respond to the change in light trend within 1 month, while the females have a latent period of 1–2 months before a change in vulval turgor is produced.

In the adult ferret there is a loss of body weight during the period of increasing day length, and a gain of weight during the next 6 months of decreasing light. The exact nature of this gain and loss—protein, fat, water, or otherwise, has not been investigated, but its inverse relation to breeding season suggests that weight loss is due to greater activity during the reproductive period.

The complete reversal of these phenomena by 6 months reversal of day length, other factors of the environment being the same, is good evidence that light determines coat changes as well as the complex adaptation of reproduction. The breeding cycle and hair-shedding cycle may be causally linked, and this association has a parallel in the effects of pregnancy on hair growth. It is possible that light may influence hair growth through a seasonal release of gonadal hormones. For instance, whenever the female ferret becomes anoestrous—whether due to decreasing light or to pregnancy—there is stimulation of hair growth and shedding takes place. In the male, too, there is no hair growth until seasonal breeding activity is reduced. This indicates that oestrogens should inhibit, and progesterone encourage, both growth and shedding.

It has, in fact, been found in this Laboratory that growth and shedding of hair follow progesterone treatment during oestrus, though treatment with oestradiol has so far been ineffective as an inhibitor of hair growth during anoestrus.

It has been known for some time (Bissonnette 1935) that hypophysectomy abolishes the cyclic hair patterns in ferrets, and it may well be that this is consequent upon the abolition of breeding cycles (Hill and Parkes 1933).

On the other hand, there is also the possibility that hair growth and shedding are influenced by a seasonal release of some other endocrine factor or factors, which are also affected by pregnancy. Sebaceous secretion and the minor ("spring") shedding occur together. It is possible that the same factor could induce both changes. Evidence has been found for a pituitary tropic factor acting on sebaceous glands in the rat, which, although contained in some gonadotrophic fractions, varies independently of gonadotrophic activity (Lasher, Lorincz, and Rothman 1955). It seems possible that this hormone or others like it may influence the skin and hair cycles. Experiments are now being carried out to investigate this problem.

V. Acknowledgments

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