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Morphological Changes in Shrews Kept in Captivity

Zmienność morfologiczna ryjówek w hodowli

[With 12 Tables and 11 Figures]

I. INTRODUCTION

Studies of shrews (*Sorex* L.) kept in captivity have several times been undertaken, but judging from data so far published (Crowcroft, 1951; 1957; Dehnel, 1952 and others) shrews are animals on which laboratory conditions have an adverse effect. The changes observed when they moult (Borowski, 1964), their excessive fatness and high mortality rate indicate disturbances of the normal physiological processes. Considerable difficulties also occur in the reproduction of shrews in captivity. The investigations made by Dehnel (1952), although crowned by successful attempts at inducing reproduction of shrews born in captivity, did not, however, completely solve the problem of the laboratory culture of these animals. Mortality among adult individuals, abortions, biting to death of newly born litters — are the most frequent disturbances observed in laboratory bred animals.

Observations made so far of shrews in captivity were chiefly concerned with such problems as behaviour, the rhythm of diurnal activity, reproduction, feeding (Tupikova ,1949; Dehnel, 1952; 1961; Wolska, 1953, Crowcroft, 1957; Mieżżerin, 1964). It is most probable that it is due to the difficulties in keeping these animals in captivity for a long period that no observations have been made of morphological changes, which may be of interest on account of changes arising during the time the animals are kept under laboratory conditions and also on account of any possible further attempts at their elimination.

It is a fact well-known from various publications that in the case of shrews we have to do with seasonal variations in the whole system of dimensions and indices (dimensions of the body and skull, weight of internal organs) included in the term Dehnel's phenomenon (Schubarth, 1958) and described in detail in various studies, including those by Dehnel (1949), Borowski & Dehnel (1953), Pucek (1955; 1957; 1963), Crowcroft & Ingles (1959), Bielak & Pucek (1960).

In 1956, for the second time in our group, attempts were made at keeping shrews in captivity. The initiator of these studies was the late Professor Dr. A. Dehnel, to whose memory I dedicate the present publication.

The aim of the present studies was as follows: 1. to make an analysis of the seasonal changes in the dimensions and weight of the body, the dimensions of the skull, the involution of the thymus gland, and of the changes connected with the process of sexual maturation in shrews kept under laboratory conditions and to compare the results with data already obtained for shrews living under natural conditions, and 2. to define more exactly the effect of laboratory conditions on the course taken by Dehnel's phenomenon.

II. MATERIAL AND METHODS

The shrews (*Sorex araneus* Linnaeus, 1758) were caught in the Białowieża National Park. The animals were kept singly (since reproduction was not the purpose for which they were kept) in wooden cages, the inside measurements of which were 33 × 33 × 20 cm (during the period 1956/1958) or in slightly smaller cages measuring 27 × 38 × 11 cm (during the period 1963/64). They were given abundant food consisting of a mixture of minced beef heart, liver, kidneys and spleen, to which baker's yeast, vitamins A and C, and germinating wheat, and also the standard rabbit food (made by the firm "Bacutil"), broken up finely, were added. The addition of the latter constituent was intended to increase the volume of the food. The supplementary components of the shrews' food was not always administered in unform amounts. The animals were given vitamins when their appearance indicated that they were suffering from a lack of them (wet, sticky-looking coats).

During the period from 1956—58 the animals were kept in rooms not really intended for the purpose, in which the relative atmospheric humidity was from 60—95% and the temperature varied according to the season, varying in one room from 10—18° C and in the other from 0—3° C. The rooms were lighted by fluorescent

lamps (about 150 luxes). This lighting was used for 18 or for 3—6 hours per day in experiments on the effect of the length of day on the animals.

During the period from 1963/64 the animals were kept in rooms specially intended for the purpose, with relative atmosphere humidity of 70—90% in winter, while temperature was maintained at 17—20° C (with central heating). Natural daylight was prolanged by means of fluorescent lamps kept lit while the animals were fed during the evening for a period of 2 hours.

A total number of 256 shrews were kept in captivity during these two periods, of which 170 lived for over 10 days, and it was these animals primarily which were subjected to morphological analysis. In certain of the tables the number of specimens considered are of course often smaller. Thus, for instance, when considering the length of life in captivity, only those specimens which died a natural death, and in relation to which the exact period of their stay in captivity was known, were taken.

The majority of the specimens at the author's disposal were animals which had died in captivity. Only 21 shrews out of the total number were killed. The death of animals in captivity may have been due to changes of a pathological character or to the natural end of their lives.

All the animals were dissected. Standard measurements of the body were made and the skull cleaned and measured. The degree of the ossification and a state of the sutures was defined by stereo-microscopic examination, as was done in the case of material consisting of free-living shrews (cf. Pucek, 1955). The condylobasal length (Cb.), maximum breadth of the braincase and height of the braincase *per bullae tympanici* were measured. The whole braincase and skull, together with the brain, or only the excised vault, were fixed in Bouin's fluid. In the 1963/64 series of whole specimens were fixed in formalin and kept in alcohol, after which the skulls were prepared from them for craniometric purposes.

During dissection the size of the thymus gland was also recorded, using the four-degree scale (large, medium, small, rudimentary) accepted by Bazan (1952). The determination of the degree of involution of the thymus gland by estimation gives a sufficiently accurate picture of the course taken by the process and makes it possible to compare data with Bazan's observations (l.c.). In addition the thymus glands were prepared and weighed. In this case, depending on the way the material had been treated and the length of time for which it had been kept after fixation, differences in weight may be very significant, and the data cannot be compared with those given by Bazan (1952).

The degree of sexual maturity was described on the basis of the condition of the genital organs. The length and thickness of the testes were measured in males and the index of the value of their cross-section calculated, according to the formula for area of cross-section of the ellipse: $a \cdot b \cdot \pi$. In the case of females three classes of size of the uterine horns and vagina were distinguished — small, medium and developed uterus (cf. Wolska, 1953; Pucek, 1961).

A certain number of the skulls which differed greatly in dimensions from the skulls of free-living shrews were subjected to histological examination. The vault of the skull was excised, then decalcified in 5% nitric acid or 5% trichloroacetic acid. Sections 10 μ thick, soaked in paraffin, were stained with Mayer's haematoxyline and erythrozine.

Three series of animals were distinguished in the material: I — young adult shrews, caught during the summer (June—August). They survived in captivity until the spring of the following year. II — young adult shrews caught during the winter

(December—March) and passing under laboratory conditions to the old adult group, III — old adults, caught from among free-living animals during the summer (June—November) when already sexually mature, born the preceding calendar year.

In the experiments with length of day two groups, kept with either long daylight conditions (18 hours — Fig. 3 A and D) or short (3—6 hours, fig. 3 B and C) were distinguished within the series of shrews from the summer (I) and from winter (II).

III. THE LENGTH OF LIFE OF SHREWS IN CAPTIVITY

The length of life of shrews under natural conditions is theoretically estimated to be 18 months at maximum (B r a m b e l l, 1935; D e h n e l, 1949; C r o w c r o f t, 1956), but practically speaking shrews live for a far shorter time, about 12—14 months. This is confirmed by the observations made by S h i l l i t o (1963) and also the investigations made at Białowieża using the CMR method.

Observations made of animals kept in captivity indicate that an age exceeding one year is attained only by a very small number of individuals (Table 1). This is certainly not the limit of the physiological capabilities

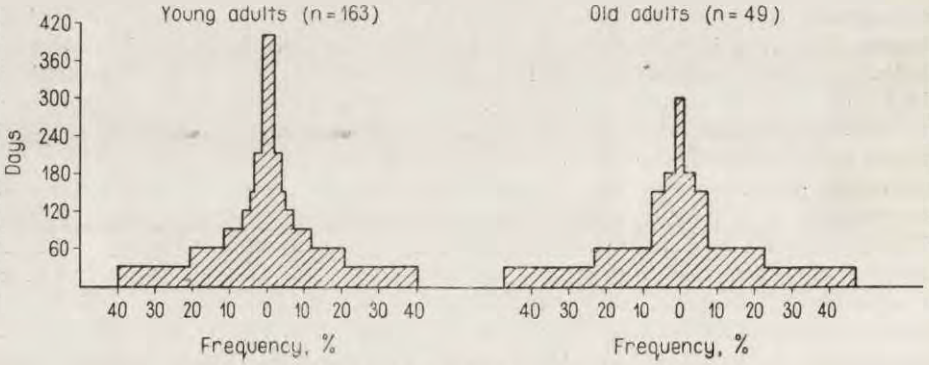

Fig. 1. Length of life of shrews in captivity.

of shrews. An especially high mortality rate is observed among shrews during the first days and weeks of their life in the laboratory (Table 1, Fig. 1). About 40% of the specimens die within the first month and scarcely 30% of the animals survive for longer than 3 months. The maximum life span of a shrew in captivity was 400 days.

The maximum length of life of young adult and old adult individuals differs greatly. In the case of the latter it is (with the exception of one specimen only) half shorter (Table 1). Mortality in both these groups during the first 90 days of their life in captivity is, however, almost identical, and the use of the Student test for comparing percentages did not reveal statistically significant differences.

Table 1.

Length of life of shrews in captivity.

Age	Days		1—	31—	61—	91—	121—	151—	181—	211—	241—	271—	301—	331—	361—	391—	n
Young adult	♂♂	n	24	12	6	3	2	1	4	2	1	2	—	1	1	1	62
		%	38.7	19.4	9.7	8 1	3.2	1.6	6.4	3.2	1.6	3 2	—	1.6	1.6	1.6	100
			67.8														
	♀♀	n	24	13	7	7	4	5	2	1	2	—	—	3	1	1	70
		%	34.3	18.6	10.0	10.0	5.7	7.1	2.8	1.4	2.8	—	—	4.3	1.4	1.4	100
			62.9														
	♂+♀ and sex indet.	n	65	33	19	11	7	6	6	3	3	2	—	4	2	2	163
		%	39.9	20.2	11.6	6.7	4.3	3.7	3.7	1.8	1.8	1.2	—	2.4	1.2	1.2	100
			71.7														
Old adult	♂♂	n	12	5	2	3	5	1	1	—	—	1					29
		%	41.4	17.2	3.4	10.3	17.2	3.4	3.4	—	—	3.4					100
			62.0														
	♀♀	n	11	6	1	1	—	1									20
		%	55.0	30.0	5 0	5.0	—	5.0									100
			90.0														
	♂♂+♀♀	n	23	11	2	4	5	2	1	—	—	1					49
		%	46.9	22 4	4.1	8.2	10.2	4.1	2.0	—	—	2.0					100
			73.4														

Table 2.

Length of life in captivity of young shrews (♂♂ + ♀♀) caught in the summer (S) and winter (W).

Period.		Days															n
		1—	31—	61—	91—	121—	151—	181—	211—	241—	271—	301—	331—	361—	391—		
W XII—II	n	11	6	3	1	1	1	2	—	1							26
	%	42.3	23.1	11.5	3.8	3.8	3.8	7.7	—	3.8							100
		76.9															
S VII—VIII	n	43	23	16	6	4	5	4	3	1	2	—	4	2	1		114
	%	37.7	20.2	14.0	5.3	3.5	4.4	3.5	2.6	0.9	1.8	—	3.5	1.8	0.9		100
		71.9															
	N	54	29	19	7	5	6	6	3	2	2	—	4	2	1		140

It will be seen from Table 2 that there is no difference in the maximum length of survival of males and females in the case of young adult shrews. The impression given that old adult females died earlier than old adult males is not confirmed by the Student test. Difference between the mortality of old adult males and females during the first 90 days of their life in captivity are within the limits of significance (significant when $P_{0.05}$, non-significant when $P_{0.01}$).

Comparison was made of the capacity for survival in captivity of young adult shrews caught during the different seasons, which showed that animals nearer the physiological end of the life, caught in December — February, live for a shorter time than animals caught in the summer (June — August). Groups not physiologically equivalent were of course compared, since the summer specimens had an absolute age of 4 months,

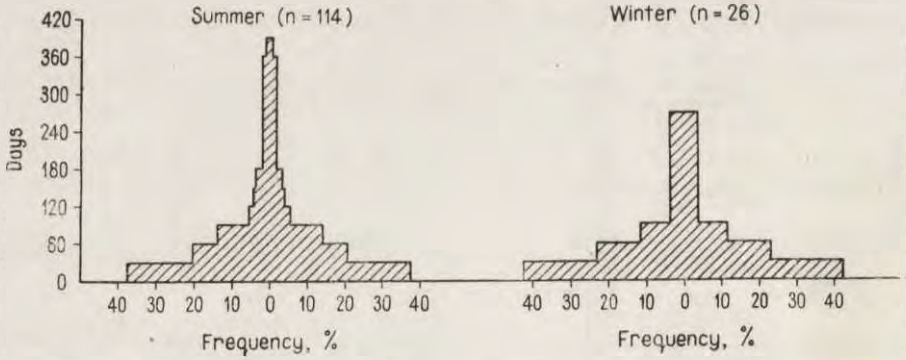

Fig. 2. Survival of young shrews in captivity depending on the period of their capture.

while the winter animals were from 4—10 months old. Mortality is uniform in both the groups distinguished during the first 90 days of life in captivity (differences statistically non-significant).

IV. VARIATONS IN DIMENSIONS AND WEIGHT OF THE BODY

1. Length of Body

The length of the body was measured, as usual, after the death of the shrews. This measurement, compared with data for free-living animals in table 3, shows that there are certain differences present. In young shrews which have lived in captivity for over 10 days the average body length is the same as that of animals caught in the open, limits of variations being, however, narrower. The highest mean monthly values for the free-living

animals exceeded the mean value for the captive animals by 1.9 mm, but the mean values for the whole summer period did not differ.

In the case of captive old adults, i.e. shrews which spent the winter in captivity or were caught in the spring and summer, it is observed that the body length is not equal to that of old adults living in the open. In a few specimens only which have spent the winter in captivity there is a spring jump in growth, while the majority of the animals have a body length at most only very slightly greater than that of young individuals. Thus the mean value for old adults is nearer the lower limit of the monthly mean values for a period of several years of this dimension measured in free-living animals.

Table 3.

Comparison of variations in the body length of shrews kept in captivity and of free-living shrews.

Captive shrew				Free–living shrews*)			
Age group	n	Min. - Max. (mm)	Avg. (mm)	Age group & period	No. of anim. in a month (& through-out the whole period)	Min. - Max. (mm)	Avg. (mm)
Young adult	100	56—72	66.1	Young adult (VI–X)	47—658 (n = 3991)	54—78	63—68 (66.2)
Old adult	54	60—88	70.9	Old adult (V–X)	10—94 (n = 778)	62—86	68—78 (75.0)

*) Data calculated on the basis of material from the 1947/48 — 1950/51 generations, taken from the study by Borowski & Dehnel (1953).

2. Body Weight

The body weights obtained by measuring captive shrews after their deaths were compared with data for free-living animals (Table 4). This table shows clearly the same relations as were observed in the case of body length. The mean values for young animals caught in the summer (June — October) and kept in the laboratory are lower than the mean body weight of free-living shrews. Specimens caught during the winter period (December—March) and passing to the group of old adults in the spring do, it is true, attain a greater weight than that of young animals caught in the summer and kept in the laboratory, but they are not equal to free-living old adults in this respect. In the same way the old adults caught during the period June—October are not equal in weight to the free-living old

animals. It will be seen from Fig. 3 that not all the shrews caught during the winter period exhibit the spring jump in growth, expressed by the intensive increase in their body weight. In the case of the animals in which this phenomenon is observed in captivity, differences in weight in the winter and spring months are very faintly expressed.

All the shrews kept in captivity during the period 1957—1958 (over 10 days $n = 97$) were weighed every second or third day. The values obtained in this way give a picture of the course taken by variations in the body weight of the shrews during the time they spend in captivity. They also made it possible to consider this dimension in relation to the season, the period of capture and in consequence, to the absolute age of the animals.

Table 4.

Comparison of variations in the body weight of captive and free-living shrews.

Captive shrews				Free-living shrews*)			
Age group & period of catching	n	Min.-Max. g	Avg. g	No. of anim. in a month (& throughout the whole period)	Min.-Max. g	Avg. g	
Young adult (VI — X)	90	4.5—10.0	6.9	107 — 854 (n=1898)	4.5—10.0	6.3—7.3 (7.0)	
Young adult (XII — III)	28	5.0— 9.5	8.1	—	—	—	
Old adult (VI — X)	18	7.0—12.0	8.9	32 — 92 (n=394)	5.5—16.0	9.0—10.8 (10.3)	

*) Data calculated on the basis of material from the period 1948—1950, taken from the study by Borowski & Dehnel (1953).

Fig. 3 shows the more interesting sections of curves of body weight of individuals chosen as examples. All the curves refer to young animals caught during the winter (January—February) — A and B, or in the summer, during July and August — C and D. In both series the shrews were kept in two groups, with a long (A and D) or short (B and C) day [1].

From Fig. 3 it is clear that the weight of the shrews kept in captivity is not constant, but is subject to certain fluctuations almost from day to day. The figures given, which are the result of comparing 20 sudden increases and less sudden decreases in body weight of different individuals, are evidence of the intensivity of these variations. The most extreme cases

[1] I shall return to the problem of the possible effect of light on the course taken by curves of body weight of shrews in the Section VIII.

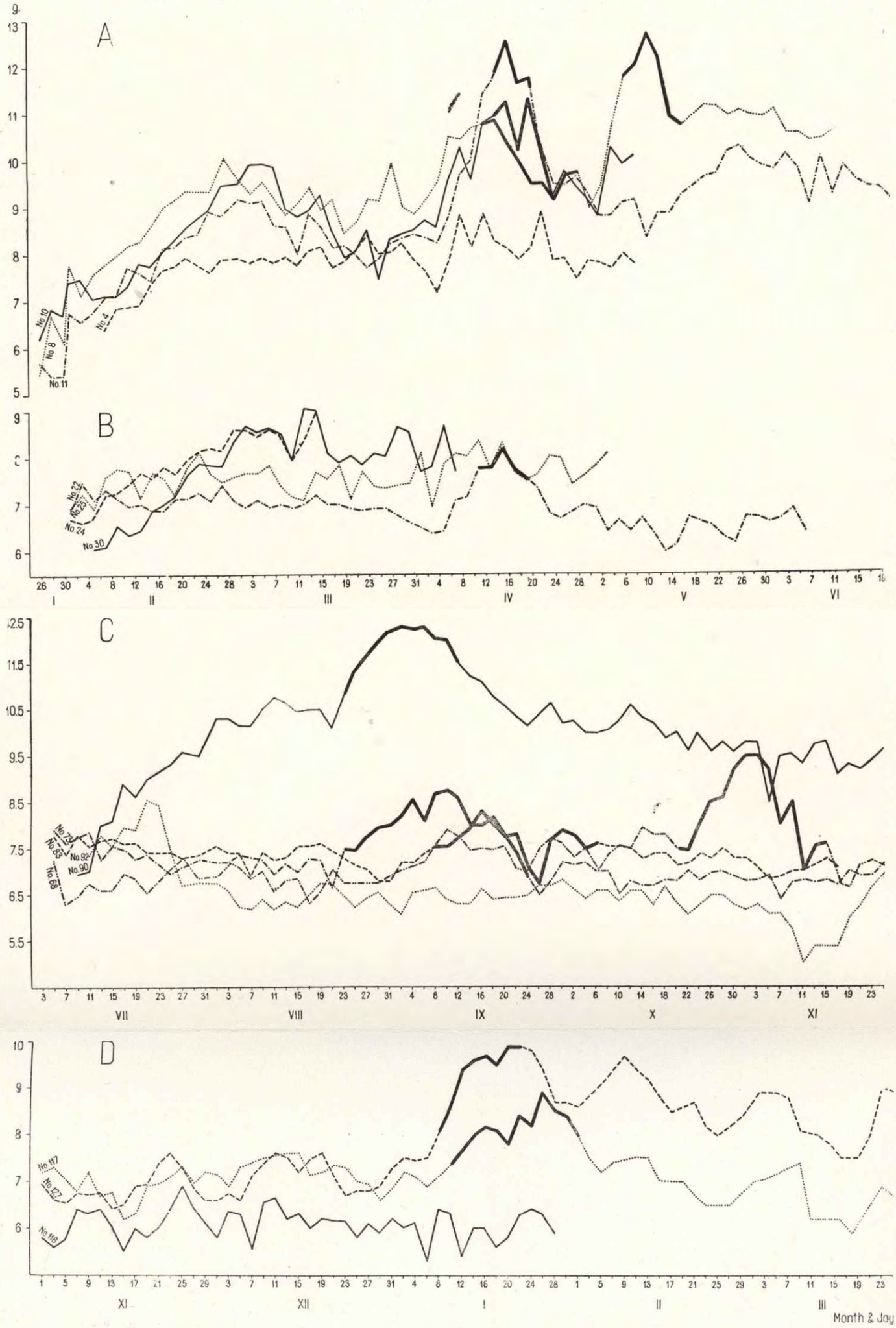

Fig. 3. Individual curves of variation in body weight of selected individuals. Thicked section of curves — periods of moult.

have been chosen here as forming evidence of the maximum potentialities of the shrews in this direction. It was found that during a period of 4—24 days the body weight of different individuals may increase by 20—25% of the initial value (comparison was made of the lowest point of the curve immediately preceding the jump in weight, with its peak). In several cases for instance, an increase in body weight of 51—52% was observed within 12 days, of 39% within 7 days etc. The calculated daily increase rate in body weight varied within limits of 1.6—6%, mean value 3.4%.

After reaching a peak point the curves of body weight decline. This fall may be very rapid (e.g. 23% within 4 days in comparison with the peak weight). The daily decrease in body weight of different individuals is however less than the daily increase ($x = 2.6\%$), although it varies within almost the same limits (0.8—6%).

These rapid changes in body weight are observed far more frequently in individuals caught during the winter than in the young adult animals from the summer months. It was also noticed that there is a salient connection here. In the case of shrews from both seasons the increases in body weight are in acordance with the occurrence of moulting. In shrews from the group A and B (Fig. 3) moulting usually started when the body weight had attained, or was close to, the culminating point in the given period. In young animals from the summer (groups C and D) moulting was observed to start slightly earlier, but always when the curve of body weight had begun to exhibit a distinct tendency to increase. The number of cases observed was too small ($n = 30$) to permit of a more precise expression in numbers of this phenomenon. The connection between the occurrence of moulting and the increase in body weight is particularly distinctly evident in those individuals in which moulting took place quickly and without interruptions. It is, however, known from the study by Borowski (1964) that in the majority of cases of animals kept in captivity we encounter an abnormal prolongation or interruptions in the change of coat. In such cases the shrew increases its body weight several times, usually before moulting is renewed or during the time that it slowly takes place, then returning to the initial condition.

In addition to these fluctuations numerous rises and falls in the curves of body weight of different shrews can be observed. It would seem that they are the result of variations in condition, and to a certain extent may result from the greater or lesser degree to which the stomach is filled.

Individual variations in the body weight of shrews in captivity were analysed at intervals of 10 days. An average for every ten days was obtained from the totalled measurements made every 2—3 days, in the winter from 90—120 measurements for a maximum of 20 individuals, and

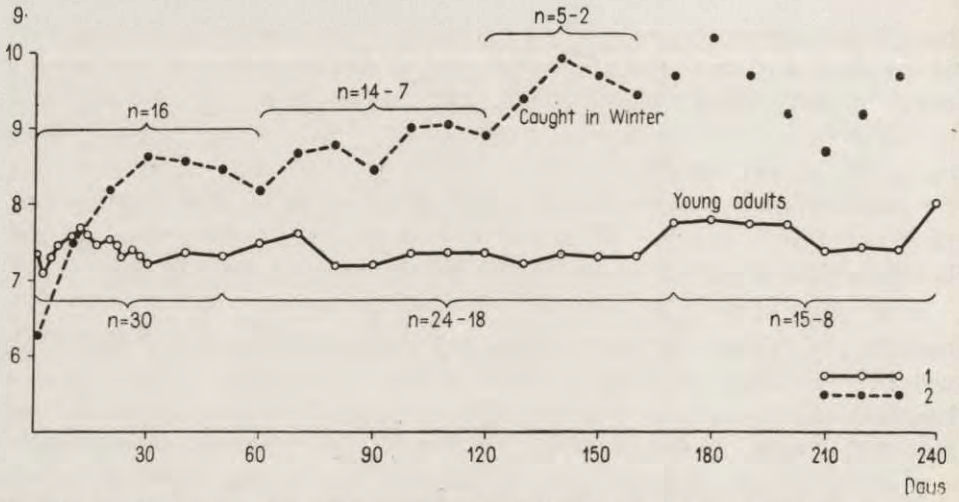

Fig. 4. Variations in body weight depending on the length of time spent in captivity. 1 — young shrews caught between June—August. 2 — young shrews caught in the winter (January—February).

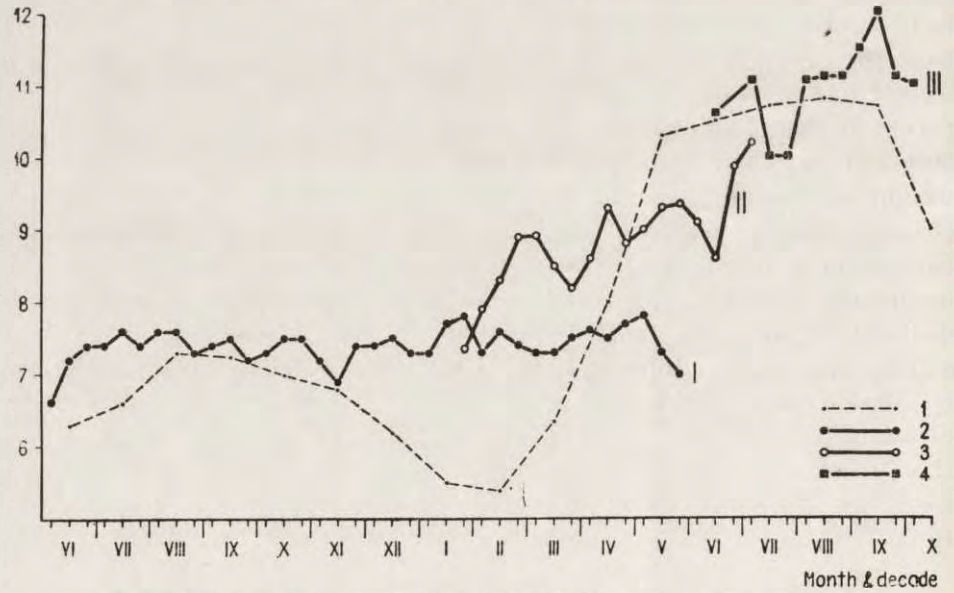

Fig. 5. Variations in the body weight of shrews kept in captivity. (mean value of periods of 10 days)

1 — young shrews caught between June—August (group I)
2 — young shrews caught in the winter (group II) and attaining the old adult class during their captivity
3 — old adults, which had spent the winter in freedom, and were caught between June—August
4 — curve of variations in the body weight of free-living shrews (acc. to data given by Borowski and Dehnel, 1953, for the period from 1948—1950, N = 2481).

in the summer from 140—180 measurements made of the initial number of 36 animals. The limits of variations in body weight within the 10-day period were wide, coming within extreme variants of 6.0—9.4 and 5.0—10.9 g for the summer period, and 6.5—10.9 and 5.0—12.4 g in animals caught during the winter. Variations in the body weight of shrews caught as old adults, that is, in which the jump in growth had taken place, came within limits of 8.5—13.4 g (data for 30 10-day measurements made of 5—6 individuals).

Fig. 4 shows the connection between the mean values of weight of shrews registered every 10 days and the length of time they had spent in captivity. Let us consider this phenomenon at the same time from the seasonal aspect also.

The following conclusions are reached after comparing the curves of variations in the body weight of shrews is captivity (Fig. 5) with the course taken by the curve of variation of this measurement during the life cycle of free-living animals:

1. Young shrews caugth in the summer (June—August) after a slight increase during the first 12 days (Fig. 4), do not exhibit any great fluctuations in body weight during the whole period they spend in captivity. The mean body weight is maintained within limits of 7.0—8.0 g, and thus on an average on a higher level than that in free-living animals. It is only during the summer that the two curves become markedly close. Nevertheless in this period also the mean body weight of shrews kept in captivity is higher (for the period August—October by 2.5% — Fig. 5). Particularly great differences are evident in June—July and especially during the winter (38%) and spring (cf. Table 5). The mean values for 10-day periods for April and May, for about 40 measurements of 8—9 individuals, are maintained within limits of 7.0—7.8 g and similarly as in January—February differs significantly (Student test) from corresponding data for free-living shrews [2].

It will be seen from the data presented that shrews caught in the summer, and spending the winter in captivity, do not exhibit a winter depression in body weight, and do not undergo a jump in growth in the spring.

2. The group of young individuals captured during the winter months (January—February) behaves in a completely different way. During the first part of their stay in captivity, the mean weight of individuals rises

[2] The conclusions reached here refer to body weight of live animals during the time they spent in captivity. The results obtained differ slightly from data given in Table 4 for shrews which died naturally or were killed. This may indicate that the animals lose weight before death, or during the period from death until the first inspection of the nests (a maximum period of 12 hours). In certain cases this is clearly evident from the course taken by individual curves of body weight.

sharply (by 39%), then exhibits fairly considerable fluctuations without, however, losing its marked tendency to increase (cf. also Fig. 4). The rise in this curve is determined by the spring jump in growth. Curves of the body weight of this group of animals and of free-living shrews cross each other in April (Fig. 5). The body weight of shrews kept in captivity remains on a lower level than that of free-living animals. The jump in growth evident here takes place far earlier than in free-living animals and can be observed as early as in February, after which it is retarded and is not intensified again until the May—July period.

Table 5.
Variations in the body weight during the life cycle of captive and free-living shrews. (in g.)

Period	Free-living shrews	Captive shrews	$\Delta_{\bar{x}}$
VIII—X (Young adult)	4.5 — 10.0 (7.24) n = 1216	5.0 — 12.4 (7.42) n* = 1741	+ 0.18 (2.5%)
I — II (Young adult)	3.5 — 7.5 (5.47) n = 40	5.0 — 10.9 (7.54) n* = 382	+ 2.07 (38%)
V — VI (Old adult)	6.5 — 16.0 (10.46) n = 111	5.0 — 12.9** (9.18) n* = 253	— 1.28 (12%)
VI — IX (Old adult)	5.5 — 16.0 (10.44) n = 329	8.5 — 13.9 (10.96) n* = 187	+ 0.52 (5%)

*) Number of measurements, **) Individuals caught as juvenales during the Jan.—Febr. period.

3. Shrews caught as old adults already sexually active, during the period from June to July, have far higher body weights than animals which spent the winter in captivity. The curve of the mean weight of this group of animals is on an average slightly higher than a similar curve for free-living (Fig. 5). We can therefore observe here relations similar to those in the case of young shrews caught in the summer.

3 Degree of Adiposity

The adiposity of shrews which died in captivity or were killed was expressed by a 4-degree scale. Table 6 includes all the shrews in which adiposity could be defined, depending on the time they spent in captivity. It may said that excess fat is deposited in almost 90% of the captive

Table 6.

Degree of adiposity of shrews depending on the length of time spent in captivity.

Class	Avg. %	Days							n	%
		1—60	61—120	121—180	181—240	241—300	301—360	361—420		
—		3	2	4	2	1	1	1	14	11.5
+	12.5	17	2	5	—	1	—	—	25	20.4
++	37.5	12	4	5	—	1	—	1	23	18.8
+++	62.5	14	11	3	—	1	—	2	31	25.4
++++	87.5	16	10	2	1	—	—	—	29	23.8
$\sum$	n	62	29	19	3	4	1	4	122	100.0
	Avg. %	50	64	44					—	—

Table 7.

Body weight (in g.) and degree of adiposity of captive shrews.

Age group	Clas	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	n
Young adult (VI—X)	—	1	3	2	2	—	1								9
	+		2	5	4	1	2	1							15
	++			4	1	2	1	2	—	3				1	14
	+++					2	5	4	3	3					17
	++++			1	—	2	—	3	4	—	3	1	1		15
	n	1	5	12	7	7	9	10	7	6	3	1	1	1	70
Young adult (XII-III)	—		1	—	—	1									2
	+					1	—	—	—	—	1				2
	++						2	—	—	—	—	1			3
	+++				1	—	—	1	—	2	—	2			6
	++++				1	—	—	—	2	3	1	3			10
	n		1	—	2	2	2	1	2	5	2	6			23

animals. The percentage of adipose animals with degrees from (+) to (++++) is more or less uniform (19—25%), and therefore there is no marked predominnance of very fat individuals (++++). Thus if we take (+) as indicating adiposity of a degree from 1—25%, in relation to

the greatest degree, and further, (+ +) — adiposity of a degree from 26—50% etc., and if we establish the middle of these classes, we can than calculate the mean degree of adiposity of shrews for each class of length of stay in captivity. These data are contained in the botom line of table 6. From this it can be seen that on an average the greatest adiposity is observed in young shrews spending from 1—4 months in captivity. In animals living in a laboratory for a longer time the degree of adiposity decreases.

Adiposity may exert a significant influence on variations in body weight. In young individuals, caught in the summer and living in captivity until the spring of the following year, a distinct correlation was found between

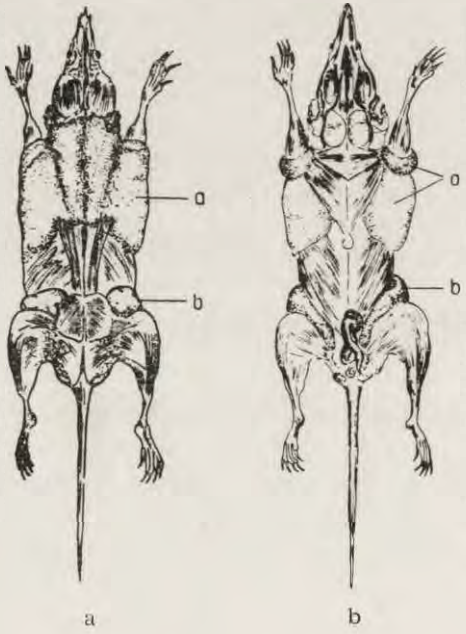

Fig. 6. Distribution of lobes of fat 1 — *norma dorsalis*, 2 — *norma abdominalis*. a — the so-called hibernation gland, b — lobes of fat in the groins of the hind limbs.

the degree of accumulation of fat and the body weight. This connection is less distinct in young animals caught in the winter, and living under laboratory conditions until the spring (Table 7). It is possible that disturbances connected with the processes of moulting which occur in the spring in the majority of the animals examined, and also the irregularities in the jump in growth discussed earlier on, exert an influence here.

It must be added that very old individuals (not taken into consideration in table 7) spending over 300 days in captivity, were also extremely adipose (+ + +), or might not possess any reserves of fat at all (such as, for instance, an individual living in captivity for 400 days).

Morphological analysis of animals kept in captivity showed that fat accumulates chiefly in the region of the back of the neck. It is a case here of the excessive growth of the so-called hibernation gland (cf. also B u c h a l c z y k, 1964). In an extreme case a thick "cushion" is formed completely occupying the nuchal region, partly occupying the back of the head and reaching to the final rib. In addition well-developed right and left lobes cover the sides of the body, filling the space under the armpits and extending to the ventral side of the chest. A narrow band (about 3—5 mm) of free space remains in the region of the sternum only (Fig. 6). The right and left lobes of this organ do not, therefore, completely meet on the chest. In addition fat is deposited in the form of paired lobes situated in the groin of both hind legs and covering the anterior part of the thighs. These lobes develop to a lesser degree than the deposits of fat in the region of the neck and chest, but their size depends on the degree of development of the latter.

V. SEASONAL VARIATIONS IN THE SKULL

The condylobasal lenght and maximum breadth of the brain case do not exhibit seasonal variations, as is the case of free-living animals (D e h n e l, 1949, and others). Limits of variation and mean values of these two measurements are shown in the enclosed table (Table 8).

Table 8.

Comparison of variation in the condylobasal length and the maximal breadth of the brain case in captive and free-living shrews.

Measuremet	Captivity shrews			Free—living shrews*)		
	n	Min.—Max.	Avg.	n	Min.—Max.	Avg.
Cb.-length	166	18.1—19.8	18.95	275	18.1—19.7	18.93
Maximal breadth of the brain case	161	9.0—10.1	9.6	236	9.2—10.3	9.8

*) Acc. to data for the Białowieża Primaeval Forest (P u c e k, 1955).

A dimension which varies with the seasons is the height of the brain case (D e h n e l, 1949; P u c e k, 1963, and others). For this reason an exact analysis of the variations in this dimension in shrews kept in captivity deserves special attention. Fig. 7 gives a comparison of curves expressing the mean monthly values of the height of the brain case in captive and free-living shrews. This general comparison indicates the existence of important differences between the two curves, which show in the first

place that under laboratory conditions the skull flattens to a lesser degree than it does in free-living animals.

In searching for the causes of these differences a detailed analysis was made of the material, animals being treated individually. Fig. 8 shows the values of the height of the brain case in 160 captive shrews (monthly mean values are illustrated in Fig. 7), giving the time at which the animals were captured (cf. section II). The ranges of variations in the height of the skull in different months, for free-living shrews (data for the corresponding curve from Fig. 7) were indicated with horizontal dashes.

From the diagram discussed (Fig. 8) and table 9 it is clear that the rate of lowering of the skull in young shrews from the summer (group I) is

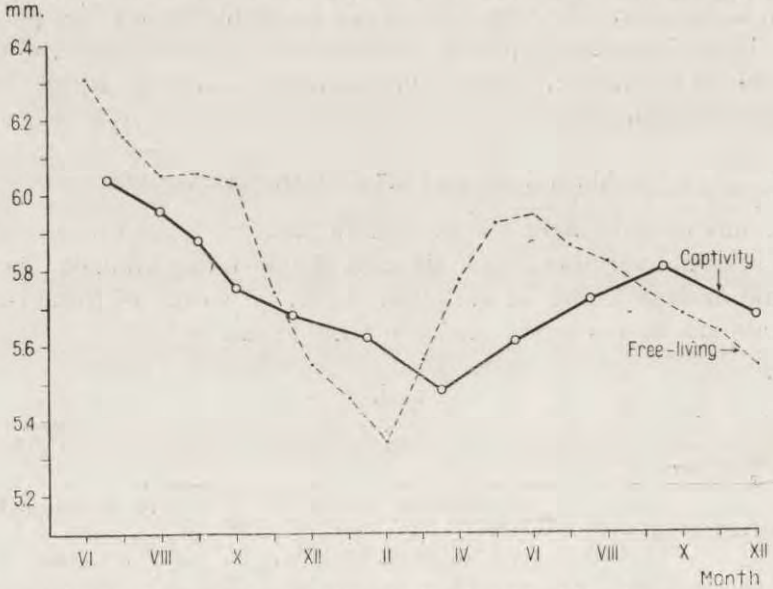

Fig. 7. Comparison of seasonal variations in the height of the brain-case in captive and free-living shrews.
(Data for free-living shrews after P u c e k, 1955).

more rapid in the second half of the summer and the autumn (up to October) than in free-living animals. Measurements of a certain number of the individuals are situated below the limits of variation of this dimension in free-living animals. During the next period this process is, however, subject to distinct inhibition. In the period from December to February certain captive shrews have skulls higher than those observed in free-living population (Fig. 8). It must be added that these are individuals kept in captivity during the period 1963/64, when temperature conditions in the laboratory were more stabilized than in the earlier series of experiments. Thus February is not a period in which the depresion of the skull is most

strongly expressed, this not occuring until the March—April period, when the skull is 9.3% lower in comparison with the mean value for July. The difference between the lowest winter dimension of skull depth in shrews, and the highest summer dimension is 1/3 lower in captive animals than in free-living ones (Table 9).

From the diagram (Fig. 8) it will be seen that young shrews from the summer attain almost the lowest winter limits of variations in the height

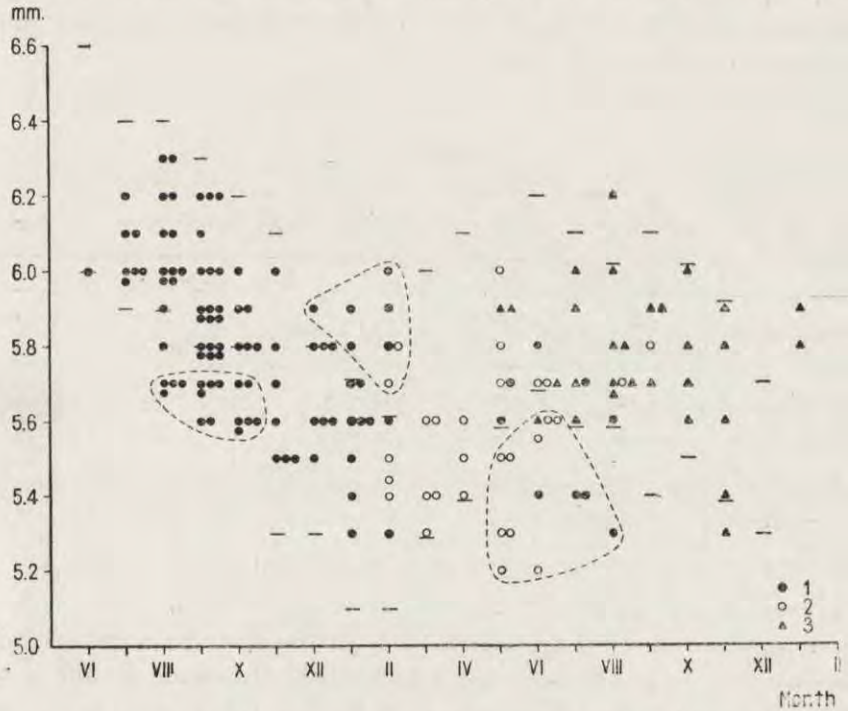

Fig. 8. Variations in the height of the brain case in captive shrews (N = 160).
1 — shrews caught in the summer (June—October),
2 — young shrews caught in the winter (December—March),
3 — old adults, which spent the winter in freedom and were taken captive between May and September.
Animals which survived in captivity for longer than 10 days were taken into consideration. Horizontal strokes determined limits of variation in the height of the brain-case in free-living shrews (P u c e k, 1955).

of the brain case proper to free-living animals. It is, however, possible that after passing through the winter skulls of this animals do not become arched again and in the June—August period remained within limits of 5.3—5.4 mm, or arch only to a slight degree (5.6—5.8 mm) and immediately undergo to the lowering processes. It was established by histological examination that these individuals were in the phase of resorption the bones of the neurocranium vault. Pictures obtained for animals with low

skulls were very similar to that of free-living shrews, during the winter months.

Details concerning the mechanism of this process have been given in an erlier publication (P u c e k, 1957).

Young shrews from group II, caught during the winter period (December—March) exhibited, in certain cases "winter" dimensions of the skull in April, May and June. Histomorphological examination did not reveal any progressive changes here, and what is more, in certain animals the resorption of the bone was observed.

Table 9.

Intensity of seasonal changes in the depth of the brain case.
(Data for free-living shrews express the changes in the curve shown on Fig. 7).

Captivity shrews			Free–living shrews		
Period	Δ (mm)	Increase, %	Period	Δ (mm)	Increase, %
VII → X	— 0.29	— 6.8%	VII → X	— 0.13	— 2.1%
VII → II	— 0.40	— 6.6%	VII → II	— 0.82	— 13.2%
VII → IV	— 0.56	— 9.3%			
III. IV→VII–X	+ 0.29	+ 5.3%	II → VI	+ 0.60	+ 10.1%

Group III of captive shrews includes individuals which spent the winter in freedom and had already passed through the spring period of arching of the skull. In extreme cases the variations in the skull should be very well advanced (e.g. in individuals from April). The height of the brain case is maintained in these animals in principle within the limits proper to free-living animals. Calculating the mean values for these two groups jointly (II and III) we obtain a relatively slow increase in the height of the skull in the spring months (Fig. 7). This increase is twice as slow as that in free-living animals in the analogical period (Table 9).

The autumn lowering of the skull in old adults is probably as slow as it is in young shrews and does not become evident until October or November. There is unfortunately no material from December available. Two specimens which lived until January (which can only exceptionally take place under free-living conditions — B o r o w s k i & D e h n e l, 1953) had, however, comparatively high skulls.

VI. THE PROBLEM OF SEXUAL MATURATION

The sexual maturation of shrews under laboratory conditions was investigated by Dehnel (1952), Wolska (1953) and recently by Crowcroft (1964). Further work on this problem is needed on more abundant material especially collected for the purpose. This will form the subject of a separate report. The material already obtained, however, permits of making certain important points.

Table 10.

Appearance of lateral scent glands.

Period of catches	Day	Days								n	Total
		1—	31—	61—	91—	121—	151—	181—	211—		
Summer	Long		2	2	2	1				7	16
	Short					1	3	5	1	10	11
Winter	Long	10	3							13	22
	Short	7	3							10	23

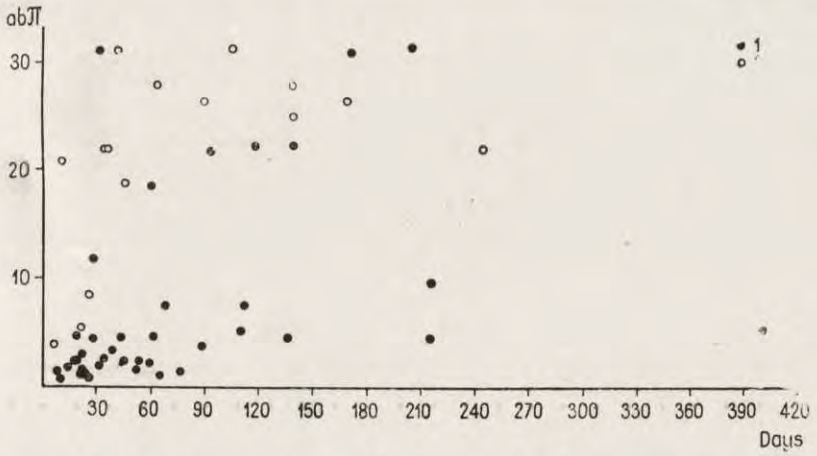

Fig. 9. Size of testes (ab π) and length of life in captivity (N = 53).
1 — shrews caught in the winter (December—March),
2 — shrews caught in the summer (June—September).

The appearance of the lateral glands (Wolska, 1953; Borowski, 1964) is taken as the first symptom of sexual maturation. Material was classified according to this feature (Table 10). The table shows that young

shrews caught in the summer exhibit the first symptoms of sexual maturation during the second month of their stay in captivity, at the earliest, and this may equally well not take place until the fifth month. In shrews caught in the winter, on the other hand, which are far nearer to the spring period of sexual activity normal to them under free-living conditions, the lateral glands become perceptible much earlier, in the majority of cases during the first 30 days of the animals captivity. It may be stated that this phenomenon occurs in a number slightly in excess of half the total number of currently captive animals.

Progressive changes in the testes of young males were expressed by the index a.b. π. Fig. 9 illustrates the dependence of the size of the testes on the period spent in captivity, and on the season in which the animals were caught. It was found that the full development of the gonads of males may be attained within a very short time (about 1 month) in the case of animals caught during the winter, or slightly later (after at least 2 months) in animals caught in the summer. On the other hand, however, shrews may survive under laboratory conditions over a period of 400 days without exhibiting any progressive changes in the genital organs.

The majority of the animals (80%) coming from the winter months attain a state of complete sexual activity and conversely, only 18% of shrews caught during the summer become sexually mature in captivity. The relations observed are thus in agreement with the development of the lateral glands.

VII. INVOLUTION OF THE THYMUS GLAND

The thymus gland of *S. araneus* is subject to involution which reduces this gland to the rudimentary stage as early as October in free-living animals. Only a very few shrews were found in November with very small (but not as yet rudimentry) thymus glands (Bazan, 1952; Pucek, in preparation).

In shrews kept under laboratory conditions this process is delayed. Of 19 specimens caught in the summer and thus undoubtedly possessing a large or medium-sized thymus gland, and which died natural deaths during the inclusive period from November to February, it was only in 5 (26%) that the rudimentary form of this organ was found (Table 11). In the remaining individuals the thymus gland was admittedly in a state of advanced involution, but the gland was not rudimentary. The weight of certain of these thymus glands varied (after fixation) within limits of 2—6 mg (Fig. 10). It must be added that some of the shrews examined which had a small or even medium-sized thymus gland, were in the maturation phase, others were sexually inactive. This would indicate an

Table 11.

Rate of involution of the thymus gland.

Size of thymus	month								
	VI	VII	VIII	IX	X	XI	XII	I	II
Large	1	5	10	4	3				
Medium		2	2	8	1			1	
Small		1	1	7	2	2	4	3	4
Rudimentary				2	3	3	1	—	1

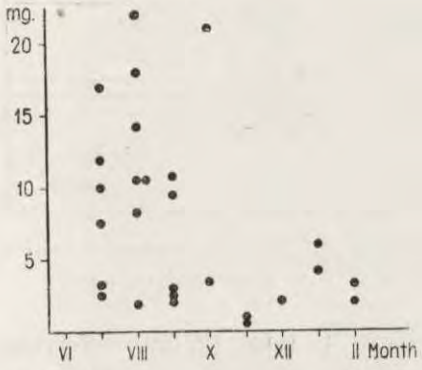

Fig. 10. Variation in the weight of the thymus gland in captive shrews (1962—64)

absence of connection between the involution of the thymus and the course taken by the process of sexual maturation (cf. also B a z a n, 1952; 1955; P u c e k, 1961).

Of the 8 shrews with small thymus glands in the winter period (December—February) three had summer coats, 2 were moulting and the remaining 3 had winter coats. It may therefore be taken that the dependence of the involution of the thymus on changes of coat (B a z a n, 1952) may be subject to serious disturbances, at least under laboratory conditions.

VIII. LENGTH OF DAY AND MORPHOLOGICAL CHANGES AND SEXUAL MATURATION

Experiments made using captive animals during the period from 1957—1958 were intended, *inter alia*, to establish whether and how the conditions formed by the laboratory habitat, especially the length of day, affect the course of seasonal morphological variations in shrews. In the tables and figures already referred to, material taken from two basic series of

animals, kept under long-day (16—18 hours) and short-day (3—4 hours) conditions, was so arranged that any possible differences became evident. More detailed information on these experiments is to be found in the study by Borowski (1964). The plan of changes in lighting is illustrated by Fig. 11. The same symbols were used here as those used to distinguish the experimental groups in Fig. 3 — A, B, C, D.

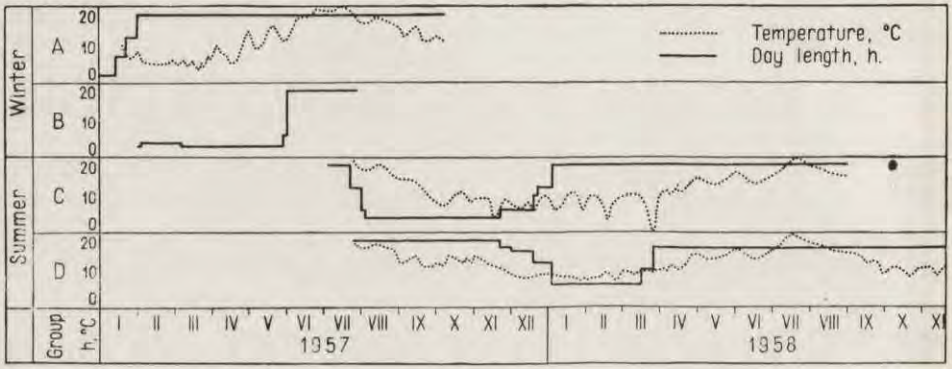

Fig. 11. Diagram of variations in length of day and in temperature in rooms in which the shrews were kept. (Acc. to Borowski, 1964 — somewhat changed).

1. The curves shown on Fig. 3 and the figures in table 12, both referring to all the shrews subjected to the action of different number of hours of illumination, and which had lived over 1 month in captivity, make it possible for the following conclusions to be reached:

A far greater percentage of the shrews caught during the summer period exhibit, irrespective of the lenght of day, an increase in body weight transition to the weight group of old adults, than shrews caught during the summer. The differences, checked by the χ^2 test, proved to be statistically significant.

Shrews from the summer months exhibited progressive changes in the body weight only in a small number of cases. This phenomenon occurred very late, at more or less the same time as in the winter group (II), in both cases only slightly earlier than is normal for free-living animals.

No differences were, however, found between young individuals, whether caught in the winter or summer, and kept with a long or short day.

2. Fig. 12 illustrates the variations in the height of the brain case of shrews kept under different lighting conditions. It can be seen from this diagram that the length of the artificial day does not effect variations in the height of the skull. In both combinations (long and short day), both in

Table 12.

Dependence of increase in body weight of the shrews on the length of day and period of capture.

Capture period	Group	n	Increase in body weight shown by:		
			n	%	
Winter	A (18 hrs.)	12	7	58	56
	B (3—4 hrs.)	4	2	50	
Summer	D (VIII—XI—18 hrs., I—15.III—6 hrs., IV—VIII—18 hrs.)	10	1	10	19
	C (II-VIII—19.XII—4—6 hrs. I—VIII—18 hrs.)	16	4	25	

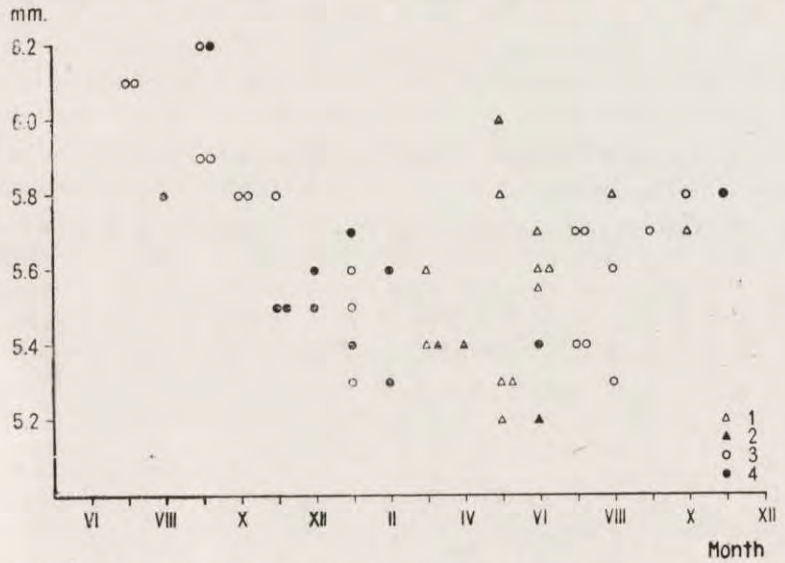

Fig. 12. Variations in the height of the brain-case depending on the length of day (1957—58; N = 47).

Comparison was made of shrews caught in the winter (December—March) and kept under long (light triangle), and short (dark triangle) day conditions, with those caught in the summer (June—August) and also kept under long (circle) and short (dots) day conditions.

series I and II, variations in this dimension take an analogical course. It is a particularly interesting fact that the low-skulled individuals from May and June originate both from the long and the short day.

3. The phenomenon of sexual maturation would seem to have a closer connection with the length of day. The influence of this factor is admittedly not evident in the group of shrews caught during the winter (Table 10), in which the process of sexual maturation progresses very rapidly, but in the case of shrews captured in the summer, individuals kept under the 18-hour summer day conditions mature earlier, and are significantly in advance in this respect of the group kept under the short day conditions. These data thus confirm the observations made by Crowcroft (1964) and point to the possibility of differences in the effect exerted by light, depending on the physiological condition of the shrews.

IX. DISCUSSION OF RESULTS

Assuming that the phenomena of seasonal variations observed in free-living shrews are normal for these animals, and taking into consideration the fact that depending on defined geographical conditions, and also climatic conditions in a given year, the phenomena may be subject to a certain degree of shifting (Pucek, 1955; 1963), it is possible to speak of deviations from this normal state in animals kept under laboratory conditions. The fact itself of finding disturbances in the process of seasonal variations is worthy of special attention. On account of the further investigations in progress on Dehnel's phenomenon, it would seem of special importance to discover to what degree the defined system of factors in the laboratory environment may affect seasonal variations in shrews. The data obtained in our investigations make it possible, however, to define with a certain degree of accuracy the effect of laboratory conditions on shrews, and on the significance of certain elements of the seasonal variations in these animals.

1. The body weight of young individuals, captured and taken to the laboratory during the summer, is maintained on a higher level and does not exhibit the decrease during the winter proper to free-living shrews. It must be assumed that this is the result of the relatively good condition of the animals, which are kept in suitably higher temperatures and abundantly fed. The winter decrease in body weight of free-living shrews would have, in the light of the above, primarily the character of a phenomenon connected with condition, and would indicate that a certain lack of food occurs at this time, caused most probably by difficulties in obtaining food suitable as regards both quantity and quality. This assumption, frequently criticised, would be supported by the recent research made by Kisielewska (1963), who demonstrated that shrews feed chiefly on the insects living in nests (*Catopidae*) and on *Myriapoda* hibernating in

treetrunks, during the winter. This points to the restricted possibilities of the shrews penetrating the area under the snow.

Niethammer (1956) finds that the winter reduction in the body weight of shrews depends on climatic conditions. In West Germany this winter reduction is more weakly expressed than at Białowieża or in Finland, where the conditions during the winter are extremely severe. Miežžerin (1964) observed a similar relation in the Ukraine, and explained the reduction in the body weight of shrews during the winter as the adaptation by these animals to obtaining an absolutely smaller amount of food. Observations made of captive animals, however, show that we are concerned here with the great physiological plasticity of shrews, and not with an inherited adaptation to living in defined habitat conditions.

2. If shrews living in captivity have relatively better conditions than free-living animals, then the absence of the spring jump in growth and weight becomes difficult to understand. This phenomenon was exhibited to a certain extent by animals which entered the laboratory as captives in the winter. In this case also, however, these shrews do not attain the weight of free-living old adults. It must be remembered that their weights may be slightly lower on account of the absence of pregnancies and lactation, which undoubtedly induces an increase in the body weight of free-living old adults, and may intensify their jump in growth. In our case, however (especially in group II) differences are too great to be capable of explanation by the above only. The jump in growth of the old adults is most certainly regulated hormonally. It is in this system that the cause of disturbances in captive animals should be sought for, disturbances causing delay or complete inhibition of their jump in growth in the spring.

3. Bazan (1952) showed that the involution of the thymus gland in shrews during the autumn is dependent on the exhausting moulting process in the autumn. In principle the thymus has reached the rudimentary form in all animals after they have finished moulting. The deteriorating habitat conditions in October and November undoubtedly hasten this process, whereas under laboratory conditions there is no question of a change of this kind in conditions. The longer retention of the thymus may therefore be the expression of food conditions in this time relatively better than those prevailing in nature. The process of the autumn moult in captive animals, as recently shown by Borowski (1964), is subject to disturbances expressed in the retardation or prolongation of the autumn change of coat. As a result captive shrews would be maintained for a longer period in a relatively good condition, not exhausted by moulting.

4. A very good index of the seasonal changes in shrews is formed by variations in the weight of the brain and in consequence — the degree of arching of the skull. The differences found here are expressed by a more rapid reduction in the height of the brain case in young shrews in the autumn than is the case in free-living animals. This may be due to the initial material in this group of animals originating from the summer. During the autumn (up to October inclusively) no young high-skulled specimens entered the group, while in free-living animals such specimens raise the monthly mean values of this dimension.

The winter depression of the skulls of captive shrews is not so strongly marked as that in free-living animals. Most certainly some factors are active here which in the beginning weaken the rapidly progressing flattening process of the skull. The spring increase in this dimension is delayed under laboratory conditions, and in fact does not take place in all the specimens. It would also seem that in certain cases (specimens caught in the winter) the depression of the skull may even continue. This is borne out by animals which died a natural death during the period between May and June, which had very flat skulls.

5. The excessive adiposity of captive shrews, which is not encountered in free-living animals, is undoubtedly the expression of the very limited activity of these animals in cages, which are not equipped with an activity wheel, and of their being supplied with abundant food rich in calories. The degree of adiposity of the animals was recorded after their death, which may of course cause certain deviations from the actual condition (less of fat deposits during the period preceding death).

Independently of these factors, the adiposity of shrews kept in captivity has the character of normal accumulation of reserve substances. It would be difficult to say at this moment, without carrying out exhaustive histological investigations, what the nature of these fat deposits is. Both the enlargement of brown adipose tissue and also the deposit of yellow fat within this tissue are possible (cf. K a r o l e w i c z, 1953).

Sharp increase in the body weight before or during moulting may be the expression of the formation of fat supplies, which are then available for rapid utilisation during the process of the change in coat.

The results obtained in the present study may have some bearing on the body weight of young free-living shrews. During the autumn an increase is found in the body weight of these animals also (Fig. 5), which lasts approximately up to and including September (D e h n e l, 1949; B o r o w s k i & D e h n e l, 1953; N i e t h a m m e r, 1956; and others). After this period a decrease in the body weight takes place, lasting until the winter. It coincides with the period of change of summer to the winter coat and

at least to a certain degree, in the light of the data obtained in this study, may be caused by this process.

6. The application of artificial lighting and regulation of the length of day has a negligible effect on the course of seasonal changes in captive shrews. Similar results were obtained by Borowski (1964) in his research on moulting. The effect of the long and short day is evident only in the hastening of sexual maturation (cf. also Crowcroft, 1964). Other conditions peculiar to the laboratory, chiefly temperature and abundant food, undoubtedly also contribute here. This would be borne out by the fact that even under the short-day conditions the animals attain sexual maturity, although later than in the conditions formed by the 18-hour day.

7. A significant result of the study is the statement of the existence of differences between shrews which entered the laboratory during the summer and winter periods respectively. Their differences from the aspect of absolute age are obvious, but there must also be differences of a physiological nature, the expression of which is to be found in the absence of the jump in growth of the young shrews from the summer. Their body weight after spending the winter in captivity does not increase, contrary to that of the shrews entering the laboratory during the winter. Sexual maturation also reveals significant differences between these two groups. Since in both groups we are concerned predominantly with specimens born during the summer (June—September) but subsequently living for different periods under natural conditions, it is impossible to speak here of differences between two generations of shrews. It may be assumed that shrews born in the summer would acquire definite physiological properties, distinguishing them from animals which were kept in captivity in the meantime, the longer they continued their free way of life. On the other hand, however, these differences may be caused by disturbances created during the period of 7—9 months which they spend under laboratory conditions.

The differences presented in this study in the course taken by the phenomenon of seasonal variations in captive and free-living shrews points to the considerable degree of plasticity of these animals and the possibility of the existence of deviation from the seasonal changes already described. They may be due both to certain habitat conditions in a given years, or to differences in various parts of the geographical range of shrews.

X. SUMMARY

Investigation was made of the seasonal variations in the length and weight of the body, dimensions of the skull and length of life, degree of adiposity, involution of the thymus gland and the sexual maturation of shrews, *Sorex araneus* Linnaeus, 1758 (N = 256), kept in laboratory conditions.

Independently of the period at which they were caught, and of sex, the mortality rate was high among captive shrews. 40% died within the first month, scarcely 30% survived 90 days, and only 5% of the individuals survived for a years or over (maximum 400 days). Shrews caught in the winter lived a shorter time.

The mean body weight of young and old adult shrews from the summer is higher than in free-living animals. The winter depression in body weight is not observed in young shrews and the spring jump in growth is evident only in certain of the animals. The majority of the shrews caught in the winter exhibit a distinct jump in growth, although earlier and more weakly than in free-living animals.

The body weight of the shrews exhibits sharp increases and decreases, expressed in extreme cases by the figure 52%. The maximum diurnal increase or decrease is 6% (corresponding means: 3.4% and 2.6%). Jumps in body weight occur before or during moulting and may have the character of accumulation of reserve substances.

In young shrews from the summer (and to a lesser degree in those caught in the winter), a distinct connection was found between the body weight and degree of adiposity. The most adipose individuals spent 3—4 months in captivity. Accumulation of fat reserves was found in 90% of the shrews.

Differences in the course taken by the curve of seasonal variation in the height of the brain case oberved in captive animals are expressed by hastening of flattening process of the skull up to October, and slowing of the rate at which variations take place during the autumn-winter period. The maximum depression of the skull is 1/3 less than in free-living animals and is shifted in time to March—April. The spring arching of the skull is slow and the decline in its height in old adults is scarcely perceptible as from November onwards. Certain of the individuals, both those from the summer and from the winter, retain their "winter" dimensions and do not exhibit arching of the brain case in the spring. No differences were found in the course taken by variations in the skull depending on the time of capture and length of day.

Sexual maturity is attained more rapidly and by a greater percentage (80%) of shrews caught in winter. Animals caught in the summer maturate more slowly, and even so only about 18% of them attain maturity. This process may be hastened by the 18-hour day and abundant food.

Involution of the thymus gland is delayed. During the period from December—February the thymus is maintained in over 70% of the individuals in the "small" or "medium-size" form, irrespective of the degree of sexual maturity and moulting process.

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STRESZCZENIE

Badano sezonową zmienność długości i ciężaru ciała, wymiarów czaszki oraz długość życia i stopień otłuszczenia, inwolucję grasicy, i dojrzewanie płciowe ryjówek, *Sorex araneus* Linnaeus, 1758 (N = 256), trzymanych w warunkach laboratoryjnych.

Niezależnie od okresu złowienia i płci stwierdzono dużą śmiertelność ryjówek w niewoli. W pierwszym miesiącu ginie 40% zwierząt, ponad 90 dni przeżywa zaledwie 30% a rok i więcej (maksymalnie — 400 dni) ca 5% osobników. Ryjówki złowione w zimie żyją krócej (Tabela 1, 2, Ryc. 1—2).

Średni ciężar ciała ryjówek młodych i przezimków z lata jest wyższy niż w terenie. U młodych nie obserwuje się zimowej depresji ciężaru ciała a wiosenny skok wzrostowy uwidacznia się jedynie u niektórych. Większość osobników złowionych w zimie wykazuje wyraźny, choć wcześniej i słabiej niż w terenie zaznaczony, skok wzrostowy (Tabele 3—5, Ryc. 4, 5).

Ciężar ciała ryjówek wykazuje w hodowli gwałtowne przyrosty i spadki, wynoszące w skrajnych przypadkach 52%. Maksymalny dzienny przyrost lub spadek wynosi 6% wyjściowego ciężaru ciała (odpowiednie średnie — 3,4% i 2,6%). Zmiany ciężaru ciała występują przed lub w czasie trwania linki i są zapewne wyrazem gromadzenia substancji zapasowych (Ryc. 3).

U młodych z lata, a w mniejszym stopniu i u łowionych zimą, stwierdzono wyraźną zależność między ciężarem ciała a stopniem otłuszczenia (Tabela 7). Najsilniej otłuszczają się osobniki przebywające w hodowli 3—4 miesięcy (Tabela 6). Odkładanie się zapasów tłuszczu stwierdzono u 90% osobników.

Rozbieżności w przebiegu krzywej sezonowej zmienności wysokości puszki mózgowej, obserwowane w niewoli, wyrażają się przyspieszeniem spłaszczania się czaszki do października włącznie i zwolnieniem tempa zmian w okresie jesienno-zimowym (Ryc. 7, 8, Tabela 9). Maksymalna depresja czaszki jest o 1/3 mniejsza niż w terenie i przesuwa się na marzec — kwiecień. Wiosenne wysklepienie się czaszki jest powolne a spadek jej wysokości u przezimków ledwie zaznacza się, poczynając od listopada. Część osobników zarówno z lata jak i z zimy zachowuje wymiary „zimowe" i nie wykazuje na wiosnę zmian progresywnych, prowadzących do wysklepienia się czaszki. Nie stwierdzono różnic w przebiegu zmian w czaszce, zależnie od okresu złowienia i długości dnia (Ryc. 8, 12).

Dojrzałość płciową osiągają szybciej i w większym procencie (80%) ryjówki złowione zimą. Złowione latem dojrzewają wolniej i tylko w ca 18% osobników. Proces ten może przyspieszać 18 godzinny dzień (Tabela 10, Ryc. 9).

Inwolucja grasicy ulega opóźnieniu. W okresie od grudnia do lutego grasica utrzymuje się u ponad 70% osobników w postaci „małej" lub „średniej", niezależnie od stopnia dojrzałości płciowej czy procesu linienia (Tabela 12, Ryc. 10).