J. comp. Physiol. 85, 267—282 (1973)

The Influence of Photoperiod and Melatonin on Testis Size, Body Weight, and Pelage Colour in the Djungarian Hamster (*Phodopus sungorus*)

Klaus Hoffmann

Max-Planck-Institut für Verhaltensphysiologie, Seewiesen und Erling-Andechs

Received May 14, 1973

Summary. The responses of testes, body weight, and pelage colour to short and long photoperiods in winter were determined in adult male hamsters with and without the implantation of melatonin. Animals in winter condition, with involuted testes and winter pelage, were kept at 20°C under conditions of either long (16 h per day) or short (8 h per day) photoperiods beginning on 2 January. In each condition one group was implanted three times at weekly intervals with melatonin in beeswax, a control group was implanted with beeswax only, and another control group was left untreated. A further control group remained in natural day light. After 37 days testes of the control groups in long photoperiods had reached summer condition, while the group treated with melatonin was delayed in testicular development, and closely resembled both the three shortday groups and the group kept in natural daylight (Fig. 2–4). In short photoperiods there was no difference between the group treated with melatonin and the two control groups. All groups showed some testis development as compared to animals killed at the beginning of the experiment. Hamsters kept under natural daylight showed a marked annual cycle of body weight which closely paralleled gonadal activity (Fig. 5). In the experimental groups there was a corresponding increase in body weight paralleling testicular development (Fig. 6). The two control groups in long photoperiods had a significantly higher increase in body weight than all other groups, while there were no significant differences between the groups treated with melatonin, the two short-day groups and the group under natural daylight. Testis size at the end of the experiment was highly correlated with increase in body weight (Fig. 7, and Table 1).

Molt into summer pelage had started in all groups at the end of the experiment. Colour change was most advanced in the two control groups under long photoperiods, while the long-day group treated with melatonin resembled the short-day groups (Figs. 9 and 10).

It is concluded that the change in physiological state from winter to summer is based on an endogenous mechanism, which is accelerated by long photoperiods, and that melatonin inhibits or greatly diminishes this acceleration while it does not inhibit spontaneous development towards summer condition.

Introduction

In recent years the function of the pineal gland has received increasing attention. In mammals the pineal has been shown to be involved in the regulation of the reproductive system and its modification by external

light (for reviews see Wurtman *et al.*, 1968; Kappers, 1969; Quay, 1969; Reiter and Sorrentino, 1970; Reiter, 1972). The exact mechanism of pineal action, however, is still unclear.

Melatonin is one of the compounds found in the pineal; in mammals it is exclusively produced here. Melatonin has been suggested to be an antigonadotropic hormone of the pineal (Wurtman *et al.*, 1968). Its administration in female laboratory rats resulted in decrease of ovarian weight, delay of puberty and in reduction of oestrus smears in cycling and constant oestrus animals. In male rats, however, the findings have been inconsistent and contradictory, especially with regard to the action of melatonin on testes (Wurtman *et al.*, 1968; Reiter and Fraschini, 1969; Reiter, 1972; Kinson and Liu, 1973). In male weasels, a clear effect of melatonin was reported (Rust and Meyer, 1969): in winter, implantation prevented the development of testes as well as the change from white winter pelage into brown summer pelage, brought about by long photoperiods, and in summer implanted melatonin caused involution of testes and molt into winter pelage, in spite of long photoperiods.

Differences in the findings between rats and weasels could be due to differences in the physiology of rodents and mustelids, or to the fact that the weasel is a seasonal breeder and the laboratory rat is not. Since there is also a paucity of data concerning the influence of melatonin on the sexual physiology of male mammals (Reiter, 1972), it was decided to test the effect of melatonin in males of a seasonally breeding rodent, the Djungarian Hamster. This animal also shows a seasonal change in pelage colour and a marked annual cycle of body weight (Figala *et al.*, 1973). The effects of photoperiod and of melatonin on pelage colour and on change of body weight were therefore also studied.

Material and Methods

The species used in these investigations was *Phodopus sungorus sungorus* (Pallas, 1770). The animals change into a whitish winter pelage and show regression of testes in autumn (Figala *et al.*, 1973). All hamsters used were from our breeding stock which is kept indoors in natural daylight, and thus exposed to the seasonal changes of photoperiod. The temperature in the animal room was $20 \pm 3°C$ throughout the year. Animals used in the experiment were housed singly in plastic cages. They received the same diet throughout the year (for details of animal care see Figala *et al.*, 1973). The original stock came from animals caught near Omsk in Western Siberia.

On 2 January 60 male hamsters in winter pelage were selected for the experiment. The animals were $3^1/_2$ to $6^1/_2$ months old (average $4^1/_2$ months). Their mean weight was 29 g (range 23.6–35.2 g). Pelage colour did not reach the extreme winter condition in all animals. On a scale from stage 1 (summer pelage) to stage 6 (white except for a grayish hue on head and shoulders) all animals were in stage 4 to 6 (see Fig. 9. For details of colour scoring, and for incidence of stages see Figala *et al.*, 1973).

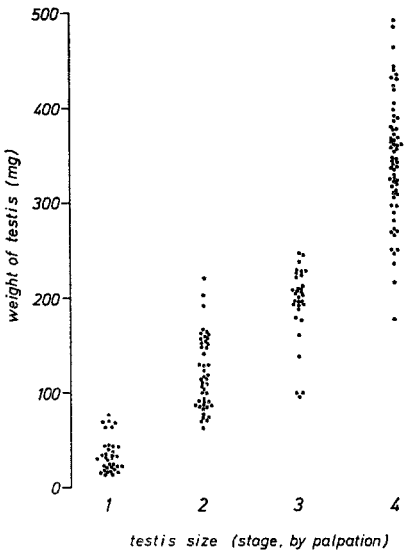

Fig. 1. Testis size (in stages) determined by palpation as a function of actual testis weight in hamsters that were sacrificed after palpation. Each dot represents one testis. For definition of stages see text

Testis size was determined by palpating the abdominal region while the animals were under halothane anaesthesia. Four sizes were recognized: stage 1 = testis not palpable, which corresponds to the fully regressed condition; stage 2 = small testis; stage 3 = testis medium sized; stage 4 = testis large, corresponding to full spermatogenic activity. Fig. 1 gives testis weight and testis stage as determined by palpation just before the animals were sacrificed, and thus illustrates the reliability of the method. In all 60 animals selected the testes were stage 1 at the beginning of the experiment.

Six groups of 10 hamsters each were established. The groups were equalized as closely as possible with regard to age, pelage colour, weight, and parentage, and were randomly assigned to the six experimental conditions. On 3 January, three groups were placed in a light-tight room with a light regime of 16 hrs light per day (from 4 a.m. to 8 p.m.); the remaining three groups were placed in an identical room, but with only 8 hrs light per day (from 8 a.m. to 4 p.m.). Light intensity during the light-time varied from cage to cage, due to its position in the room, between 40 and 600 lux. Within this range no influence of light intensity could be detected in the results. Temperature was kept at $20 \pm 1°C$. In each light condition, one group was implanted subcutaneously with a small disk of melatonin in beeswax (melatonin:beeswax = 1:10) on the first day of the experiment (M), the second group received beeswax only (C), and the third group was left untreated (U). Implantation was repeated on the 8th and 15th day of the experiment.

The implants were prepared by melting beeswax (Cera flava, D.A.B. 7) at 66°, and adding melatonin powder (Melatonin crystalline from Sigma Chemical Company). After stirring, the mixture was poured into prefabricated forms and allowed to cool. The round tablets thus formed were about 5 mm in diameter and 2 mm in

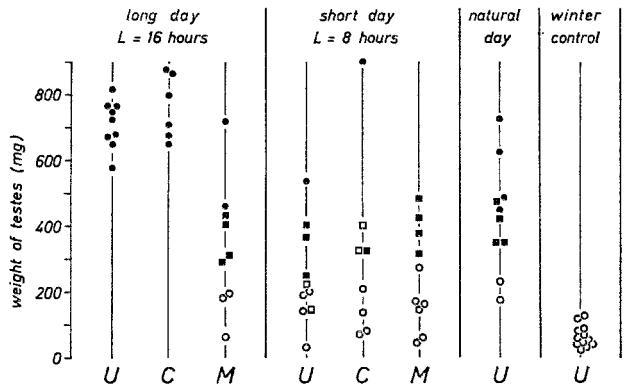

Fig. 2. Weight of testes (both combined) and spermatogenic activity (from smears of the cauda epdidymidis) in the different experimental groups. *U* untreated; *C* control: implanted with beeswax only; *M* implanted with melatonin in beeswax. Full circles: smears full of motile spermatozoa; full squares: less motile spermatozoa in smears; open squares: only isolated spermatozoa in smears from one or both caudae; open circles: no spermatozoa

height and averaged 34 mg in weight containing about 3.1 mg melatonin. Implantation was performed under halothane anaesthesia by inserting the implants through a small dorsal skin incision at a shaved area on the back, and pushing them as far under the skin as possible. The wound was closed by clamps. At weekly intervals all animals were weighed, stage of pelage colour was estimated, and testis size was determined by palpation.

The other hamsters were left in the animal house under natural light conditions. This group corresponded to the others in age, testis stage, and body weight. Winter pelage colour, however, was less well expressed in these animals (stage 3 to 5). The hamsters were checked for testis stage, body weight, and pelage colour on 31 December, and again on 15 and 25 January; otherwise they were left untreated. To characterize testis weight at the start of the experiment, data were obtained from 12 comparable adult males which were sacrificed between 16 December and 10 January for other purposes (Fig. 2, winter controls).

Five hamsters died during the experiment (4 from an overdose of halothane during checks, one fell ill and had to be killed) and 2 turned out to be females. The remaining animals were sacrificed on 8 and 9 February. The testes were removed, weighed, fixed in Bouin's, preserved in ethanol, embedded in Paraplast, sectioned at 10 μ, and stained in Mayer's haemalum and eosin. In all cases the caudae epididymidis were cut and smears were taken, diluted with physiological saline solution, and inspected for the presence of motile spermatozoa. One hamster had a tumor on the left testis and was therefore discarded; the data of the other 62 animals were evaluated.

Results

I. Testes

Testicular weight after 37 days in the experimental conditions is given in Fig. 2. Testis size was highest and had reached summer condition in all hamsters of the two long-day groups that did not receive

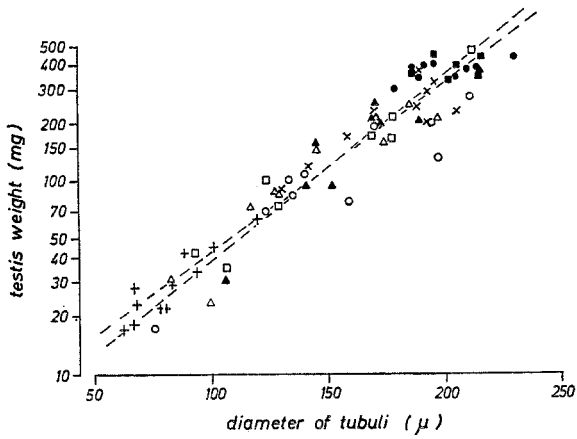

Fig. 3. Correlation between diameter of seminiferous tubules and weight of the right testis. Diameter of tubulus is mean of 10 determinations in the middle of the testis. Closed symbols: long day; open symbols: short day. Circles: untreated; squares: beeswax only implanted; triangles: melatonin implanted, × natural day; + winter controls. The two regression lines are given ($r = 0.96$, $p < 0.001$)

melatonin (U and C); in each of these groups testis size differed significantly from that in each of the other groups ($p < 0.01$ or < 0.001, U test). In the long-day animals treated with melatonin (M), testis development corresponded to that found in the three short day groups and in the animals kept in natural daylight (no significant differences). The hamsters in short-day conditions treated with melatonin (M) had testis weights corresponding to those of the two other short-day groups (U and C) under the same conditions. Testis weight in the group under natural light conditions was slightly higher than that in the short-day groups ($p < 0.05$). In all 7 groups, testis development had significantly progressed in comparison to winter controls sacrificed at the beginning of the experiment ($p < 0.001$).

In all groups, except for the two groups in long-day conditions without melatonin and in the winter controls, there was a considerable amount of individual variation in testis development. Spermatogenic activity, as indicated by the contents of the caudae epididymidis, closely corresponded to testis size (Fig. 2). In individual testes weighing more than 210 mg the cauda epididymidis was always tightly packed with motile spermatozoa, while in testes weighing 110 mg or less no spermatozoa were found in all but three cases, and in these only a few isolated spermatozoa were seen.

Histological examination corroborated the above findings. There was good correspondence between tubicular diameter and testis weight (Fig. 3). For quantitative evaluation, spermatogenic activity was classed

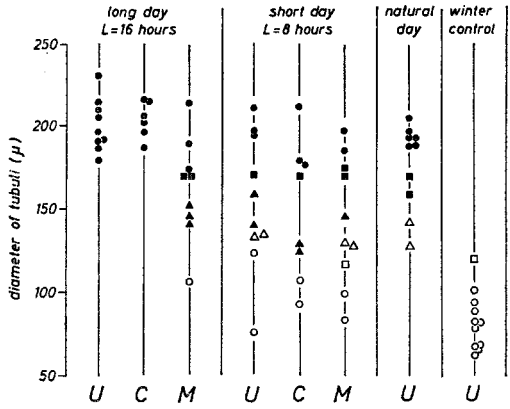

Fig. 4. Diameter of seminiferous tubules, and spermatogenic activity according to histological evaluation, for the right testis of all hamsters, arranged according to treatment. Symbols: open circles: stage 1; open squares: stage 2; open triangles: stage 3; closed triangles: stage 4; closed squares: stage 5; closed circles: stage 6. For definition of stages see text. For further explanation see Fig. 2

into 6 stages: Stage 1 = sertoli cells, spermatogonia, and only very few primary spermatocytes; stage 2 = many primary spermatocytes, a few secondary spermatocytes; stage 3 = more secondary spermatocytes, a few spermatids; stage 4 = many spermatids, spermatozoa beginning to appear; stage 5 = spermatozoa present in some but not all tubuli; stage 6 = full spermatogenesis. Fig. 4 gives the spermatogenetic activity and the diameter of the tubuli for the right testis of all the hamsters in the different groups. The results closely resemble those for testis weights. Large tubuli and full spermatogenesis were found in all animals of the long-day groups that were not treated with melatonin, while the three short-day groups, the group kept in natural daylight and the long-day group that had received melatonin, showed a high degree of individual variability but were otherwise similar to each other. In the 12 winter controls the testes were quiescent in all animals but one. If the diameters of the tubuli are considered, the two long-day groups without melatonin differed significantly from all other groups ($p<0.05$, <0.01, or <0.001, U test), while the long-day group which received melatonin did not differ significantly from the short-day groups or the group under natural daylight. Tubuli diameters of the winter control were also significantly different from all experimental groups ($p<0.001$). In the appearance of interstitial cells no obvious differences between animals with and without melatonin were detected when corresponding stages were compared.

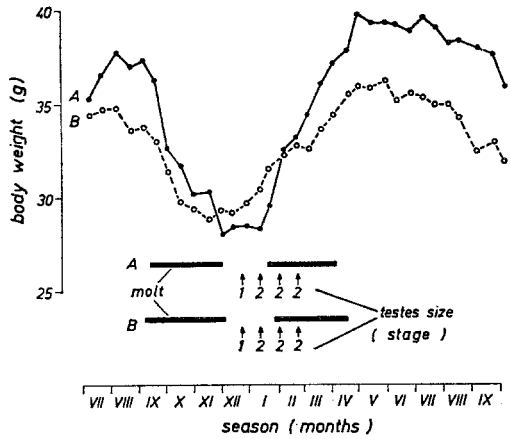

Fig. 5. Annual cycle of body weight and of molt in two male hamsters (A and B) kept in natural daylight at $20 \pm 3°C$ throughout the year. Testis size was determined by palpation at the times indicated. The black bars give the times of molt into winter pelage (left) and back into summer pelage (right). The animals were born in April 71 and weighed weekly from July 1971 to September 1972; the averages of two weighings are given

In general, these results show that long photoperiods in winter accelerate testicular development, and that this acceleration is suppressed by the application of melatonin.

II. Body Weight

Our stock of *Phodopus sungorus* shows a marked annual cycle of body weight under natural illumination running parallel to the annual molting cycle and the gonadal cycle. Fig. 5 gives the weight of two male hamsters from July, when the animals were three months old, until September of the following year. Times of molt into winter pelage and back again into summer fur are also indicated. On four occasions testis size was determined by palpation in these animals. Body weight decreased shortly before or at the beginning of molt into winter pelage, and reached a minimum during the state of winter colouration when the testes were maximally regressed. With redevelopment of testes and molt into summer fur body weight again increased. A corresponding annual cycle in body weight was also observed in females. In animals kept under outdoor temperatures decrease of weight in winter and subsequent increase in spring and summer could be even more drastic (Figala *et al.*, 1973).

Similar changes in body weight were found in the present experiments, with marked differences between the different experimental

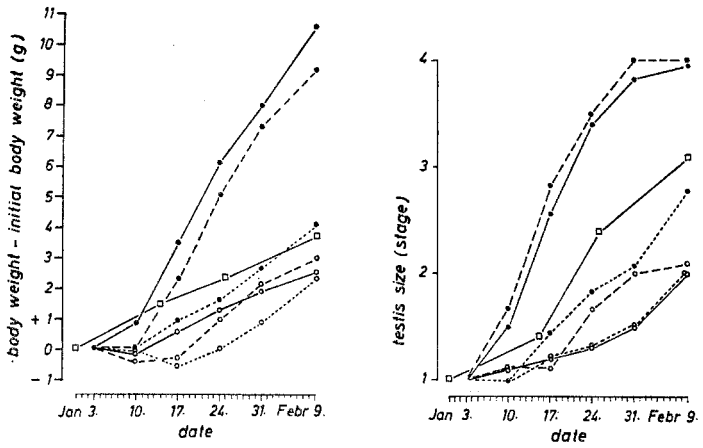

Fig. 6. Change of body weight (left) and testis size determined by palpation (right) throughout the experiment for the different experimental groups. Mean values for each group are given. Note the differences between the groups, and the correspondence between change of body weight and testis size. Full circles: long day; open circles: short day; open squares: natural day. Solid lines: untreated; long-dashed lines: beeswax only implanted; short-dashed lines: melatonin in beeswax implanted

groups, corresponding to their testicular development. Fig. 6 (left) gives the changes in body weight for each of the times the animals were checked; Fig. 6 (right) gives testis size as ascertained by palpation. In the two long-day groups without melatonin there was a marked increase in testis size, recognizable after only one week in the experimental conditions. A definitive increase in body weight was noticeable after two weeks (significant at $p<0.01$ for group U and at $p<0.05$ for group C as against group M and the three short-day groups, U test). During the experiment the increase continued, and when the animals were sacrificed these two groups differed even more drastically from all the other groups ($p<0.01$ or <0.001). The other five groups showed only a modest increase of body weight during the course of the experiment, and no significant difference could be detected between any two of them. There was a strong correlation between change of body weight during the experiment, and testis weight at its end (Fig. 7). When the individual groups are considered a similar correlation is found in all the groups except the two long-day groups without melatonin (Table 1).

These results show that the seasonal rise in body weight is also enhanced by exposing the hamsters to long photoperiods in midwinter, and that the stimulating light effect is suppressed or at least diminished

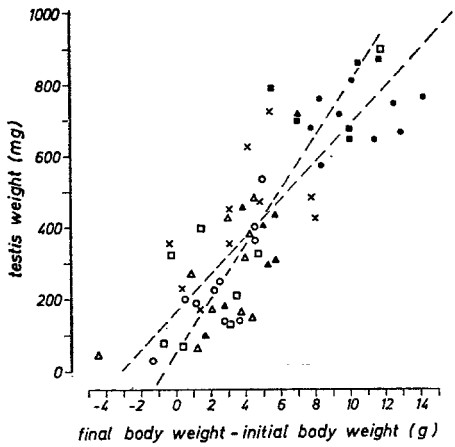

Fig. 7. Correlation between change of body weight and testis weight at the end of the experiment. Closed symbols: long day; open symbols: short day; crosses: natural day. Circles: untreated; squares: beeswax only implanted; triangles: melatonin implanted. The two regression lines are given. For statistical treatment see Table 1

Table 1. Correlation between change of body weight during the course of the experiment, and testis weight at the end of the experiment for the seven experimental groups. Correlation coefficient r, regression coefficient b, and value for p are given

Group		n	b	r	p
Total		62	52.7	0.84	<0.001
Long day	U	9	8.2	0.26	NS
	C	6	7.1	0.23	NS
	M	9	93.7	0.85	<0.01
Short day	U	10	58.1	0.79	<0.01
	C	8	56.2	0.84	<0.01
	M	10	33.4	0.60	<0.1
Natural day		10	32.9	0.57	<0.1

by the action of melatonin. The findings also show that development of testes and increase in body weight are closely parallel and are most probably internally interconnected. Increase in body weight could therefore be used as an indicator for testicular development.

Earlier experiments in which hamsters were exposed to long photoperiods in late autumn, and implanted with melatonin, suggest that similar results can be expected at that season. Twelve male hamsters, born in May or June, and weighing between 23.3 and 37.8 g (mean 30.8 g), were exposed to an artificial light cycle with 15 hours

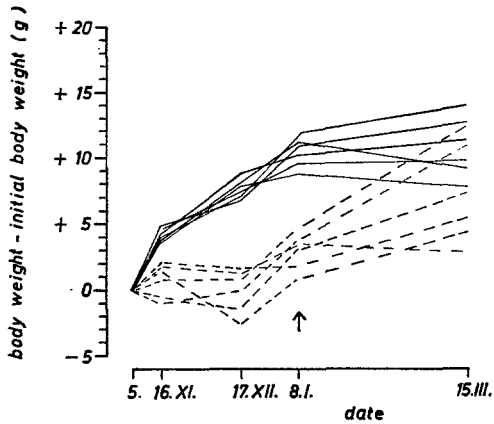

Fig. 8. Change of body weight in hamsters that were kept in 15 h of light per day from 15 Oct. and were implanted with melatonin in beeswax (broken lines) or with beeswax alone (solid lines). Arrow: time of removal of implants. For times of implanting see text

light per day (from 4.30 a.m. to 7.30 p.m.) from 15 October onward, at a time when they had just started to change into winter pelage. On 5, 16 and 24 November and 2 and 6 December, six animals were implanted with melatonin in beeswax, the other six with beeswax only. On 15 January the implants were removed. Fig. 8 gives the change in body weight for these animals. Body weight increased rapidly in the animals treated with beeswax only, while in the hamsters that received melatonin increase in body weight was delayed. On 15 March some had still gained less weigth than the animals without melatonin though the implants had been removed as carefully as possible two months before. However, it cannot be excluded that some small residues remained in the animals. Testis size was not determined in these animals, but by inference one can conclude that testis development was similarly retarded by the melatonin treatment. Similar experiments with two females suggest that in these melatonin also delays the increase in body weight caused by long photoperiods.

III. Fur Colouration

At the beginning of the experiment all hamsters were in winter fur but at the end most animals had started to molt into summer pelage. However, there were marked differences among groups of animals in the degree to which they were advanced towards summer colouration. Fig. 9 gives the colouration of the hamsters under artificial light conditions at the beginning and at the end of the experiment. Colouration is given by stages (see Methods). It must be stressed that the extreme winter colouration is normally reached only in a few individuals (for method of colour scoring, and for incidence of stages under natural daylight see Figala

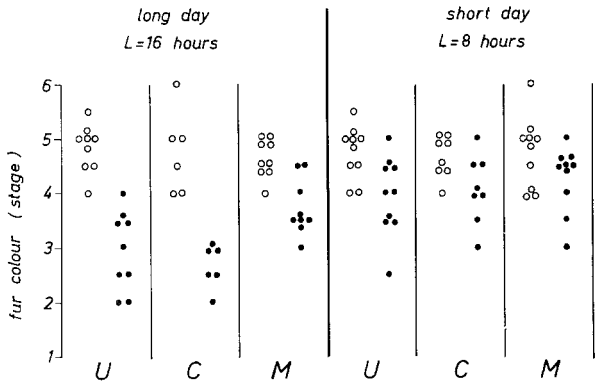

Fig. 9. Pelage colouration (stage) of the hamsters at the beginning (open circles) and at the end (closed circles) of the experiment. Groups as in Fig. 2. For further explanation see text

et al., 1973). The group in natural daylight is not included since their winter colouration was less well expressed at the beginning of the experiment. As can be seen, return into summer pelage was most advanced in the two long-day groups that did not receive melatonin. Each of these differs significantly from each of the other four groups ($p<0.001$ or <0.01, except for long-day U versus long-day M, which was only <0.05). In the long-day group treated with melatonin, colouration was slightly advanced with respect to the short-day groups, but the difference was not significant except with the short-day group treated with melatonin ($p<0.05$).

In order to check for personal bias in colour scoring, all 52 hamsters of the six groups were arranged according to their colour in a linear rank order, with the whitests hamster (most clearly still in winter pelage) ranked no. 1, and the darkest hamster (most advanced towards summer coat) ranked no. 52. For this procedure the dead animals were randomly placed on a table, with no information on the experimental group to which they belonged, and were independently arranged by seven people. The averages of these ranking procedures were determined. The results of this evaluation were closely similar to those presented in Fig. 9, with the two long-day groups without melatonin differing significantly from all others ($p<0.001$ or <0.01). The long-day group that received melatonin was somewhat advanced in comparison to the three shortday groups ($p<0.05$, and in comparison to short-day with melatonin $p<0.01$). There were no significant differences between the three short-day groups.

In addition, the type of hair regrown in the animals sheared for implantation was evaluated. Five categories were recognized: summer hair (S), probably summer hair (S ?), intermediary between summer and winter Hair (S-W), probably winter hair (W ?), and clearly winter hair (W). The animals were classified according to these categories inde-

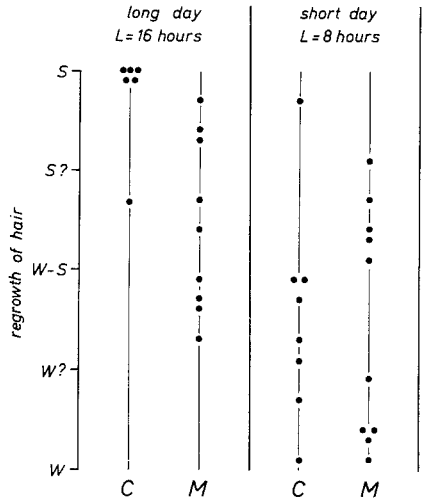

Fig. 10. Type of hair regrown after shearing for control (*C*) and experimental (*M*) groups. For further explanation see text

pendently by seven people, the means of these evaluations are given in Fig. 10. Summer hair was clearly regrown in 5 of the six control animals in long-day, while in the other groups regrown hair was more towards winter pelage.

The results show, that the pelage change is accelerated by exposure of winter animals to long photoperiods, and that this acceleration is delayed by the administration of melatonin.

Discussion

In Djungarian Hamsters long photoperiods clearly stimulated testicular development, increase in body weight, and change into summer pelage in control animals. Such photoperiodic phenomena have been repeatedly described in mammals (for reviews see: Aschoff, 1955; Farner, 1961; Farner and Lewis, 1966; for the golden hamster see: Gaston and Menaker, 1967; Ellis *et al.*, 1972). However, in the short-day groups, development towards summer condition was also noticeable. These findings suggest that at least the transition from winter to summer condition is partly based on an endogeneous mechanism which continues even in the absence of stimulating long photoperiods. This view is supported by the observation that Djungarian Hamsters in which winter colouration in summer was instigated by short photoperiods spontaneously changed back into summer pelage after some months though the

short photoperiods were maintained (Figala *et al.*, 1973). In the golden hamster, redevelopment of testes, after involution induced by very short photoperiods or by blinding, has also been reported (Hoffman *et al.*, 1965; Reiter, 1969). In recent years an endogeneous circannual cycle has been reported in several vertebrates under unchanging external conditions (Pengelley, 1967; Gwinner, 1971).

The implantation of melatonin suppressed or greatly diminished the stimulating effect of the long photoperiods in *Phodopus*. However, it did not completely suppress testicular development, increase in body weight, and molting into summer pelage; this is apparent because the short-day group treated with melatonin did not differ from the two untreated short-day groups although it was significantly advanced in comparison to the winter controls. This suggests that the action of melatonin was not antigonadotropic *per se*, but only counteracted the stimulating effect of light. Closely corresponding observations were made in another seasonal breeder, the ferret, by Herbert (1971). He found that injection of melatonin in oil delayed the premature onset of oestrus in animals kept in long-light periods, but did not suppress onset of oestrus. Our results in *Phodopus* also correspond to the findings of Rust and Meyer (1969) in weasels, though these authors did not control whether there was some gonadal development in spring in spite of the presence of melatonin. All these findings link the effect of extraneously administered melatonin with the suppression or diminuition of the effect of long photoperiods, and thus with the synchronization of the annual cycle with the seasons. Differences in the effect of melatonin in animals like weasels and rats seem to be due to the fact that light actions are more pronounced in seasonal than in aseasonal breeders rather than to differences in the physiology of mustelids and rodents.

That the pineal is involved in mediating light effect on gonadal function has been frequently reported (Wurtman *et al.*, 1968; Reiter and Fraschini, 1969; Reiter, 1972). In general, pineal extirpation counteracts the effects of short photoperiods or of constant dark, or those of blinding. In male mammals, the clearest and most drastic effects have been observed in the golden hamster which, under conditions of natural daylight, is also a seasonal breeder (Reiter, 1969, 1972, 1973; Eichler and Moore, 1971). The most convincing evidence for the assumption that the pineal's main function is the synchronization of the gonadal cycle with the seasons comes from a recent report by Herbert (1972). He found that after pinealectomy in autumn, ferrets came into oestrus at about the normal time, irrespective of the light regime, but that the next onset of oestrus was no longer in phase with the seasons instead occurring much later. Duration of the oestrus periods was about normal. This suggests that there is an endogeneous circannual cycle in these

animals, and that pinealectomy results in the uncoupling of this cycle from the changes in photoperiod, thus revealing its endogeneous character. Melatonin seems to take part in the interaction between external light period and the annual cycle.

The amounts of melatonin administered in the experiments reported here were relatively large: approximately 3.1 mg per animal given three times. However, amounts actually reaching the circulation were certainly only a small fraction thereof. In pilot experiments 4 implants that were removed after more than a month were hardly smaller than before (maximally 8%, part of which might be due to losses during implantation and recovery), and contained on the average 8.8% melatonin versus 9.1% in 4 unimplanted controls. It can be assumed that there was a sustained release of melatonin from the implants. A similar sustained release can be expected if melatonin is injected in oil, as indicated by the findings of Herbert (1971).

In our experiments melatonin counteracted the stimulating light influence, not only on testis size and activity, but also on pelage change. This corresponds to the findings of Rust and Meyer (1969) in weasels. The pituitary has been shown to be involved in the change from winter to summer coat via its secretion of MSH in weasels (Rust, 1965; Rust and Meyer, 1968). Since both testis activity and pelage colour were similarly influenced, it is probable that melatonin acted on the pituitary via the hypothalamus. However, direct effects of melatonin on the formation of testosterone in testis tissue in vitro have also been reported (Ellis, 1969). It must also be kept in mind that antigonadotropic substances other than melatonin have been reported (Reiter, 1972; Benson *et al.*, 1971). After injection of labeled MIF and LRF, high concentrations were found in the pineal (Redding *et al.*, 1972; Redding and Schally, 1973), indicating that some type of feedback system may operate between hypothalamus and pineal.

In long photoperiods *Phodopus* showed a marked increase in body weight which was also reduced by melatonin, and this increase was closely paralleled by the testis weight at the end of the experiment. It must be stressed that the increase in testis weight was not proportional to the increase in body weight: testis weight in the two control groups in long-day conditions increased about 900%; body weight about 30%. Testis involution in autumn under natural daylight was accompanied by a decrease in body weight (Fig. 5, see also Figala *et al.*, 1973, for further data and discussion). In adult golden hamsters, no effect of photoperiod on body weight was observed (Gaston and Menaker, 1967; Eichler and Moore, 1971). In three other small rodents, *Microtus agrestis* (Khateeb and Johnson, 1971a; Evans, 1973), *Dipodomys microps* and *D. merriami* (Kenagy, 1973) a similar cycle of body weight with maxima at the time

of maximal gonadal activity, and minima at the time of gonadal quiescence has been reported, and photoperiodic effects on both functions were shown (Khateeb and Johnson, 1971b).

In immature rats pinealectomy accelerated growth, whereas blinding or darkness retarded growth which could be reversed by removal of the pineal (Reiter and Fraschini, 1969). I am unaware of any work on the physiological basis of the annual cycle in body weight in adult small rodents as described here.

I am most grateful to Frau Dipl.-Biol. M. Güttinger for the histological work, and to Prof. K.-H. Frömming, Pharmazeutisches Institut, Freie Universität Berlin, for the determination of melatonin content in the implants as well as for technical advice. Mr. H. Biebach, Mr. and Mrs. Goldau, Dr. E. Gwinner, and Dr. and Mrs. I. F. Spellerberg assisted in colour scoring; Miss M. Wendon, and Drs. J. Aschoff, E. Gwinner, G. Heldmaier, G. J. Kenagy, and H. Underwood critically read the manuscript and made many helpful suggestions. Thanks are also due to Dr. W. B. Quay, Dept. of Biology, Berkeley, and Dr. G. Heldmaier, for much valuable information and many helpful suggestions on pineal physiology and on technical points.

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Dr. Klaus Hoffmann
Max-Planck-Institut
für Verhaltensphysiologie
D-8131 Erling-Andechs
Federal Republic of Germany