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Seasonal and Age Changes in the Weight of Internal Organs of Shrews

[with 18 figures and 16 tables]

An analysis was made of variation in relative and absolute weights of the brain, heart, spleen, liver, kidneys, interscapular gland, adrenal glands, thymus and gonads of *Sorex araneus* Linnaeus, 1758, from the individual, age and seasonal aspect, for three successive generations (1961/62—1963/64). The individual variation in the organs differ (V = 7—52%) depending on the season and age of the animals. The relative connection between weights of the organs and body weight is perceptible only in certain cases (brain, heart, kidneys, liver). Absolute weights of the majority of organs in young shrews exhibit slight increase in the summer. The autumn regression is distinctly accelerated as from October onwards. An exception is formed by the heart, which is not subject to these changes. The spring jump in growth applies to all the organs, but is manifested to different degrees — increases from 16% (brain) to 495% (spleen). The rapid rate of autumn regression and spring growth results in each of these processes lasting about 2 months. The autumn regressive changes, and in particular the spring jump in growth synchronize in different organs. Analysis of the changes in relative weights of the organs and of the correlation between them and body weight show that the internal proportions of the animals' bodies alter over the shrews' life-span. Differences were found between different generations, more distinctly evident in the weight of certain organs (liver, kidneys, spleen) than in body weight. Using the changes described in the organs, and also the measurements and weight of the body, skull, brain, endocrine glands and certain physiological indices as a basis, it proved possible to distinguish 7 stages of postnatal development of shrews. The duration of the stages of development differs from those in other *Micromammalia*. Uneveness of postnatal development is treated as the result of the specific adaptation of shrews developed during their phylogenesis.

I. INTRODUCTION

The phenomenon of seasonal variation in shrews, discovered by Dehnel (1949) is also manifested, in addition to changes in the skull and brain, by far-reaching fluctuations in body weight. These variations are simultaneously of twofold character: age and seasonal and under natural conditions it is not possible to consider them separately. Seasonal rhythm is manifested by a reduction in body weight in autumn and winter (Stein, 1938; Borowski & Dehnel, 1953; Pucek, 1955; Niethammer, 1956) and may be treated as the expression of the shrews' specific adaptation anabling them to survive the difficult winter period (Dehnel, 1949; Miezhzherin, 1964). The expression of age changes is formed e.g. by the activisation of growth processes at a given stage of development, and the characteristic changes in old adults.

These variations are differently reflected in the fluctuations in weight of the various internal organs. In the case of *Sorex araneus* L. the weights of certain organs have already been examined. In addition to earlier studies based on single specimens (Welcker & Brandt, 1903; Rensch, 1948) there are more extensive reports by Schwarz (1955; 1962). Correct interpretation of the results so far obtained is only possible when the seasonal changes established as taking place in these animals are taken into consideration. The fact itself of the existence of seasonal and age variations creates the obvious necessity for analysing a large amount of representative material, both for the different periods and also the different phases of the shrew's life cycle, that is, material making it possible to grasp the full range of variability of these animals. Such treatment has been represented in several publications of our group. Thus, starting with changes in capacity of the braincase (Pucek, 1955), seasonal variations in weight and volume of the brain were examined both in *Sorex minutus* Linnaeus, 1776 (Caboń, 1956) and *Sorex araneus* Linnaeus, 1758 (Bielak & Pucek, 1960). Continued studies made it possible to establish that the mechanism of variations in the weight of the fresh brain as a whole consists in fluctuations in the water contents and also lipids and dry rest contents (Pucek M., 1965).

Buchalczyk (1961) investigated the variations and mutual proportions of the salivary glands in *S. araneus*. On account of the seasonal character of the variation, observations of the weight of brown adipose tissue (*BAT*) are more significant in this context (Buchalczyk & Korybska, 1964). The above authors showed that the course taken by the seasonal changes in this organ is specific and differs from that observed in, for instance, hibernating animals. These variations are undoubtedly connected with the dynamics of physiological transformations in the shrew's organism, evidence of which would seem to be provided by the periods of increased weight of this organ in May and June immediately after leaving the nest, in the winter. and during the sexual maturation period, in the spring.

The existence of seasonal rhythm has also been demonstrated in the morpho-histological pictures of the endocrine organs such as the thymus gland (Bazan, 1952), the thyroid gland (Dzierżykray-Rogalska, 1952), the parathyroid glands (Dzierżykray-Rogalska, 1955), and the adreal glands (Siuda, 1964). Taken altogether this gives a fairly complete picture of the variation in the shrew's organism, which undoubtedly facilitates an analysis of morphological variation in these and other internal organs.

Morphological variation is of course the expression of intensity of physiological processes. Certain grounds for this statement are provided by studies of blood indices in shrews (Kunicki-Goldfinger & Kunicka-Goldfiger, 1964), food (Mezhzherin, 1964) and metabolism and the diurnal activity rhythm (Gębczyński, 1965). These indices, as has been stated, exhibit distinct differences depending, *inter alia*, on the season. It is interesting to see, however, how these changes affect the variation in weight of different internal organs. The weight of the organ may be considered as an approximate indicator of its function. The existence of connections of this kind in relation to many vertebrates has been demonstrated in earlier studies: Hesse (1921), Rensch (1948) and others, and recently in the publications by Schwarz (1949; 1958; 1959b; 1963) and his co-workers. The relative weights of the internal organs and certain physiological indices have defined by Schwarz by the joint term of "morphophysiological indicators" and are considered by him to be of great importance in ecological research, particularly to an accurate description of a population.

In the present study special emphasis has been laid on obtaining a knowledge of the course taken by seasonal and age changes in the weight of the internal organs of shrews, in particular of those which play a basic part in physiological processes, whether as organs of digestion and metabolism or of the circulatory system, or as endocrine glands. The second aspect is connecting up the changes in the organs with the fluctuations in body weight. It is primarily a question here of what changes the internal morpho-physiological proportions of the body are subject to during the life cycle of shrews. The period of intensive spring growth occurring at a relatively late phase of the individual develepment of these animals is praticularly discussed. The problem of changes in the weight of internal organs in the group of primitive mammals also deserves consideration on account of the application to them of general laws of the reciprocal proportions of different organs in homoiothermal vertebrates.

II. MATERIAL AND METHODS

The object of our investigations was the Common shrew, *Sorex araneus* Linnaeus, 1758. The animals were caught in several biotopes of the Białowieża National Park *(Querco-Carpinetum typicum, Querco-Carpinetum stachyetosum, Circeo-Alnetum)*, mainly in metal cylinders, but also in live traps. A total number of 655 shrews was caught during the period from April 1961 to February 1964. The animals were dead when brought to the laboratory, the few live specimens being exceptions. Death occurred in the trap or cylinder, chiefly from starvation and cold. The stomachs were therefore empty or almost so, and it was therefore assumed that any contents still present would not have any significant effect on body weight as a whole. The gross body weight, obtained as quickly as possible after the animals' death, was therefore taken for all further calculations. The time lapse between the shrews' death in the trap or cylinder and the measurements and dissection of the carcass was about 6—8 hours. The few live animals were anaesthetized with ether and dissected, similarly to those brought dead to the laboratory, i.e. without bleeding.

The internal organs were prepared, cleaned of fat and blood clots (the heart was incised) and rinsed in normal saline solution in Petrie dishes. This prevented their drying up, which might otherwise have taken place during the time between removing the first and the last organ. After dissection was completed the organs were in turn lightly dried on filter paper or lignine and weighed on an automatic analytical scale with accuracy of 0.001 or 0.0001 g depending on organ size.

Analysis was made of the absolute and relative weights (in percentages of the gross body weight) of the different internal organs. The material has been so arranged in the majority of the comparisons and diagrams that it is possible to trace the course taken by phenomena over the life cycle; that is, from June (young adults) of one calendar year, the year of birth, through the winter, spring etc. to the late autumn of he following calendar year (the year in which death ensues). The course taken by different phenomena was therefore traced within the span of different generations each of which is begun by the young adults entering the population from June to September, and exceptionally only, up to the beginning of October, of each calendar year. At certain seasons of the year we are concerned with one generation of shrews only, since from January to May there is only the generation of shrews born the previous calendar year. In the other months (from June to December) two generations co-exist: 1. the young adults, born in the current year and 2. old adults — born the previous calendar year. Since young shrews do not in principle enter the population apart from the period from June to September, it is perfectly simple to separate these two main age groups from each other. The fundamental criteria here are the quality and colour of the fur, the degree of wear of the teeth and character of the changes in the skull sutures (Dehnel, 1949; Dunajeva, 1955; Pucek, 1955).

In the majority of the comparisons combined material has been used, that is, the incomplete three generations of shrews (1960/61—1963/64) have been considered as one combining material from the months and periods corresponding to each other.

Two main age groups were distinguished:

1. young adults — caught from June of one calendar year to March of the following year,

2. old adults — caught from April to the late autumn, and even as late as December, when they die off.

The criterion setting the limits of the two groups is intensification of growth and attainment of sexual maturity by all the individuals in the population. Under the conditions at Białowieża these processes take place at the turning point between March and April. The animals which atained sexual maturity in the first year of their lives were considered, in accordance with the above division, as belonging to the "young adults" group, as the growth changes peculiar to the old adults were not observed in them (P u c e k, 1960; S t e i n, 1961; D o l g o v, 1961).

For certain comparisons seasonal-age groups were distinguished which correspond to the basic stages in changes during shrews' life cycle, as follows:

I. Young adults, summer (June-July, and sometimes August as well),
II. Young adults, winter (December to the first half of March),
III. 1. Old adults, summer (June—August) — males,
2. Old adults, summer (May—August) — females.

The variation in the various indices were described by the arithmetical mean ($\bar{x}$) confidence interval, standard deviation (*S.D.*) and coefficient of variation (*V*) calculated according to generally accepted principles (S i m p s o n *et al.*, 1962). The interdependence of the characters was expressed by the correlation coefficient (*r*). In order to demonstrate differences between seasonal groups calculation was made of the regression coefficients and analysis of variance (for regression) after S t e e l & T o r r i e (1960). Regression coefficients for each group were campared by means of multiple range test (D u n c a n, 1957).

III. CHANGES IN BODY WEIGHT

The problem of changes in body weight of shrews is sufficiently well-known from the studies made by many authors (S t e i n, 1938; D e h n e l, 1949; B o r o w s k i & D e h n e l, 1953; P u c e k, 1955, 1964; N i e t h a m m e r, 1956, and others), but I consider it essential to present the curve of changes in body weight of the series of shrews examined (Fig. 1), primarily on account of the reference often made in the present study to these data and the expression of the weight of different organs in relation to the body weight.

Fig. 1 shows the changes in the body weight of males and females in different months of the life cycle. Sex differences are inconsiderable in young animals and are only significant in old adults. In the case of the latter the females are heavier than the males. As is well known, during the summer practically all the females are pregnant or nursing young and have greatly developed milk glands (T a r k o w s k i, 1956) which of course increasse the body weight of these animals.

Young adults from the summer to the autumn (September) increase slightly in body weight. The winter specimens from February are 32.1% lighter than the September shrews. The spring jump in growth takes place a little more rapidly in males than in females which is probably connected with the generally earlier manifestations of sexual activity in males. Increase in body weight from February to June, on the average for both sexes, is 106.7% and takes place over a period of approximately two months. It must be added that the males increase their body weight by 100%, and females by over 129%, during this period. On the basis of earlier data for captive shrews (P u c e k, 1964) it may be assumed that the growth rate may be even more intensive in some animals during this period than would appear from the mean monthly values given above for the whole population.

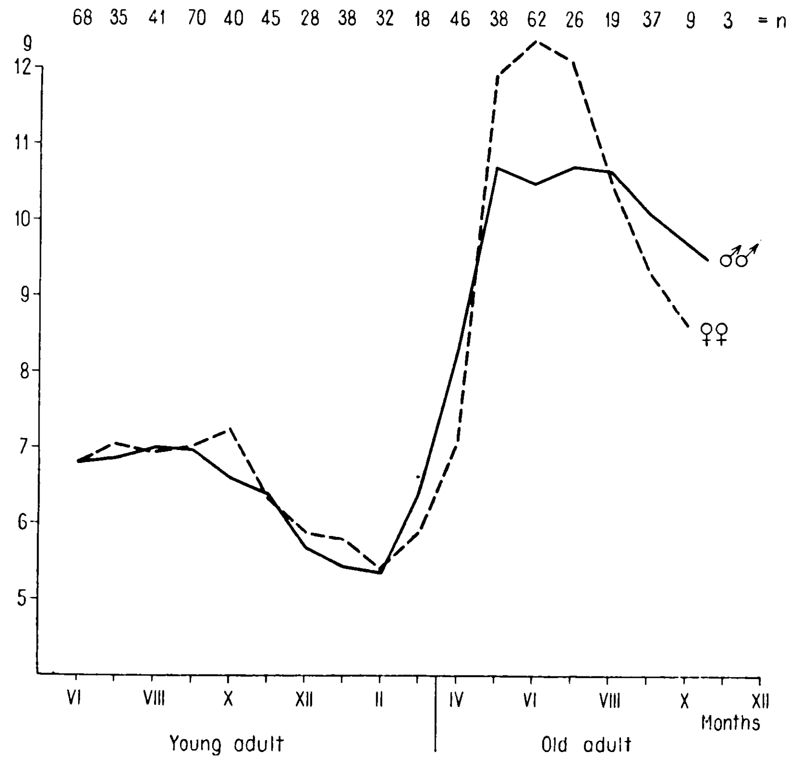

Fig. 1. Changes of body weight in males and females over the life cycle of common shrew.
Figures at top of fig. indicate the number of animals examined each month.

Fig. 1 also contains the numbers of the monthly series describing the amount of material examined. These figures are sometimes slightly smaler in analyses of different organs as it was not always possible successfully to prepare, clean and weigh all the organs of the animals examined.

IV. VARIATION IN ABSOLUTE AND RELATIVE WEIGHTS OF INTERNAL ORGANS

1. Brain

Seasonal changes in the weight of the brain were established in fixed material of *S. minutus* (C a b o ń, 1956) and *S. araneus* (B i e l a k & P u c e k, 1960), and this was next confirmed for material weighed in the fresh state (P u c e k M., 1965). These earlier observations must be supplemented by some further ones obtained from fresh material.

Absolute values of the monthly mean brain weights for both sexes are given in Fig. 2. As can be seen from this figure, the reduction in the brain during the winter is expressed by a decrease in its weight in February of 21.2% in relation to July. The weight of the brain increases in the spring (from February to July by 6.8%). Towards the end of the shrews' life — in the autumn — the brain decreases again. The weight of the brain in old adults from the summer is almost 16% smaller in relation to that of young adults from the same season (Table 1). It is a characteristic feature here that in almost all months of the shrews' life cycle (except January and February) the brain in females is lighter than in males (Fig. 2).

The relative brain weight changes in a different way over the life span of the shrew. In young animals this index does not in principle vary and both in summer and winter is on an average 3.8% (Table 1). The explanation for the break in the curve of the variation during the autumn may be the slight increase in body weight at this time and the simultaneous reduction in the absolute weight of the brain.

During the period from October to February regression is much quicker, and the body weight and brain weight decrease, but the rate of these changes is different in each case. The differences are respectively 23.1% for body weight and 17.0% for brain weight. As a result the relative brain weight rises to the same level as was attained in the summer.

Fundamental changes in the relative brain weight take place as from March, when the weight of the brain, in relation to the body, is sharply reduced by half as much (45.0%) in comparison with the winter period. Simultaneously the body weight increases by over 100%. In the autumn a slight increase in the relative brain weight is observed (as in the case of young adults), which can also be explained by the different rate of changes in body weight and brain weight. There is a certain stabilization in the mean values of this index in the summer, both in young and in old adults. During this period, however, there is a distinct reverse proportional dependence between the weight of this organ and body weight (Table 14). As can be seen from a comparison of the mean values of relative brain weight in different weight classes, the shrews' brain clearly conforms

Table 1.
Variation of absolute and relative brain weights in different seasonal and age groups.

Season & Age		Summer Young adult /VI - VIII/ n = 142	Winter Young adult /XII - II/ n = 97	Summer Old adult /V - VII/ n = 124
Absolute wt., in g.	O.R. $\bar{X}$	0.197 - 0.289 0.256	0.173 - 0.260 0.210	0.186 - 0.254 0.220
Relative wt., in %	O.R. $\bar{X} \pm S_{\bar{X}}$ S.D. V	2.76 - 4.65 3.77 ± 0.0578 0.3518 9.33	2.76 - 4.65 3.81 ± 0.0672 0.3344 8.75	1.24 - 3.13 2.04 ± 0.0511 0.2877 14.10

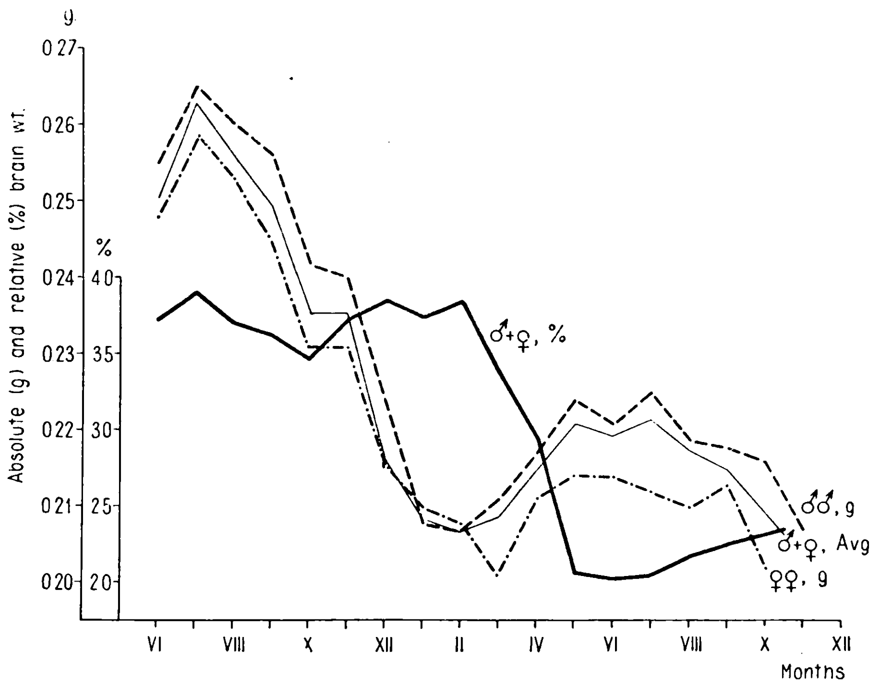

Fig. 2. Seasonal and age changes in absolute and relative brain weight in *S. araneus*.

with the rule of orders (Hesse. 1921), subject to its application to an equal age and seasonal group (young adults from the June—September period, old adult males from May to August, etc.).

Correlation between the relative brain weight and body weight is fairly considerable and rather stable in different seasonal groups (Table 11). This phenomenon is illustrated by Fig. 3 in which, as in other diagrams of this type, the individuals of different groups have been distinguished in a different way in order to demonstrate differences in the strength of these connections between different groups. Diagram (Fig. 3) and table 14 show that the relative weight of the shrews' brain within one homogeneous group generally decreases with an increase in body weight. The influence of the season is evident here in a specific way. The relative weight of the shrews' brain during the winter varies within almost the same limits as in the case of young adults from the summer, although the body weight in the winter is far smaller than in the summer.

The connection between relative brain weight and body weight is not rectilinear. Resorting to a certain degree of simplification of the question, each of the seasonal-age groups characterising the basic points on the curve of variation in the brain over the shrews' life cycle has been treated separately. Calculation of the regression coefficients was made for each

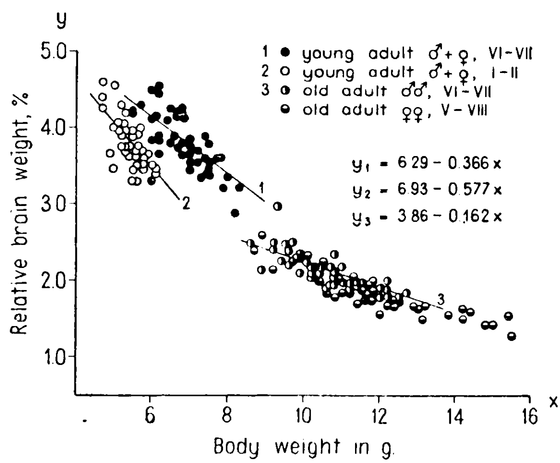

Fig. 3. Relation of relative brain weight to body weight.

of the groups and compared with each other by the method of analysis of variance for regression. The coefficients obtained are:

Age group, period	n	b	F
Young adults, summer	50	—0.366	30.73
Young adults, winter	50	—0.577	48.00
Old adults, summer	50	—0.162	54.98,

and in all cases they are statistically significant, as is shown by the values of test F for significance of the regression coefficient. They are always higher than the critical value $F_{0.05} = 4.04$. The mean regression is also highly significant ($F = 88.97$, with a critical value of $F_{0.05} = 3.92$).

Regression analysis gave a result of $F = 23.99$, which in relation to the critical value $F_{0.05} = 3.07$ is highly significant and indicates the existence of differences between the regression coefficients for each age group.

In order to show which of the regression coefficients mentioned differ significantly, the Duncan multiple range test was made. The results obtained:

Comparison	test	critical value
Young adults, summer — Old adults, summer	4.16	2.82
Young adults, summer — Young adults, winter	2.69	2.82
Young adults, winter — Old adults, summer	5.83	2.96,

show that the regressions in the relative brain weight and body weight of old adults from the summer differ significantly both from the summer young adults and the winter ones. Probably the young adults from the summer differ significantly from those from the winter, but the number of observations made was too small to permit of establishing this with complete certainty. The value of the Duncan test is very close to the critical value.

The results given above show that each of the groups is significantly different from the other, and therefore there is no rectilinear dependence of the relative brain weight on the body weight in the combined material from the whole life cycle of the shrews (from different seasons). This correlation exists, however, within each of the groups taken separately. The clear-cut dividing line between young adults from both summer and winter, and the old adults, that is, animals having undergone the spring jump in growth, would appear of particular interest here (Fig. 3).

Changes in the relative brain weight during the autumn (Fig. 2) can be explained by an increase in body weight, probably not connected during this period with the growth of the shrews. The increase in body weight in young shrews from the time of leaving the nest (June) until September—October may depend more on the accumulation of reserve substances for the later highly energetic changes (e.g. moult) than on growth. It is a known fact that no growth in the skeleton is observed during this period (Pucek, 1955; Dolgov, 1961), this process not being manifested until the spring of the following calendar year.

The autumn drop in body weight in old adults depends to a great degree on such factors as cessation of reproductive functions and the regression of the genital apparatus, milk glands, absence of pregnancy etc. These changes undoubtedly affect the relative weight of the brain.

2. Heart

The weight of the heart has been considered as one of the more important morpho-physiological indicators in vertebrates. The amount of literature on this question is vast. Perhaps the most important event, however, was the discovery by Robinson (1748) of the law, confirmed in the studies by Parrot (1894), Hesse (1921), Rensch (1948) which

Table 2.
Variation of absolute and relative heart weights in different seasonal and age groups.

Season & Age		Summer Young adult /VI - VIII/ n = 142	Winter Young adult /XII - II / n = 90	Summer Old adult /V - VII/ n = 120
Absolute wt., in g.	O.R. $\bar{X}$	0.058 - 0.091 0.0729	0.056 - 0.088 0.0708	0.081 - 0.145 0.1120
Relative wt., in %	O.R. $\bar{X} \pm S_{\bar{x}}$ S.D. V	0.85 - 1.44 1.08 ± 0.0168 0.1020 9.44	1.00 - 1.59 1.28 ± 0.0242 0.1162 9.08	0.70 - 1.54 1.06 ± 0.0300 0.1459 14.03

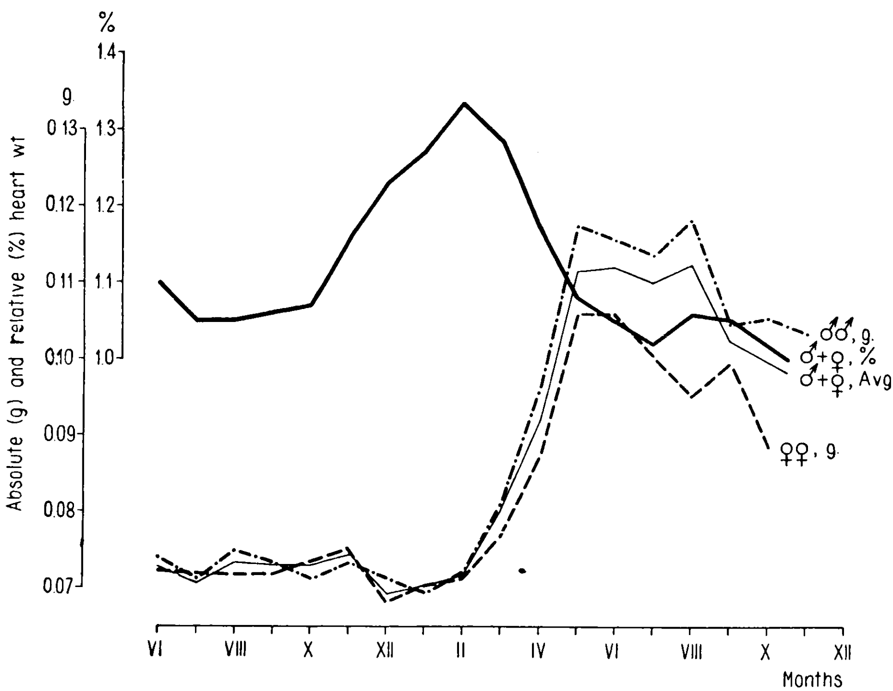

Fig. 4. Seasonal and age changes in monthly mean values of absolute and relative heart weight.

states that the relative weight of the heart increases with an increase in the animals' dimensions. Next it was shown that the heart index depends in many ways on geographical and habitat conditions, intensivity of work etc. (H e s s e, 1921; R e n s c h, 1948; S c h w a r z, 1949; 1959a; 1960; 1962). These authors, in particular S c h w a r z (*l. c.*) also demonstrated how many deviations there are from the rules laid down earlier on. The material presented below provides support for a critical view of this question and reveals the seasonal changes taking place in the heart index.

In young shrews from June to February inclusively, the mean absolute weight of the heart is not subject to any significant changes (Tab. 2). A sudden jump in the growth of the organ is observed in the spring in old adults of both sexes on an average of 58.9% in relation to the winter. Sex dimorphism in the weight of the heart shown by certain authors (Kopeć, 1939; Frick, 1957) does not occur in young shrews but is clearly evident in old adults, beginning in the spring. The weight of the heart in males is then greater than in females (Fig. 4), although the reverse relations are observed in the case of body weight.

The relative weight (index) of the heart during the summer has almost identical values in young and in old adults. The monthly means fluctuate

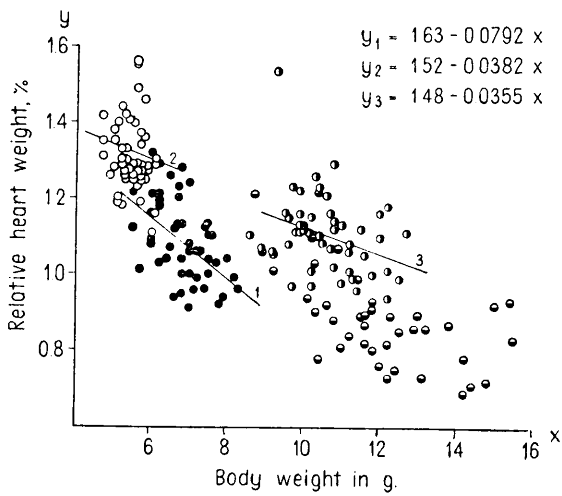

Fig. 5. Relation of relative heart weight to body weight (Explanation as in Fig. 3).

at this time within limits of 1.02—1.08%, and only exceptionally 1.10% in young shrews from June. During the winter the heart index increases intensively, increase beginning in November and attaining a maximum in February, after which the curve falls to May—June, when in old adults it attains the level peculiar to the young adults from the summer. The maximum value of the heart index in February (1.36%) is 27.1% greater than the index for the young shrews caught between June and October (Fig. 4). No increase in the relative heart weight is observed in old adults in the autumn, and therefore these animals behave differantly from the young animals before the first winter of their life.

Correlation of the relative heart weight with the body weight is not as great as in the case of the brain (Fig. 5, Table 11), but in higher for the young adults from the summer than for the winter specimens or old adults. The dispersion of points in the diagram (Fig. 5) is particularly great in the case of old adult females, which is uderstandable in view of the considerable variation in the body weight of these animals.

As in the case of the brain, calculation was made of the regression coefficients for each of the age groups separately. The results obtained:

Age group, period	*n*	*b*	*F*
Young adults, summer	50	—0.079	17.39
Young adults, winter	50	—0.038	1.05
Old adults, summer	50	—0.036	7.09.

indicate that significant connections can be observed both in the young adults and in the old adults from the summer, when the relative heart weight decreases together with increase in body weight (Table 14). With decreased variation in body weight in young animals from the winter the regression coefficient is statistically non-significant. The mean regression is highly significant ($F = 21.56$, with critical value of test $F_{0.05} = 3.92$) Analysis of regression gave a result of $F = 3.56$, which in relation to the critical value $F_{0.05} = 3.07$ is significant and points to the existence of differences between the regression coefficients of the groups compared. Comparison of the coefficients with each other by means of the Duncan test does not, however, give a significant result for the various combinations:

Comparison	test	critical value
Young adults, summer, — Young adults, winter	1.37	2.82
Young adults, winter — Old adults (♂♂), summer	0.97	2.84
Young adults, summer — Old adults, summer	2.64	2.96.

As, however, the result of analysis of variance is significnat, and the regression coefficients for the young adults from the winter and old adults from the summer are very close and do not significantly differ from each other, it may be stated that the regression in the relative heart weight and body weight for young shrews from the summer does not differ significantly until compared with the two remaining groups jointly (young adults from the winter + old adult males from the summer).

3. Liver

Seasonal changes in absolute weight of the liver (Fig. 6) are very similar to that of body weight. In young individuals we observe, from June to August—September, a relatively small increase in the weight of this organ of 17.01%. The decrease in liver weight which follows from October to February inclusively is 34.6%. The minimum values occur in February (Fig. 6). During March and April there is a sharp increase of 122.5% in the liver in relation to February, and by May it has attained almost maximum weight in old adults. Continued increase in the weight of this

Table 3.
Variation of absolute and relative liver weights in different seasonal and age groups.

Season & Age		Summer Young adult / VI / n = 67	Summer Young adult / VIII - IX / n = 109	Spring Old adult / IV / n = 43	Summer Old adult / VI - VII / n = 76	Autumn Old adult / IX - XI / n = 45
Absolute wt., in g.	O.R. $\bar{X}$	0.30 - 0.69 0.45	0.35 - 0.74 0.53	0.35 - 0.79 0.50	0.50 - 1.22 0.76	0.60 - 1.19 0.84
Relative wt., in %	O.R. $\bar{X} \pm S_{\bar{X}}$ S.D. V	5.00 - 8.49 6.77 ± 0.155 0.6329 9.35	6.00 - 10.49 7.81 ± 0.170 0.8954 11.46	5.00 - 9.49 6.36 ± 0.260 0.8427 13.25	5.50 - 10.49 7.11 ± 0.210 0.9192 12.93	6.50 - 10.99 8.97 ± 0.329 1.091 12.16

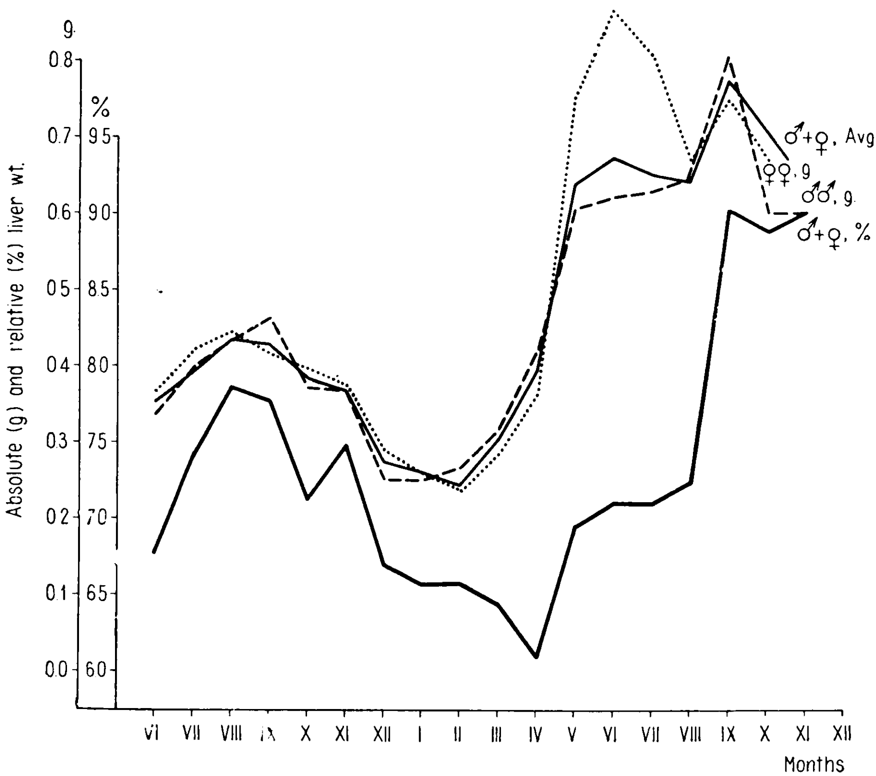

Fig. 6. Seasonal and age changes in mothly mean values of absolute and relative liver weight.

organ does not occur until the autumn, in September—October, that is, after almost complete cessation of the reproductive functions.

Fig. 6 and Table 3 show the changes in weight of the liver in males and females. These differences are small in young adults, nevertheless the mean values are higher for females than for males in most of the months. During the spring period from February to April the reverse applies, which is undoubtedly connected with the earlier appearance of sexual maturation and jump in growth in males. Differences are very considerable in old adults in the summer, and the liver is far heavier in females than in males.

The relative liver weight varies within wide limits. The coefficient of variation is particularly high in the spring and in the summer in sexually active old adults. The seasonal variation in relative weight of the liver is interesting when compared with other organs (Fig. 6). After leaving the nest the liver weight in the youngest animals, in June, has not, yet attained its greatest values. From June to September there is an increase in the liver index of 15.4%, which in even more distinct than in the case of the absolute value. The autumn-winter decrease in the relative weight of the liver begins from the above period. This process undergoes a certain degree of inhibition during the winter (January—February), but in the spring becomes even more intensive. The minimum value of the liver

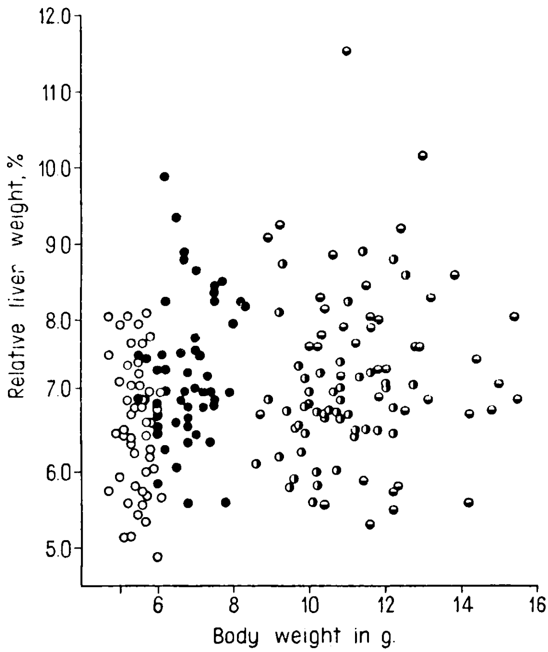

Fig. 7. Relation of relative liver weight to body weight (Explanation as for Fig. 3).

index is reached in April, when it is 18.6% smaller than the summer maximum for young shrews (Table 9). This is a period of relatively intensive physiological functions in the organism of the shrews, due to sudden growth of the whole body, the oestrus, pregnancy expressed, *inter alia,* in increase in metabolism to a level almost equal to that peculiar to young animals (cf. G ę b c z y ń s k i, 1965). In May, when the phase of most intensive growth in shrews is completed, the relative liver weight begins to rise and to a certain extent is stabilized during the summer (June—August). During this period the index of this organ does not, however, attain the level proper to young shrews from the summer. It is not until the period from August to September that there is continued increase in the weight of the liver. In the autumn this leads to an increase of 41% in the index in the case of old adults, in relation to its value in April. It must be added that the absolute weight of the liver increases during this time, whereas the body weight as a whole decreases. Increase in the liver before the shrews' death may therefore be explained to a certain extent by the disproportional changes in the weights of the organ and body, and by the accumulation of reserve substances with simultaneous reduction in their utilisation. The metabolism of old adult shrews from the summer (July) and undoubtedly also in later months attains its minimum values (G ę b-c z y ń s k i, *l. c.*).

The relative weight of the liver does not exhibit significant connections with the weight of the body within the seasonal groups distinguished, with the assumed probability of $P = 0.05\%$ (Table 11 and Fig. 7). Within a larger group of young shrews, however, caught from June to September inclusively, a fairly distinct connection can be observed between the relative liver weight and the body weight. With transition from the lowest to highest classes of body weight the liver index increases, although to a far smaller degree than, for instance, in the brain index (Table 14). This connection is evident in both males and females, but only in the young adult shrews. The mean values given for the different classes of body weight of old adults do not exhibit any regularity (Table 14).

Individual variation of the liver index, expressed by the coefficient of variation are relatively great, particularly in old adults in the spring (Table 3).

4. Kidneys

The weight of the kidneys is held to be a good indicator of metabolic changes in the organism (S c h w a r z, 1960), sensitive to changes in habitat factors causing increase or decrease in the fundamental physiological processes in the organism. This is probably the reason why the variation in weight of the kidneys in our material is relatively great particularly in the summer, both in young adults and old adults (Table 4), especially in the case of the relative weight of these organs.

The absolute weight of the kidneys exhibits distinct seasonal changes similar in character to the fluctuations in liver weight and in body weight

Table 4.
Variation of absolute and relative kidney weights in different seasonal and age groups.

Season & Age		Summer Young adult /VI - VIII/ n = 140	Winter Young adult /XII - II/ n = 89	Summer Old adult /VI - VIII/ n = 120
Absolute wt., in g.	O.R. $\overline{X}$	0.100 - 0.209 0.142	0.090 - 0.149 0.115	0.149 - 0.259 0.196
Relative wt., in %	O.R. $\overline{X} \pm S_{\overline{x}}$ S.D. V	1.49 - 2.92 2.09 ± 0.0361 0.2178 10.42	1.67 - 2.38 2.08 ± 0.0295 0.1400 6.73	1.13 - 2.65 1.80 ± 0.0451 0.2138 11.88

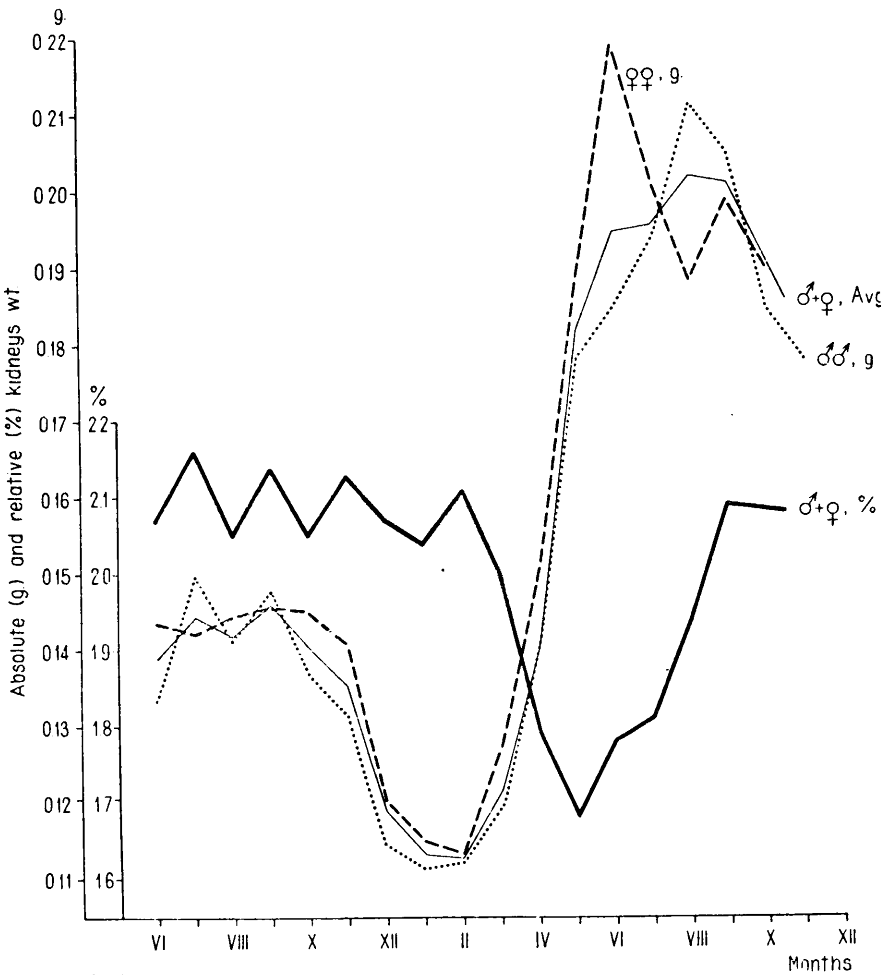

Fig. 8. Variation in absolute and relative weight of both kidneys over the life cycle of *S. araneus*.

(Fig. 8). In young shrews a slight increase can be observed in the weight of the kidneys, during the summer and lasting until September inclusively. From October to February the kidneys rapidly decrease in weight and attain the minimum mean value of weight. The difference between the mean values for both sexes during the periods from June—September and December—February is 18.6%. The spring jump in weight increase of the kidneys causes the maximum dimensions of these organs to be attained by old adult shrews from the summer (June—August). This organ is then almost 70% heavier than the winter values and 38.2% heavier in comparison with the young individuals from the corresponding period (cf. Fig. 8 and Table 4). In the autumn a repeat decrease in the size of the kidneys is observed in old adults at about the same time as in the young adults, i.e. in October. Unfortunately it was impossible to trace this process further on account of the lack of old adults from the late autumn.

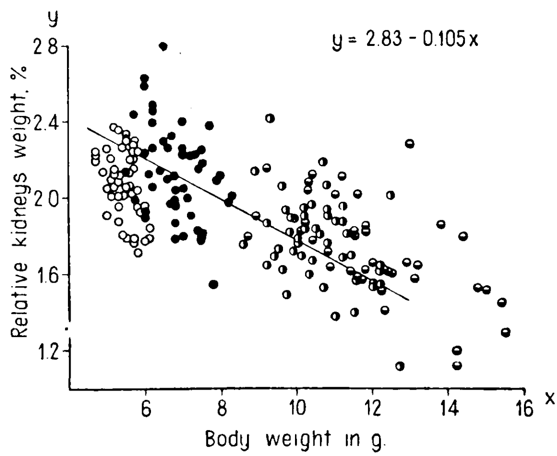

Fig. 9. Correlation of relative kidney weight and body weight (Explanation as for Fig. 3).

Sex dimorphism is faintly marked in the absolute weight of the kidneys. In the majority of cases, however, the monthly means are higher for females than for males, although the body weights, particularly during the spring, exhibit a reverse connection (cf. Fig. 1). From table 14 in can be seen that in the case of young adult shrews there are no differences in the relative weight of the kidneys of males and females of the same weight class. Differences in the monthly means of weight of the kidneys may therefore be explained by the slight differences in the body weight of young shrews. Sex dimorphism is distinct in old adults, and as in the case of body weight is expressed by the heavier weight of the kidneys in females. These relations are, however, reversed in August and September (Fig. 8).

The relative weight of kidneys in young shrews from the time they leave the nest up to February inclusively does not exhibit any particular trend in changes. We are not as yet in a position to give the reasons for the fluctuations in the mean values of this index from month to month, which in fact vary within limits of 0.12% only (from 2.04—2.16%). In the spring, from March to May, the kidney index decreases sharply by 19.2% in comparison with the values for the winter months (Table 4, Fig. 8). From June until the autumn this index increases in old adults and in final phase of the shrews' life is the same as it is in young adults in the summer and autumn (Fig. 8).

The correlation between the relative kidney weight and the body weight is fairly distinct in young adult individuals. The kidney index decreases together with an increase in body weight (Fig. 9, Table 14). Correlation between these two characters is, however, smaller than in the case of the weight of the brain and is relatively highest in the group of winter shrews ($r = -0.409$) — table 11.

In order to check whether the connections between the relative weigth of the kidneys and body weight differ in the various age groups calculation was made of the regression coefficients for each of the groups separately, and their variances analysed. The folowing regression coefficients obtained:

Age group, period	n	b	F
Young adults, summer	50	—0.159	8.51
Young adults, winter	50	—0.203	8.04
Old adults, males, summer	50	—0.069	5.43,

were statistically significant in all cases, since the values of test F for their significance are higher than the critical value $F_{0.05} = 4.04$. Similarly the mean regression is significant ($F = 18.34$, $F_{0.05} = 3.92$).

Analysis of variance for regression gives a result of $F = 3.97$, which is statistically significant with a critical value $F_{0.05} = 3.07$. In this case, however, there is considerable lack of uniformity in the residual variances. It was therefore only possible to make the Duncan's multiple range test where variances were non-uniform. The results obtained for the respective comparisons are as follows:

Comparison	test	critical value
Young adults, summer — Young adults, winter	0.70	2.82
Young adults, summer — Old adults (♂♂), summer	2.04	2.82
Young adults, winter — Old adults (♂♂), summer	2.45	2.96.

In all cases the critical values are higher than the results of the test, and therefore the differences between the pairs of regression coefficients compared are not statistically significant. We therefore reach the conclusion than differences in the regression coefficients of relative kidney

Table 5.
Variation of absolute and relative spleen weights in different seasonal and age groups.

Season & Age		Summer Young adult /VI - VIII/ n = 142	Winter Young adult /XII - II/ n = 62	Summer Old adult /V - VII/ n = 93
Absolute wt., in g.	O.R. $\bar{X}$	0.035 - 0.164 0.087	0.008 - 0.048 0.018	0.047 - 0.199 0.120
Relative wt., in %	O.R. $\bar{X} \pm S_{\bar{x}}$ S.D. V	0.56 - 2.50 1.28 ± 0.0543 0.3300 25.78	0.11 - 0.85 0.34 ± 0.0409 0.1609 47.32	0.41 - 2.20 1.12 ± 0.0712 0.3467 30.96

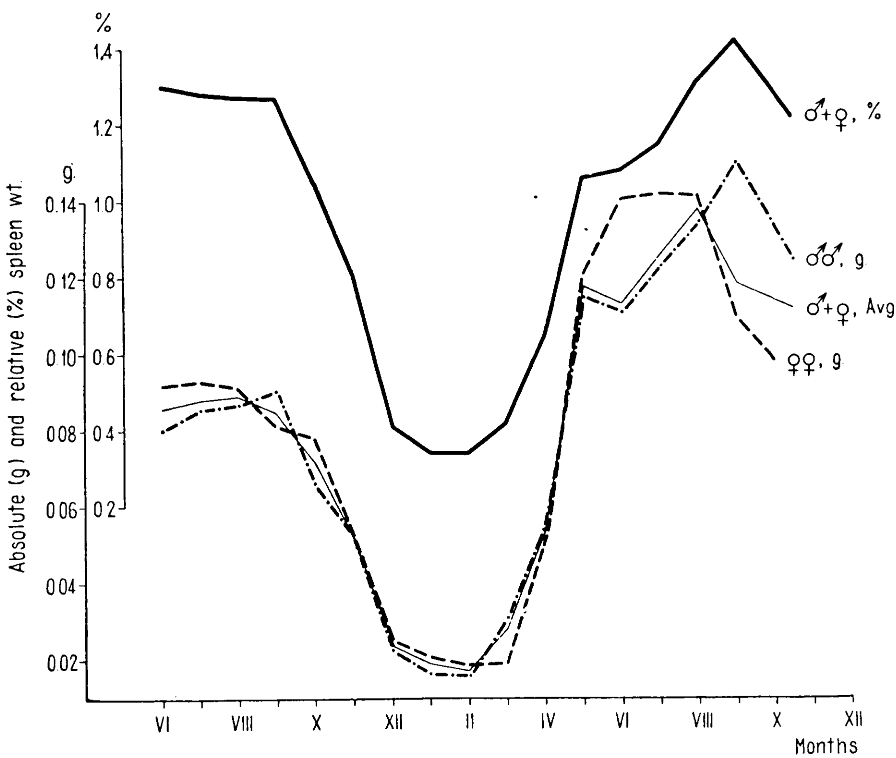

Fig. 10. Seasonal and age changes in spleen weight in *S. araneus* (absolute and relative values).

weight and body weight cannot be considered as significant in any of the seasonal-age groups.

5. Spleen

The spleen is an organ generally exhibiting very great individual variability in size and weight, resulting from its function. This has been emphasised by many authors (Rensch, 1948; Webster & Liliengreen, 1949; Lidicker & Davis, 1955; Hèroux & Gridgeman, 1958; Seeliger, 1960; Fateev, 1962), who found that the coefficients of variation of weight of the spleen were highest in comparison with corresponding values for other organs.

In our material the weight of the spleen was subject to particularly considerable variation, both individual and seasonal (Table 5, Fig. 10, 11). High coefficients of variation are noted, particularly in young adults in the winter ($V = 47.3\%$). In young adults and old adults from the summer period these coefficients are far lower, being respectively 25.8 and 31 %.

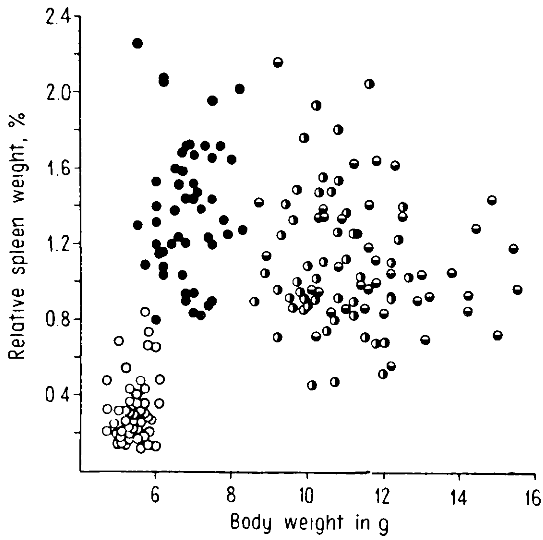

Fig. 11. Relation of relative spleen weight to body weight (Explanation as for Fig. 3).

Fig. 10 illustrates the course taken by variation in the absolute weight of the spleen in males and females and for both sexes jointly. It may be said that during the period of sudden sharp changes, both in the autumn and spring, there are almost no differences between the weight of the spleen in males and females. At the beginning of spring (March) in the first phase of the jump in growth, the increase in the spleen in males only slightly exceeds that in females. Greater dimorphic differences are evident in old adults, the spleen being haevier in females from May to September, and in males at a later period.

Seasonal changes are expresed by a decrease in the weight of the spleen of 77.0 %, taking place mainly during the period from October to December. This difference is of course slightly lowered by the mean values for the periods June—August and December—February, and not extreme monthly means, being taken for comparisons. In comparison with the winter the weight of the spleen in old adults from June—July—August increases absolutely by 495 % (i.e. from 0.021 g to 0.1196 g). In the autumn, beginning with September—October, the reverse process can be seen in old adults, i.e. a decrease in weight of the spleen.

The relative weight of the spleen exhibits seasonal variations which take an almost identical course, as in the case of absolute spleen weight. The mean values from the summer are almost the same for young and for old shrews. When the course taken by the curve of variations of this index is examined more closely (Fig. 10) we find that in the young adults from summer the relative spleen weight is maintained for several months (June—September) at a more or less constant level (1.29 %). During the autumn there is a sharp decrease (of 73.6 %) to a value of 0.34 % in the middle of the winter (January—February). In the spring there is an increase in the spleen index which is 229.4 % higher during June—August period than in winter. This increase continues until September, when the mean values of the relative spleen weight are highest (1.42 %, $n = 31$), 317.6 % higher than for the winter period (cf. data in tables 5 and 9).

No distinct correlation was found in shrews between the relative spleen weight and the body weight, even within each of the seasonal-age groups distinguished (Fig. 11, Table 11, 14). Similar data for other mammals were also obtained by Rensch (1948), Frick (1957), Seeliger (1960) and others.

6. Brown adipose tissue (*BAT*)

Brown adipose tissue that is the so-called "hibernation gland" of shrews, formed the object of investigations by Buchalczyk & Korybska (1964). These authors had at their disposal material fixed in alcohol and made an analysis of seasonal variation and fluctuations in the weight of this organ in different years. The general character of seasonal variations demonstrated for fresh organs is in general in agreement with the report mentioned above. In view of the fact, however, that the biochemical composition of the organ may differ in different seasons, the differences between the various points of the curve of variations in weight of *BAT* before and after fixation are not uniform. This is obvious from the data given in table 13. For this reason it would appear useful to trace the real variations in *BAT* based on the weights of fresh tissue.

Variations in *BAT* over the life cycle of shrews in absolute values are given in Fig. 12. The maximum values of the weight of this glands in young shrews are attained immediately after leaving the nest. This is later

Table 6.
Variation of absolute and relative weights of brown adipose tissue (BAT) depending on season and age.

Season & Age		Summer Young adult /VI/ n = 59	Autumn Young adult /IX - X/ n = 98	Winter Young adult /XII - II/ n = 90	Summer Old adult /V - VII/ n = 103
Absolute wt., in g.	O.R. $\bar{X}$	0.040 - 0.170 0.087	0.030 - 0.130 0.067	0.020 - 0.100* 0.066*	0.040 - 0.200 0.103
Relative wt., in %	O.R. $\bar{X} \pm S_{\bar{X}}$ S.D. V	0.56 - 2.35 1.32 ± 0.1149 0.4414 33.44	0.41 - 1.90 0.98 ± 0.0497 0.2486 25.37	0.56 - 2.20 1.26 ± 0.0629 0.3013 23.91	0.26 - 2.20 0.95 ± 0.0604 0.3094 32.57

*) Only material from January and February.

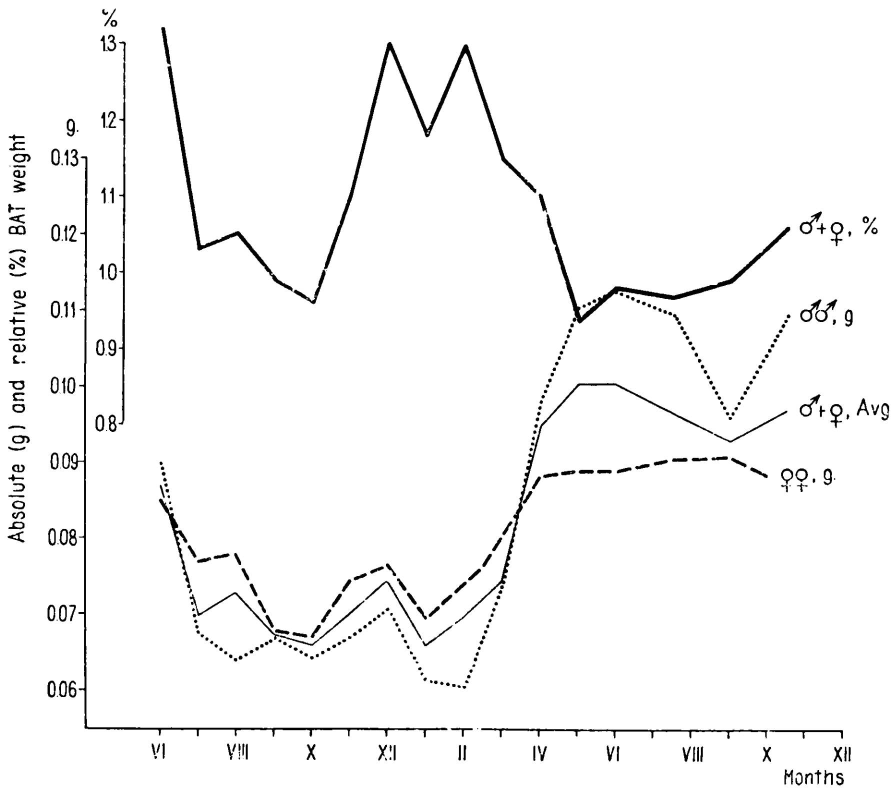

Fig. 12. Seasonal and age changes in brown adipose tissue (absolute and relative values) in *S. araneus*.

followed by a decrease taking place up to July inclusively, which causes reduction of this organ by 23.6 % to an autumn minimum in September-

-October. As was the case with fixed material, *BAT* increases up to December inclusively. The later decrease in the weight of this gland is visible in both males and females. The spring increase in *BAT* is expressed by a weight increase of 54.6% (difference between means from January—February and June—August). In the case of males the differences during this period are 84.2% and in females only 21.9%. In the second half of the summer a slow decrease in the *BAT* weight can be observed in males, while values remain more or less constant in females.

As can be seen from the above summary, sex differences in the weight of *BAT* are sharply defined and according to the investigations made by Buchalczyk & Korybska (1964) are statistically significant. In young shrews *BAT* is heavier in females, particularly during the summer and winter, and in old adults the reverse is the case. Differences are absent only immediately after the animals leave the nest in June and during the autumn minimum.

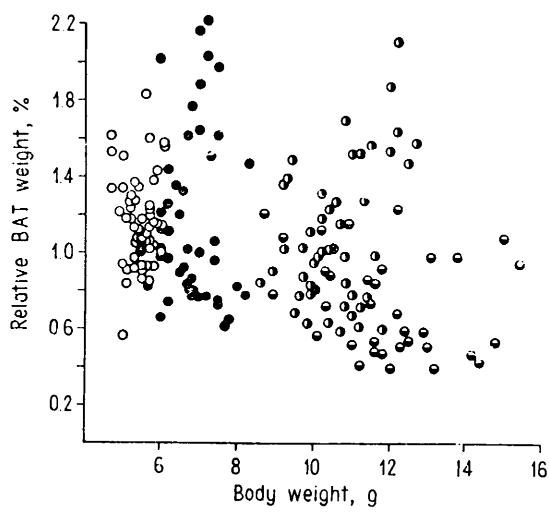

Fig. 13. Relation of relative *BAT* weight to body weight (Explanation as for Fig. 3).

The relative weight of *BAT*, expressed in percentages of body weight in young shrews decreases from June to September—October (chiefly, however, during July) by 25.8%. During the period December—February there is an increase in the *BAT* index to almost the same value as in the young June shrews. As was found in the fixed material, there is a slight decrease in January in the mean values of the index. In this case therefore fixed material faithfully reflects the character of the changes in weight of the organ.

In spring, together with growth of the whole body, the relative weight of BAT decreases. The lowest values are obtained in old adults in the middle of the summer (May—July), when the mean values differ by 24.6% from the winter ones. There is a repeat increase in the relative weight of *BAT* in the autumn. These changes take place slightly differently from those observed in the fixed material (Fig. 12).

Correlation of the absolute and relative weight of *BAT* with the body weight are in general slight (Tables 10 and 11, Fig. 13). In the diagram refered to greater connections are observed only in one group, the old adults ($r = 0.44$). The various seasonal groups are in addition distinctly separate, and variations in the *BAT* index are very considerable depending on body weight. This is particularly clearly evident in the case of young shrews from the summer, and would seem to point to the higher rate of variations in *BAT* during the period of its involution.

Changes in the relative and absolute weight of the hibernation gland in shrews may be explained, at least to a certain extent, by the increased or decreased accumulation of reserve substances at periods important to the development of these animals. The young shrews leave the nest with large hibernation glands but during the first difficult period of adaptation to independent life in the open the weight of *BAT* declines sharply, both in its absolute and relative values. It is not only the arrangement of mean values which indicates this (Fig. 12) but also the distribution of numbers in different classes of variations. From June to September, that is, throughout the whole period of entry of young individuals into the population we find a certain number of animals in the material in which the weight of *BAT* exceeds 0.1 g. No such animals occur during the later period up to and including March. The lower limit of the weight of *BAT* in different months of the summer and autumn is more constant (0.03—0.04 g). The increase in the relative *BAT* weight during the winter takes place primarily as the result of the considerable decrease in body weight as a whole. The absolute weights of this organ (Fig. 12) are not subject to any great changes during this period. In the spring *BAT* increases in weight similarly to other organs, but not as intensively as the increase in body weight, hence the relative values of the weight of this organ decrease.

7. Thymus gland

Variations in the size of the thymus have been analysed by several authors in different species of shrews (Bazan, 1952; 1956; Schwarz, 1959a; Pucek, 1960). All the above authors unanimously state that this organ undergoes complete involution in the autumn of the first year, and therefore at least six months before sexual maturity is attained. Using *Neomys fodiens* (Pennant, 1771), *Sorex arcticus* Kerr, 1792 and *Sorex araneus* Linnaeus, 1758, all of which mature in the first year

Table 7.

Involution and variation of weight of thymus.
Comparison of data for the fresh gland and gland prepared from specimens previously fixed in alcohol. *) Data after B a z a n, 1952).

Month	Fresh gland						Fixed gland, mg.*		Diff. between columns 4 & 9, %
	N	Absolute weight, mg.				Relative wt.			
		Min.- Max.	Avg.	S.D.	V	‰	N	Avg.	
1	2	3	4	5	6	7	8	9	10
VI	66	20 - 87	47.6	15.1	31.72	6.91	39	26.8	43.6
VII	31	15 - 68	45.1	15.2	33.63	7.13	23	21.0	56.0
VIII	37	4 - 66	34.4	12.0	35.00	4.70	32	18.0	47.7
IX	57	2 - 63	14.3	9.2	64.09	2.04	20	8.6	40.0
X	11	5 - 26	13.7	6.2	45.35	1.97	7	8.4	38.7
XI	4	3 - 9	6.5	5.1	79.94	1.02			

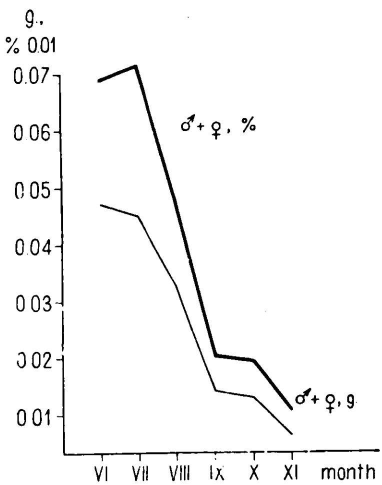

Fig. 14. Involution of thymus. The figure illustrates mean monthly values of absolute and relative weight of gland.

of life, as examples, it was shown that the process of involution of the thymus is independent of sexual maturation (cf. the studies referred to above).

The data obtained in the present investigations make it fully possible to confirm the observations of the above authors as to the time of involution of the thymus. The data given in table 7 and fig. 14 also permit of expressing these changes in absolute and relative values and of comparing them with the weight of the gland after fixing.

As can be seen involution of the thymus is very rapid in *S. araneus*, particularly from the time at which the entry of young shrews decreases, that is, in September and October. By November this organ has reached rudimentary size so that no weighings were made in the following months on account of its small dimensions. It is worthy of emphasis that considerable individual variations were observed in the weight of the thymus in different months of summer and autumn. Reduction of mean values took place not so much as the result of the shift in the lower limit of variation, which is stabilized as from August, as from the absence in the population of individuals with very large thymus glands (Table 7).

Reduction of the relative weight of the thymus (Table 7, Fig. 14) takes place independently of any possible changes in body weight. Increase in body weight during this period causes only more intensive reduction of the relative thymus weight. It can be seen from table 14 that there is no kind of regularity between the relative thymus weight and body weight.

It is an interesting fact that in the case of the thymus also we find considerable differences between the mean values obtained for fresh and fixed material. These differences are not uniform and vary in different months from 39 to 57%.

It appears from the data given here and also from earlier studies that the process of involution of the thymus in shrews is an irreversible one. During the spring growth period this organ is not regenerated. The situation here therefore differs from that in rodents, in which involution and regeneration of the thymus is connected with the inhibition or acceleration of rate of growth and with the biological age of the given generation (Schwarz *et al.*, 1964). These observations cannot therefore be generalized for all mammals.

8. Adreal glands

The weight of the adrenal glands has been treated by many authors as an index of the function of this organ (Christian, 1960; 1962; 1963; Chitty, 1961; McKeever, 1959; Schwarz, 1963; 1964). Consideration has also been given to differences between the right and the left adrenal, seasonal, and age differences and differences depending on habitat and population conditions (Bachmann, 1954; Jones, 1957; Christian, 1963). The adrenal glands of shrews have only partially been studied in *Sorex arcticus* Kerr, 1792 (Schwarz, 1959). More exhaustive data are to be found in the study by Siuda (1964), which is primarily concerned with histological changes and includes measurements of the cortex of the adrenals in *Sorex araneus* L.

Changes in the absolute and relative weight of the adrenals in both sexes over the full life cycle are shown in Fig. 15, which shows that from many aspects these glands behave differently in the shrew from the changes observed in other mammals, particulary in rodents. In the initial stage of the life cycle there is a slight increase in the absolute weight of the adrenals in young shrews, up to August—September inclusively. As from October there is a decided and rapid decrease in the weight of these organs. No increase in the adrenal weight is observed during the period of the animals adaptation to winter cold, which has been emphasised in

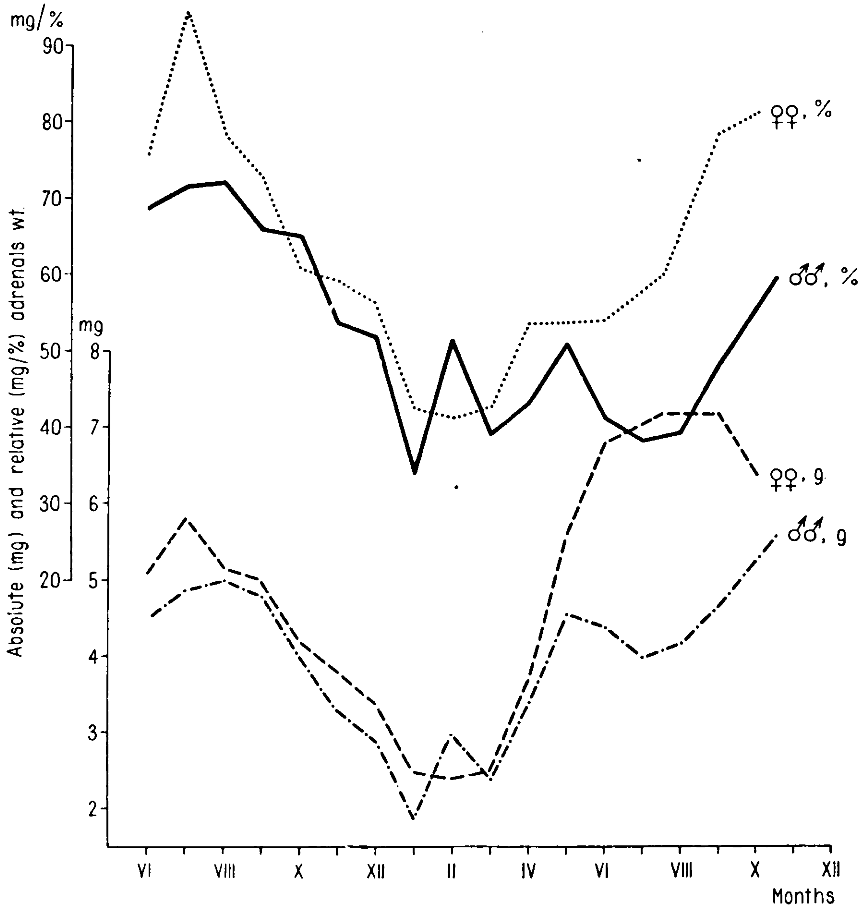

Fig. 15. Changes in relative and absolute adrenal weight over the shrews' life cycle, depending on sex.

rodents, by, for instance, Sellers *et al.* (1951), Schwarz (1959c); Schwarz & Smirnoff (1960); Ovčinnikova (1962). The shrews caught during the winter have attained the minimum adrenal weight. In January and February these glands are 52% lighter than those of animals caught in the summer (June—August) (Fig. 15, Table 8). The rapid spring growth of shrews also affects the adrenal glands, but considerable differences are observed here which make it essential to consider changes in adrenal weight separately for each sex. Judging by diagram (Fig. 15) and table 8, it may be generally stated that the adrenal glands of females are heavier than those of males. This difference is evident in all the months of the life cycle with the exception of February, when the reverse conditions may be due to the small number of specimens examined ($n = 13$ ♂♂ and 13 ♀♀). In old adults, however, the differences in adrenal weight of males

Table 8.

Variance of absolute and relative adrenal weigts depending on sex, age and season.

Season and Age			Summer Young adult / VI - VIII / n = 69♂, 48♀	Winter Young adult / I - III / n = 39♂, 33♀	Summer Old adult / VI - VIII / n = 69♂, 27♀	Autumn Old adult / IX - XI / n = 21♂, 25♀
Males	Absolute wt., in mg.	O.R. $\bar{X}$	2.80 - 8.50 4.74	0.90 - 5.80 2.38	1.40 - 7.60 4.27	-
	Relative wt., mg. 100/g.	O.R. $\bar{X} \pm S_{\bar{x}}$ S.D. V	47.8 - 121.5 70.3 ± 3.797 15.771 22.43	14.0 - 92.7 41.4 ± 6.577 20.325 49.14	10.0 - 67.0 40.5 ± 2.725 11.3165 27.97	31.6 - 74.1 51.6 ± 5.801 12.780 24.76
Females	Absolute wt., in mg.	O.R. $\bar{X}$	2.30 - 8.50 5.23	1.00 - 6.70 2.46	2.30 - 9.40 6.95	-
	Relative wt., mg. 100/g.	O.R. $\bar{X} \pm S_{\bar{x}}$ S.D. V	46.8 - 122.5 79.8 ± 5.438 18.643 23.38	12.6 - 87.4* 42.2 ± 7.760 21.8324 51.71	23.7 - 98.0 57.2 ± 6.956 17.614 30.81	23.4 - 98.0 79.8 ± 8.988 21.8166 27.36

*) Only shrews caught in January and February.

and females increased markedly. Thus in females the weight of the adrenals continued to increase uninterruptedly until July—September, then attained values 182.5% higher in comparison with the winter period (January—February). In males, on the other hand, there is a decrease in the weight of these organs in June and July. During the period July—August the weight of the adrenals in old adult females is 77.3% higher than in males. Corresponding differences in young shrews during this period are only 10.3%. In the autumn the weight of the adrenals in old adult males rises (by 21.7% in comparison with July), while in females it distinctly decreases from October onwards.

The relative weight of the adrenals expressed in mg. 100/g of body weight varies over the life cycle of the shrews in a very similar way to the absolute weight. The maximum values are found in young shrews in the summer. After a slight increase from June to July the adrenal index falls sharply and reaches a minimum in males in January and in females in February. It is then lower than the July values by respectively 52% (♂♂) and 55% (♀♀). In the winter the relative weight of the adrenals is in principle equalized. In the case of males, however, a slight increase in the mean values of the index is observed in February, as it is with the absolute weight, but in March these values return to the January level. I should not consider these differences as significant since the number of animals obtained in these months was relatively small.

In old adult females a progressive increase in the relative adrenal weight is observed, its mean values being maintained on a uniform level from April to June (Fig. 15). In males, on the other hand, as in the case of the absolute values, the adrenal index decreases during the period June—August. In the autumn, however, the curves for the two sexes exhibit parallel progression, which leads to attaining similar values to those in young animals. In this case the adrenals in shrews behave in a similar way to that observed by McKeever (1959) in *Microtus montanus* (Peale, 1848), in which the relative weight of these organs increased on cessation of the reproductive functions.

The relative adrenal weight in our material does not exhibit distinct connection with the gross body weight (Table 14), particularly in relation to old adults. In young males from the summer with body weight up to 7.5 g, the relative weight of the adrenals is maintained plus minus on a constant level, of about 70 mm%. The weight of the adrenals is greater in females (about 80 mg%) and does not alter in the classes of body weight of 5.0—7.0 g. In higher divisions of weight (7.5—9.0 g) reduction in the weight of the adrenals is observed both in males and in females (Table 14).

Variation in the adrenal weight is more or less as great as in the spleen, especially during the winter period, with narrow limits of variation in body weight. Coefficients of variation for the winter specimens are almost twice as high as in the summer, being about 50% (Table 8).

9. Gonads

The question of weight of the gonads has two aspects: 1) it is directly connected with maturation and sexual activity, 2) the connections between hormonal functions of the gonads in the whole endocrine system, and also with other internal organs, are important. In both cases the weight of the gonads is usually treated as an index of their function.

Sexual maturation in the shrew has been fairly comprehensively explained in many studies (Brambell, 1936; Wolska, 1953; Dunajeva, 1955; Tarkowski, ;1957; Pucek, 1960; Stein, 1961; Schwarz, 1962) and in itself deos not constitute the subject of these reasonings. It would, however, appear useful to present the variations in

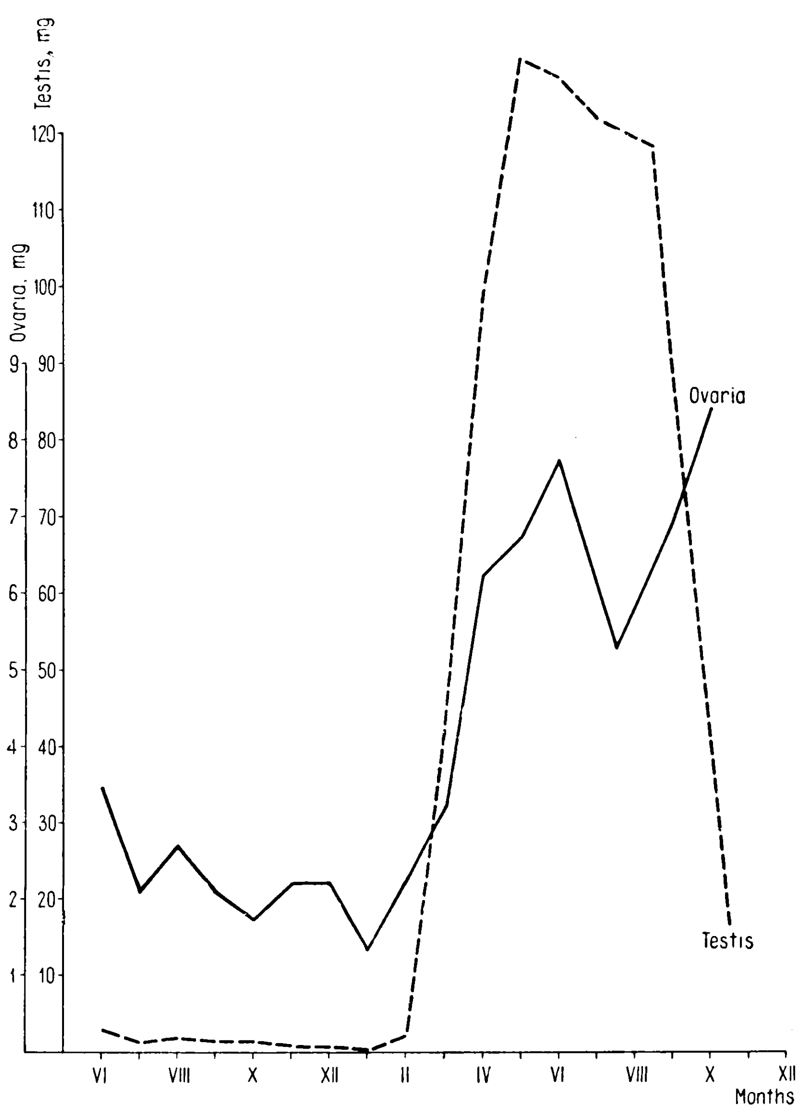

Fig. 16. Changes in mean weight of ovaries and testes over the shrews' life cycle.

weight of the gonads in this second aspect, as an indicator of the hormonal activity of these organs. The curves given (Fig. 16) illustrate the fluctuations in the monthly arithmetical means of the weight of one testis and both ovaries.

M a l e s. The weight of the testes in young males is highest in June (3 mg) and decreases gradually to a value six times smaller up to January, reaching 0.5 mg. During the last ten days of February a slight progression of the testes is observed (mean value for this period = 2.5 mg), followed by a sharp jump in March and April. Maximum dimensions are attained in May (130 mg). In the following months of the summer the gonads of old adult males gradually decrease but dimensions are still fairly large (119 mg) during the period August—September. More rapid regression of the testes takes place in October and November.

Females. The maximum weight of ovaries in young females is observed immediately after the animals leave the nest, in June (3.5 mg). In the following months up to January inclusively a decrease is observed in the weight of the ovaries to mean values of 1.5 mg. Increase in the gonads weight of females in the spring takes place slightly later than in males. The maximum size of the ovaries is also attained a month later than that of the testes, that is, in June. During this period the majority (almost 100%) of all females are sexually active (pregnant or nursing). The break in the curve of variation during the period July—August (Fig. 16) is probably connected with the gradual decrease in the number of pregnant and nursing females in the second half of summer (Tarkowski, 1957). Complete regression of the female gonads most probably does not take place until November—December. In the autumn the mean monthly values of the weight of the ovaries are still high. Here also a certain shift in time in relation to males can be observed.

In the material examined relatively high weights of the gonads of both sexes can be observed immediately after the animals leave the nest, that is, in the youngest animals. This phenomenon is more intensively expressed in females than in males. These data are in complete agreement with the results obtained earlier on, when it was suggested that progressive changes of this kind may lead in some years to attainment of sexual maturity by the young shrews in the year of their birth (Pucek, 1960). The hormonal activity of the gonads during this period may be of greater significance only when a considerable percentage of the young animals attain full sexual maturity. This phenomenon, however, occurs somewhat sporadically and is never of a mass character (Pucek, 1960; Stein, 1961).

V. GENERAL DESCRIPTION OF VARIATION AND CHANGES IN CORRELATIONS BETWEEN INTERNAL ORGANS

The detailed results presented above can be put in more synthetic form. With this aim in view diagrams were drown up making comparison possible of the course taken by the curves of variations of absolute (Fig. 17) and relative (Fig. 18) monthly means of the weight of different organs.

The majority of organs examined here (liver, kidneys, spleen, adrenals) exhibit similar changes and in young shrews during the period from June to August—September reveal slight increases only in aboslute weight (Fig. 17). Later a rapid decrease in the weight of these organs, lasting up

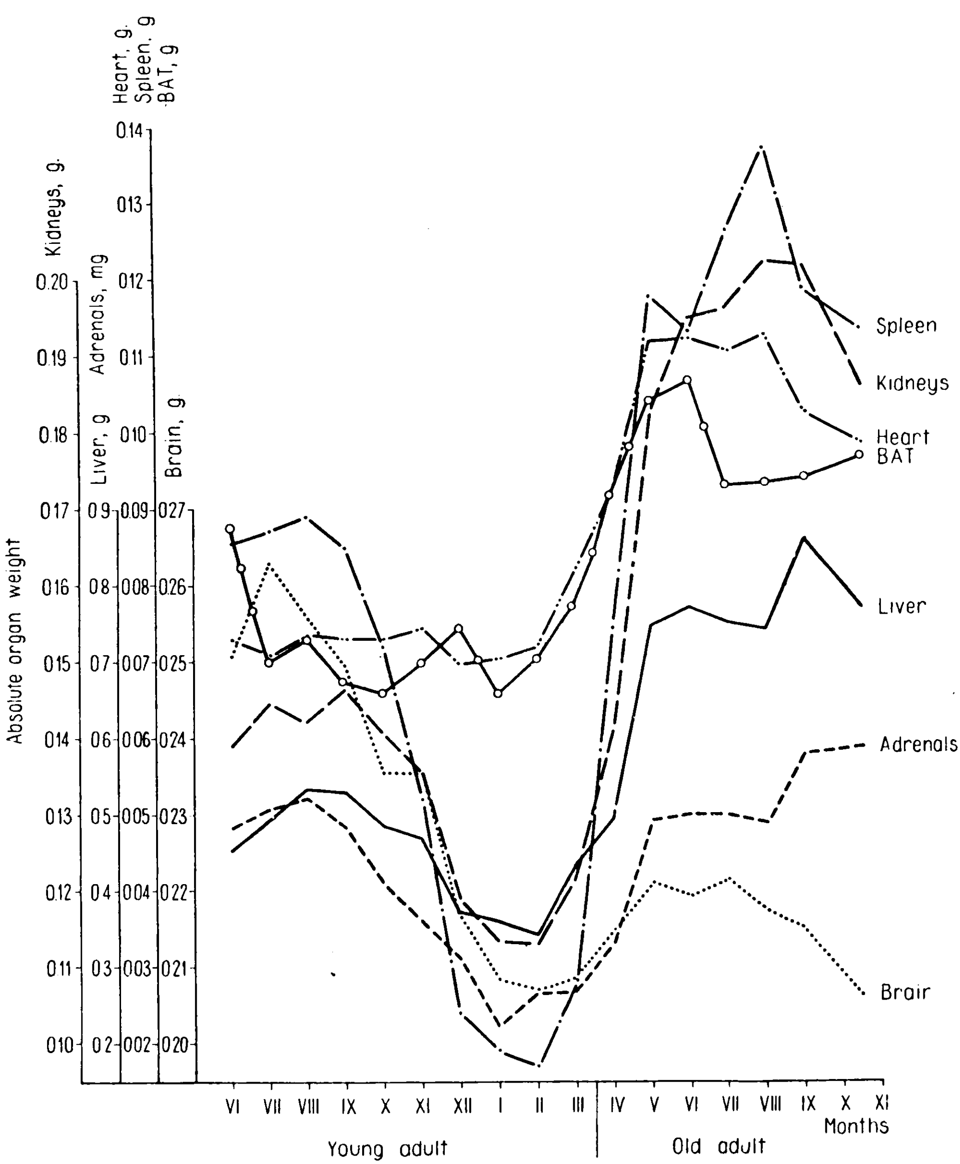

Fig. 17. Comparison of seasonal and age changes in absolute weights of different internal organs in *S. araneus*.

to the winter (January—February) can be observed. The other organs differ from this type. The brain increases only up to July, and as from August onwards exhibits distinct regression. *BAT* and the thymus involute from July onwards, while the heart does not undergo any changes until the winter. The spring growth includes all organs except the

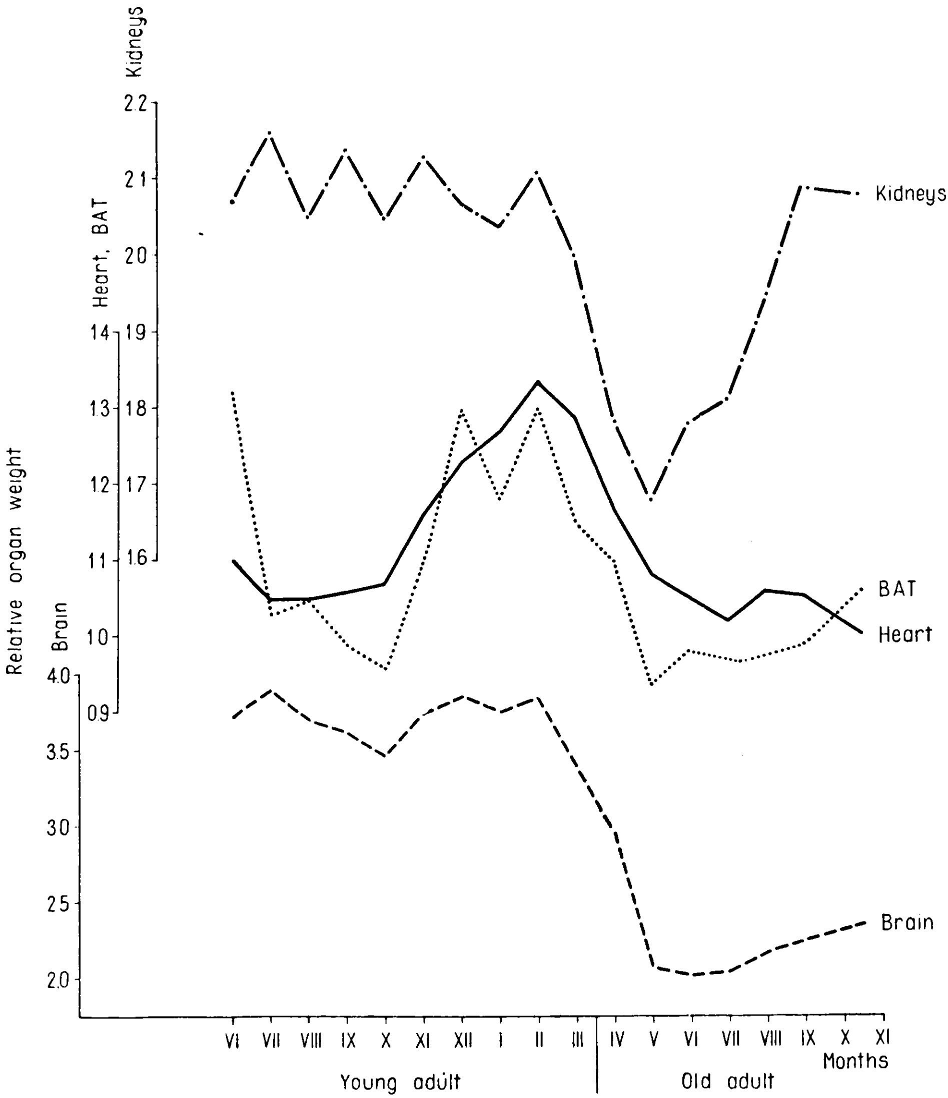

Fig. 18. Comparison of seasonal and age changes in indices of some internal organs in *S. araneus*.

thymus, which is not regenerated. The degree to which the various organs are subject to the spring jump in growth differs, however, the spleen and liver increasing very considerably (495 and 122.8%), the kidneys (69.8%), the heart (59%) and *BAT* (30%) to a lesser degree. The adrenal glands attain more or less the same level as in young shrews (females) or are lighter (males). Finally the brain in old adults is approximately 16% lighter than in young individuals.

Differences in the course taken by changes in the relative values of the weight of internal organs in shrews are considerable (Fig. 18, Table 9). The heart loses in relative weight during the period when the body weight increases in the summer, but this loss is far greater in the case of *BAT*. Both these organs increase their relative dimensions in the winter, to return in the spring to the same proportions as in young shrews. The brain and kidneys in young shrews do not exhibit any considerable changes in weight over the whole period of summer and winter, while their relative weight decidedly decreases in the spring. In old adults from the summer

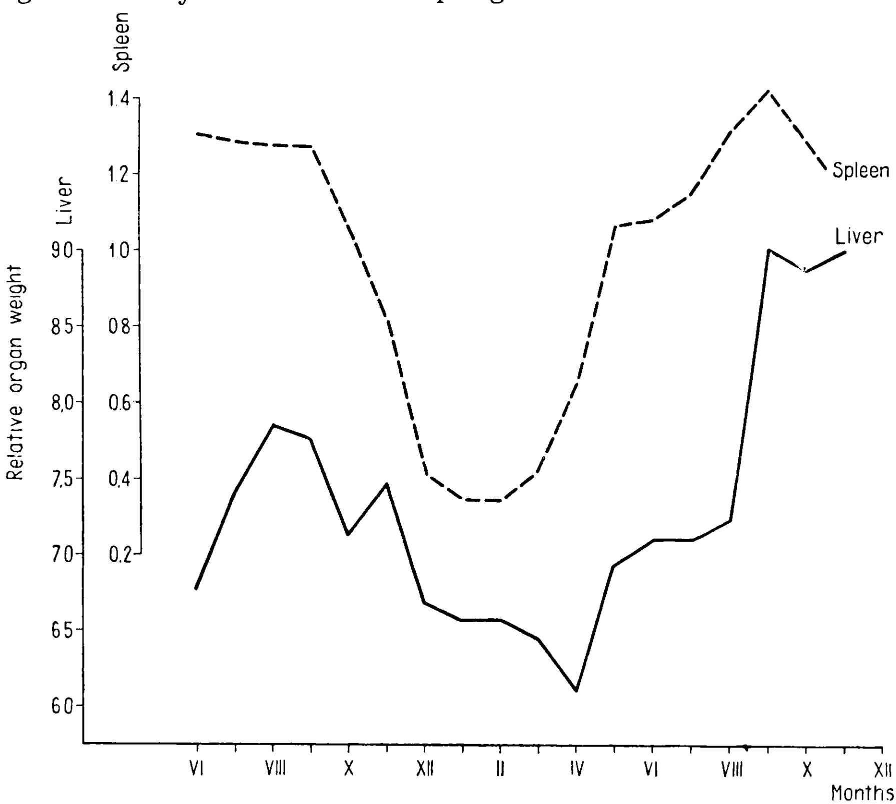

Fig. 18. Explanation on p. 402.

and autumn the kidneys return to the same proportions as in young animals, while the brain remains proportionately smaller although the mean values of this index increase slightly in the autumn. Despite many differences the character of variations in indices of the liver, spleen and adrenals is fairly similar over the shrews' life cycle. The relative weight of the spleen and adrenals decreases in the winter and attains the same values in old adults from the spring and summer as those in young shrews.

Comparison of seasonal variations in the weight of internal organs and of body weight (Fig. 1) shows that the internal organs of shrews are subject to different changes from those of body weight. In the case of the spleen, adrenals and liver the winter depression is more intensively evident than in the body weight as a whole (respective decreases in weight of 77, 52 and 34%). The depression in the absolute weight of the brain, kidneys and hibernation gland (*BAT*) is more or less of the same order as that of the body weight — 20—33%. Differences of the same kind are manifested

Table 9.

Comparison of differences (in %) in relative weight of some internal organs, between the basic points of their curves of variation over the shrews' life-span.

Difference between :	Brain	Heart	Liver	Kidneys	Spleen	BAT	Adrenals ♂♂	Adrenals ♀♀
Summer, YA → Winter, YA	+ 0.11	+18.5	-	- 0.5	-73.4[2]	- 4.5[3]	-41.1[5]	-47.1[5]
Winter, YA → Summer, OA	-46.4[1]	-17.2	-	-13.5	+229.4[2]	-24.6[1]	- 2.2[5]	+35.5[5]
Summer, YA → Summer, OA	-45.9[1]	- 1.8	-	-13.9	-12.5	-28.0[1,3]	-42.4	-28.3
Summer, YA /VI/ → Summer, YA /VIII IX/	-	-	+15.4	-	-	-25.8[4]	-	-
Summer, YA /VIII IX/ → Spring, OA /IV/	-	-	-18.6	-	-	-	-	-
Spring, OA /IV/ → Autumn, OA /IX - XI/	-	-	+41.0	-	-	-	-	-
Winter, YA /I - III/ → Autumn, OA /IX - XI/	-	-	-	-	-	-	+24.6	+89.1

Remarks: Summer = VI—VII, Winter = XII—II. In some cases other periods were compared. 1) Summer, YA, V—VII; 2) Winter, YA, I—II; 3) Summer, YA, VI; 4) Difference between June and Sept. — Oct.; 5) Winter, YA, Jan. — March; In all cases: YA — young adult, OA — old adult.

in the spring jump in growth. These data lead to the assumption that significant changes in the internal proportions of the body must take place during the shrews' life cycle.

The correlation coefficient of organ weight and body weight and of the various organs in relation to each other were taken as a measure of the internal proportions in the shrews' organism, and in particular as an indicator of changes in these proportions depending on age and the season. The value of these coefficients is simultaneously evidence of the strength of the connections existing between different organs.

In connection with the above 100 individuals ware taken from each seasonal-age group as defined in the section II. Calculation was made for these individuals only of 74 correlation coefficients for all possible combinations (Table 10). With the exception of a few cases the correlation coefficients within each of the groups are positive, but not very high,

Table 10.
Coefficients of correlation between absolute weight of internal organs and body weight, and of different organs with each other, in all possible combinations.

Correlation	Summer Young adult, ♂+♀ / VI - VIII / n = 100	Winter Young adult, ♂+♀ / XII - III / n = 100	Summer Old adult, ♂+♀ / VI - VIII / n = 100	Summer Old adult, ♂♂ / V - IX / n = 100
Body x Liver	.6956	.4363	.4614	.4368
Body x Kidneys	.5461	.2718	.3522	.2786
Body x Heart	.4634	.4500	.3387	.6265
Body x Spleen	.3885	.5291	.3125	.2344*
Body x BAT	.3140	.2752	.2382*	-
Body x Brain	.1406*	.0262*	.0780*	-
Liver x Kidneys	.5928	.4836	.5403	.4805
Liver x Heart	.4360	.2949	.2581	.3070
Liver x Spleen	.4962	.3181	.3804	.4564
Liver x BAT	.0616*	.2870	.2035*	-
Liver x Brain	.1358*	.1110*	- .0891*	-
Kidneys x Heart	.3102	.2928	.1534*	.2217*
Kidneys x Spleen	.5428	.2297	.2321*	.2939
Kidneys x BAT	- .1188*	.3294	.1048*	-
Kidneys x Brain	.1205*	.0000*	- .3042	-
Heart x Spleen	.3617	.3922	.0471*	.0896*
Heart x BAT	.3210	.2839	.5696	.6005
Heart x Brain	.2582	.0377*	.4775	-
Spleen x BAT	.0548*	.2863	.0239*	-
Spleen x Brain	.0171*	.1035*	- .1690*	-
BAT x Brain	.0332*	.0734*	.4282	-

*) Not significant. Remained correlations are significant at $P_{0.01}$ level.
Differences statistically significant in comparisons: Summer, YA — Winter, YA, Summer, YA — Summer, OA (♂♂ + ♀♀) and Summer, YA — Summer, OA (♂♂) are underlined.

Table 11.
Comparison of coefficients of correlation between relative weight of organs and body weight.
Coefficients statistically significant — underlined.

Age group	Brain / Body	Heart / Body	Kidneys / Body	Liver / Body	Spleen / Body	BAT / Body
VI - VII, Young ad.	- 0.625	- 0.515	- 0.387	0.045	0.166	0.153
I - II, Young ad.	- 0.688	- 0.146	- 0.409	- 0.176	0.058	- 0.023
VI - VII, Old ad.	- 0.730	- 0.346	- 0.317	0.252	- 0.034	0.444

usually not exceeding the value $r = 0.70$, and frequently coming within the interval up to 0.40. The greatest correlations in relation to body weight are attained by such organs as the liver, kidneys, heart and spleen. In the majority of cases the correlations of these organs with each other are statistically significant and come within limits of 0.26—0.59. In old adults, however, in the case of the heart and kidneys there are no significant relations between the weight of these organs, or the values of coefficient r are very low. The weight of the brain in young shrews from the summer and winter, with the exception of one case (heart — brain) does not exhibit any significant connections with either body weight or with other internal organs. In old adults the situation is similar, with the exception of the medium correlation of weight of brain with that of the heart, *BAT* and kidneys (respectively 0.48, 0.43 and —0.30). *BAT* in general exhibits a small correlation with other organs. Coefficient r does not exceed the value 0.33 and is non-significant in half of all the combinations. The situation is exceptional in the case of old adults, when the correlation between *BAT* and the heart weight is relatively high ($r = 0.57$). In this case, and also in certain others similar to it, it would be difficult to find any connection of a functional or causal character. It is more a case here of coincidence in time of growth or depression processes exhibiting the same tendency and the same rate of changes in a given stage of development of the shrews.

It is clear from the remarks made above and also from a further analysis of table 10 that there are differences in the degree of correlation of different internal organs in the shrew, depending on the age of the individuals. Comparison of correlation coefficients between young adults and old adults from the summer are particularly significant here. It can be seen that in the majority of the combinations the connections between such organs as liver, kidneys, heart, spleen are smaller in old adults than in young shrews. On one-third of all the cases low, but significant correlations in the case of young adult shrews become non-significant in relation to old adults. Correlation of the brain and *BAT* reversely are higher in old adults than in young shrews. Coefficients of correlation have been converted to value z and compared in pairs; young adults, summer — young adults, winter; young adults, summer — old adults (males), summer; and yound adults, summer — old adults (♂♂ + ♀♀), summer. Differences between correlation coefficients were found to be statistically significant only in certain comparisons. The respective pairs of such coefficients have been underlined in table 10. Passing over comparisons of significant and non-significant correlation we find that only the connection: body — liver, body — kidneys, kidneys — spleen, heart — *BAT* are significantly different in young and old adults.

Similar data were also obtained for the correlation of relative weight of organs with body weight (Table 11).

To sum up it may be said that both the proportions of different internal organs in relation to body weight and also the proportions between different organs change during the life cycle of the shrews. The changes observed are not only an age, but also of a seasonal character. In general higher correlations were found in young shrews, more in those caught during the summer months than during the winter. The reverse situations do, however, occur, when the correlations are higher in the winter material (body — spleen), or significant in relation to non-significant correlation in the summer (liver — *BAT*, spleen — *BAT*). Correlation coefficients during the winter are closer to those for old adults than for young shrews from the summer. Changes in correlation coefficients do not take a parallel course in all the combinations and in certain cases increase, and in others decrease, in old adults. This points to a change in internal proportions and the organisation of the shrews' bodies during their postnatal life. We consider these changes are the morphological reflection of the age and seasonal adaptation of shrews to a given level of their functional changes in successive physiological stages of the postnatal period of their ontogenesis.

VI. VARIATION IN SHREWS OVER THE PERIOD FROM 1961—1964

The study by Borowski & Dehnel (1953) shows that the dimensions and weight of shrews' bodies are subject to changes over the course of a cycle of several years. The statement of this fact is interesting on account of the changes observed in the weight of certain internal organs. It may therefore be expected that changes in body weight depending on the state of the population of these animals in a given year will be reflected in the weight of different internal organs.

The material available was somewhat scanty for analyses of this kind, since it covered only three not wholly complete life cycles (generations) of shrews. The mean values of body weight and the weight of internal organs are set out in Table 12 for each of three basic seasons: young shrews from the summer, young shrews from the winter and old adults from the summer of the following calendar year. As can be seen from this table the differences in body weight between the various generations are in general slight (from 3—6%). Certain organs, however, exhibit a different scale of variation over the course of this sequence of years. Thus in the case of the brain and heart differences of the order of 4—5% are observed, liver and kidneys — 10—12%, *BAT* — 25% and finally the spleen — about 35%. These are approximate data, mainly calculated for young adults from the summer. It is characteristic here that the differen-

Table 12.
Changes of mean values of weight of organs (in g.) in generations 1960/61—1963/64

Organ	Generation	Summer /VI-VIII/ Young ad. n	Abs.wt.	Winter /XII-III/ Young ad. n	Abs.wt.	Summer /VI-VIII/ Old ad. n	Abs.wt.	Diff. between : Summer and Winter /Young adul:/, %
Body wt., g	1960/61	-	-	-	-	17	10.44*	-
	1961/62	76	6.75	14	5.66	19	10.57*	16.1
	1962/63	45	6.97	55	5.78	34	10.51*	17.1
	1963/64	14	6.95**	45	5.46	-	-	21.4
Brain, g.	1960/61	-	-	-	-	29	.2168	-
	1961/62	83	.2534	11	.2067	24	.2250	18.4
	1962/63	44	.2577	37	.2107	55	.2176	18.2
	1963/64	11	.2671	44	.2086	-	-	21.9
Heart, g.	1960/61	-	-	-	-	28	.1082	-
	1961/62	85	.0721	10	.0730	24	.1123	-
	1962/63	45	.0737	33	.0720	41	.1139	2.3
	1963/64	14	.0750	40	.0697	-	-	7.1
Liver, g.	1960/61	-	-	-	-	30	.7450	-
	1961/62	84	.4620	20	.3900	22	.7609	15.6
	1962/63	44	.5198	41	.3748	41	.7804	27.9
	1963/64	14	.5164	40	.3450	-	-	33.2
Spleen, g.	1960/61	-	-	-	-	27	.1218	-
	1961/62	85	.0824	20	.0254	24	.1145	69.8
	1962/63	45	.0894	41	.0198	39	.1185	77.8
	1963/64	14	.1114	40	.0190	-	-	82.9
Kidneys, g.	1960/61	-	-	-	-	28	.1985	-
	1961/62	84	.1390	20	.1039	23	.1863	25.2
	1962/63	45	.1416	41	.1157	41	.1988	18.3
	1963/64	14	.1564	40	.1125	-	-	28.1
BAT, g.	1960/61	-	-	-	-	27	.1005	-
	1961/62	46	.0860***	14	.0657	24	.1025	23.6
	1962/63	12	.1074***	41	.0740	35	.1087	31.1
	1963/64	8	.0812***	38	.0708	-	-	12.8
Adrenals, mg.	1960/61	-	-	-	-	28	5.4	-
	1961/62	85	4.9	17	2.0	24	5.1	59.2
	1962/63	45	4.9	41	3.1	41	4.7	36.7
	1963/64	14	5.2	35	2.1	-	-	59.6

*) Males only; **) June and July only; ***) June only.

ces between different generations appear fairly consistently in both the body weight and the weight of the majority of the organs. For instance the generations 1962/63 and 1963/64 have in general a higher weight of body and internal organs than the generation 1961/62, the highest values attained being in almost all cases in the 1963/64 generation. This arrangement, so distinct in young adults in the summer, undergoes some disturbance during the winter and in old adults of the respective generations. It would appear understandable that differences in habitat conditions in the summer period of successive generations will not necessarily retain the same relation of succession during the winter, and especially in the summer, a year later. A warm summer may be followed by either a mild or severe winter, which may have a significant effect on the intensivity of changes in the weight of the body and internal organs. In our material, for instance, the greatest weights of these organs were observed in the summer of 1963, and the lowest value for the winter period — in shrews of the same generation (1963/64). In the case of this generation we found the greatest range of mean values of organ weights in shrews from the summer and winter periods and thus the winter depression was most intensively expresed here (cf. the final column in Table 12).

It is not possible to grasp the scale of intensivity of seasonal changes in different morpho-physiological indices of the shrews over the course of only three consecutive years. It would, however, appear obvious that as observed in the case of the skull (Pucek, 1955; 1963; Pucek & Markov, 1964) there are significant deviations from the average course of seasonal changes in the weight internal organs, depending on the current habitat and population conditions.

The data presented lead to the conclusion that differences in the course taken by winter depression in shrews in consecutive years is manifested with different degrees of intensity in the changes in various internal organs. Organs such as liver, kidney, spleen react more intensively to the actual conditions in a given year than does the body weight or the weight of other organs. The weight of the organs mentioned may therefore be a more sensitive index of intensivity of seasonal changes than body weight.

VII. DISCUSSION OF METHODS AND RESULTS

1. Some Questions of Methods

The data obtained in the present investigations are undoubtedly burdened by certain errors. Several causes, requiring more detailed discussion, have contributed to this, in addition to the normal subjective measurement error.

1.1. The shrews were caught in live traps and survived in them for a certain time, but usually died either from starvation or possibly as the result of shock. They ate the invertebrates or the bait in the traps or cylinders. They undoubtedly tried to escape from the trap. Behaviour of this kind might cause stress reactions. The reactions of a rodents' organism to capture and further handling of the animal after capture have been observed several times (cf. Christian, 1963). The changes taking place in the adrenal glands with such reactions may widen the limits of variance in the weight of these organs over a very short space of time. The possibility of rapid changes in spleen weight may be concluded from the results of studies by Herreid (1961) and Lidicker & Davis (1955). The latter observed a sharp decrease (of 500%) in spleen weight in bats, with transition from the state of hibernation to active life. It must therefore be borne in mind that individual changes in weight, at least of certain organs, may increase as the result of zoopsychological and physiological reactions of animals to the fact itself of capture and to the kind of trap.

1.2. The shrews were dissected a cosiderable time after their death. The changes taking place immediately after death in the internal organs might alter both the body weight an the weight of organs. In the case of rabbits significant differences were observed in the organ weight of animals dissected immediately after, and 6 hours after, death (Webster & Liliegreen, 1949). Different organs change variably in this connection.

1.3 The animals had not bled even when live shrews were brought to the laboratory. Depending on the kind of death (from starvation, as the result of nervous shock or ether anaesthesia) the blood might accumulate in certain organs to a greather or lesser degree and thus alter their reciprocal proportions and also widen the limits of individual variance in the organs. These differences are most probably not so great as to exceed the seasonal variations observed here. Some confirmation of this assumption is provided by the data given by Davis *et al.* (1961) who showed that in the case of *Peromyscus leucopus* (Rafinesque, 1818) no influence is exerted either by the kind of death (spring trap, chloroform) or sex or season on spleen weight, despite the fact that this organ in particular would seem to be sensitive to influence of this kind. Other authors in turn have shown that spleen weight in uneasy or active rats is twice as small as in rats left alone (McRobert, 1928, cited after Rensch, 1948). Our data show that the seasonal differences observed in shrews spleen are of the order of 500%.

1.4. Relative weights of internal organs were referred to the gross body weight. This procedure was justified by the specific character of shrews. As is well known the digestive processes take place incomparably more rapidly (10—20 times) in these animals than in rodents (Kostelecka--Myrcha & Myrcha, 1964). The stomachs of animals which died in the open are almost empty or contain very little remains of food. It was therefore taken that food remains exerted no significant effect on variation in body weight. In addition, contrary to what was observed in captive animals (P u c e k, 1964) shrews under natural conditions do not accumulate large reserves of that which could be estimated by, for instance, weighing the appropriate tissues. The organ which accumulates fat reserves is undoubtedly that known as the hibernation gland (*BAT*). This organ was in fact weighed but it was held that variations in its weight, within limits of 0.02—0.2 g would have no important influence on the gross body weights, which usually were estimated with accuracy to

Table 13.

Differences between mean values of absolute weight of internal organs expressed in percentages of the weight of the fresh organ.

Symbol — indicates decrease, + increase in organ weight due to fixation. Numbers (n) given in first place for fresh organs, in second place for fixed organs.

Organ	Summer /VI-VIII/ Young adult	Winter /XII-II/ Young adult	Summer /V-VII/ Old adult
Brain	- 17.6 / n = 139, 119[1] /	- 24.3 / n = 99, 37 /	- 20.0 / n = 126, 46 /
Heart	- 7.1 / n = 144, 191 /	- 5.1 / n = 90, 76 /	0 / n = 120, 110 /
Spleen	- 39.0 / n = 144, 132 /	+ 71.6 / n = 90, 29 /	- 26.1 / n = 116, 75 /
Liver	- 20.0 / n = 142, 182 /	+ 1.6 / n = 89, 23 /	- 20.0 / n = 118, 76 /
Kidneys	- 31.8 / n = 143, 201 /	- 20.1 / n = 90, 44 /	- 37.0 / n = 119, 94 /
BAT	- 24.7 / n = 138, 1536[2] /	- 18.7 / n = 88, 112 /	- 7.0 / n = 111, 377 /

[1]) Data for fixed brains, after B i e l a k & P u c e k (1960).
[2]) After B u c h a l c z y k & K o r y b s k a (1964). Remaining data are original.

0.1 g. Thus, with a certain degree of approximation, the gross body weight was taken instead of net weight in view of the fact that in shrews differences between these two weights are not as great as in other mammals. The errors referred to would in addition be difficult to avoid in work on wild animals so sensitive and dying so rapidly after capture as shrews. The reality of the results presented is based on an analysis of mean values calculated in the majority of cases from extensive monthly series of material (30—70 specimens).

1.5. In some earlier studies the authors have based the results of similar investigations on material fixed in alcohol or formalin, starting with the assumption that the curves of variation are similar in character and run parallel to the absolute weights of different organs. It would seem that this assumption is admissible only in certain cases. There is no question that reference of the weight of organs fixed to the gross body weight and calculation of proportions between different organs is indefensible. The weight of different organs and of the body as a whole change to a different degree depending on the kind and duration of fixation, procedure after fixation and similar factors (Lusk & Pokorny, 1964; M. Pucek, *in litt.*). It is necessary to bear in mind the different chemical composition and degree of hydration of different organs and also that these indices may be subject to seasonal changes. This is borne out by the studies by Sealander (1951), Górecki (1965), M. Pucek (1965) and others reviewed by Héroux (1961) or Barnett (1965).

The data given in table 13 compare differences obtained between the weight of certain internal organs of *S. araneus* L. both fresh and also prepared from whole animals previously fixed in the usual way in 70—80% alcohol. These data come from different years but the differences between the various generations are not so great (cf. Table 12) as to be taken into consideration in so rough a comparison. The data in table 13 show that the differences between the mean weights of fresh and fixed organs are variable at different seasons, and therefore the variation curves of these indices, obtained in a double way. will not run parallel over the whole life cycle of the shrew.

The conclusion is obvious from the data given and the above reasonings that it is essential in investigations of this type to use mainly fresh material, elaborated in accordance with strictly defined methods and sufficiently abundant to be able to grasp both seasonal and age, and also populational, differences. Material collected in this way permits of correct interpretation of the results obtained. Although these matters have frequently been emphasised in literature (Schwarz, 1949; Kleinenberg, 1952), they have not always been properly comprehended.

2. Individual Variability of the Weight of Internal Organs

2.1. Range of Variation

A comparable measure of variation in different internal organs is the coefficient of variation — *V*. It will be seen from comparison of the data set out in tables 1—8 that this coefficient varies greatly. The range of its variation in our material, bearing in mind the dependence on the kind of organ, age and season comes within limits of 7 and 52%. We can consequently distinguish more or less variable organs. Among the less variable are organs such as the heart, kidneys and liver, with relatively low variation coefficients ($V = 8.75—14.10\%$, and exceptionally for the kidneys of young adult shrews from the winter — $V = 6.73$). The second group includes the spleen, *BAT* and adrenals, which have far higher variation coefficients of their relative weights ($V = 22.43—51.71\%$). This rule agrees in general with observations of other mammals (Kopeć & Latyszewski, 1931; Webster & Liliegreen, 1949; Latimer & Sawin, 1955; Héroux & Gridgemann, 1958; Schwarz, 1958, 1960; Fatieev, 1962). This is completely understandable in view of the definite functions of the various organs.

The differences in coefficient V for the same organ, depending on season and age, were also demonstrated. A wider range of variation is generally observed in old adults, which is undoubtedly due to the wider scale of variation in gross body weight than that in young shrews. In the case of the spleen and adrenals variance was found to be almost twice as high in winter as in summer. The increase in variance of these indices during the winter is most certainly functional in character.

It has already been emphasised above that in the case of shrews variance coefficients calculated may be slighty higher than the real values as the result of taking the gross body weight for calculating indices of the organs. Comparison of the data obtained with the results of other authors shows that the variations in the internal organs of the shrew are by no means greater than those observed in, for instance, the mole (Fateev, 1962), laboratory mice (Kopeć & Latyszewski, 1931) or the rabbit (Latimer & Sawin, 1955). In certain cases (brain, liver, heart, kidneys) the variance coefficients of the respective organs of shrews are even lower than in the uniform mouse or rabbit material specially chosen for investigation. It can be seen from this that treatment of the material by splitting into age and seasonal groups causes it to be more even. Treatment of this kind is more correct in the case of free-living animals and permits of correct comparison of groups corresponding to each other.

2.2. Dependence of Organ Weight on Body Weight

A certain amount of attention has been paid in the present investigations to the dependence of relative organ weight on body weight. It has been shown that the different organs differs in shrews greater from this aspect. It was also found that there are differences in the occurrence of these relations in young and old adult shrews. Table 14, and also the diagrams referred to and analysis of the regression of relative weights of the organs with body weight with the different age and seasonal groups

Table 14.
Comparison of mean values of relative weight of some internal organs in respective classes of body weight.

Body weight class	n	Brain %	Heart %	Liver %	Kidneys %	Spleen %	BAT %	Thymus ‰	Adrenals mg. 100/g
Young adult males / VI - IX /									
5.00 - 5.49	-	-	-	-	-	-	-	-	-
5.50 - 5.99	3	4.36	1.11	7.21	2.32	1.10	0.98	4.24	70.3
6.00 - 6.49	19	4.03	1.11	6.90	2.16	1.22	1.16	6.99	70.4
6.50 - 6.99	37	3.85	1.10	7.48	2.15	1.32	1.09	5.32	70.1
7.00 - 7.49	26	3.59	1.05	7.57	2.02	1.24	1.08	4.54	70.8
7.50 - 7.99	9	3.50	1.06	7.79	1.98	1.50	1.04	6.54	63.7
8.00 - 8.49	2	3.52	0.92	7.73	1.96	0.95	1.06	4.03	62.2
8.50 - 8.99	2	3.02	1.01	8.37	1.86	1.33	-	5.66	66.2
Young adult females / VI - IX /									
5.00 - 5.49	2	4.26	1.16	6.50	2.07	1.08	1.34	7.78	80.9
5.50 - 5.99	8	4.20	1.12	6.91	2.22	1.30	1.07	5.72	79.5
6.00 - 6.49	21	3.86	1.13	7.13	2.20	1.19	1.12	5.00	81.3
6.50 - 6.99	30	3.73	1.06	7.47	2.16	1.26	1.11	4.29	76.5
7.00 - 7.49	30	3.53	1.05	7.52	2.08	1.26	1.23	4.98	74.5
7.50 - 7.99	15	3.41	1.03	7.65	2.04	1.42	1.40	6.42	71.1
8.00 - 8.49	3	3.12	0.92	7.39	1.97	1.28	1.12	2.01	49.6
8.50 - 8.99	-	-	-	-	-	-	-	-	-
Old adult males / V - IX /									
8.50 - 8.99	6	2.35	1.06	7.59	2.04	1.24	0.90	-	51.5
9.00 - 9.49	11	2.48	1.18	7.22	2.02	1.13	1.01	-	49.0
9.50 - 9.99	23	2.28	1.11	7.14	1.85	1.06	0.93	-	47.4
10.00 - 10.49	18	2.18	1.14	7.03	1.87	1.34	1.09	-	41.1
10.50 - 10.99	14	2.08	1.12	6.93	1.79	1.17	0.99	-	40.1
11.00 - 11.49	17	2.01	1.06	7.92	1.78	1.34	0.99	-	42.6
11.50 - 11.99	7	1.95	1.06	7.10	1.76	1.09	1.16	-	43.2
12.00 - 12.49	13	1.85	1.02	6.75	1.56	1.06	1.48	-	36.8

show that not all the organs exhibit distinct correlations with the size of the body or conform to "the rule of orders" — Hesse (1921). These relations are particularly distinct in the changes in the relative brain weight, both in young adults and old adults. In young shrews far weaker connections in reverse proportion to body weight are exhibited by the heart and kidneys indices and in direct proportion — by the liver index.

The changes in the relative heart weight are particularly slight, although regular. In old adults, on the other hand, the kidney index is clearly dependent on body weight, the heart index exhibits far weaker connections than in young animals, and the liver index none at all.

Indices of the remaining organs, both in young and old adults, exhibit no regular connections with body weight. Similar observations were made in relation to rodents: laboratory mice (S e e l i g e r, 1960) and free-living house mice (N o r d, 1963) and also *Apodemus sylvaticus* (L i n n a e u s, 1758) — K l e m m t (1960).

It can be seen from the above that the "rule of orders" formed on the basis of an analysis of the relative weights of the heart in land vertebrates (H e s s e, 1921) cannot always be applied to other organs. A number of exceptions have been found, not only when comparing this same index in different species of a given taxonomic group (S c h w a r z, 1959b) but also when analysing different morphological indices within the same species.

2.3. Sex Dimorphism

The problem of sex dimorphism in the weight of different internal organs has frequently been emphasised in literature (H e s s e, 1921; K o p e ć, 1939; K l e m m t, 1960; F r i c k & N o r d, 1963 and others). No particular attention has been paid to this problem in relation to shrews. It is of course chiefly a question here of the young animals which are fully comparable from thin aspect. From the diagrams given in Section IV there are grounds for concluding that dimorphic differences exist in the absolute values. These differences may, however, be due to dimorphism in relation to body weight. A different picture was obtained when the relative values of the weight of different organs within corresponding classes of body weight were considered. The data given in table 14 show, even without making statistical tests, that sex dimorphism is perceptible only in the case of the brain and adrenals. The relative weight of the brain in young females is smaller than in males, while the adrenals are heavier in females.

2.4. Comparison of Morphological Indices of Shrews and Other Insectivores and Rodents

Metabolism in shrews *(Soricidae)* is, as is well known, higher than might appear from the known relation between metabolic level and body size (P e a r s o n, 1948; G ę b c z y ń s k i, 1965 and others). These differences are not of course as great as stated by S c h w a r z (1955; 1956) who wrote that shrews' metabolism is four times higher than that of rodents. In the light of data so far given in literature (for references see G ę b c z y ń s k i, 1965) no justification can be found for such a statement. It is however a fact that the mean 24-hour oxygen consumption of such representatives

Table 15.

Comparison of relative weights (in % or ‰) of internal organs of some species of

Species, locality	N	Sex	Age	%,‰	Body wt., g	Brain	Heart
Talpa europaea	28	♂♂		%	68.2		0.582
Germany	17	♀♀		%	63.8		0.564
Talpa europaea	54	♂♂	1959	%	88.57 ± 1.54		0.850 ± 0.087
Kostroma Palat.	31	♀♀	1959	%	79.12 ± 1.93		0.800 ± 0.03
	24	♂♂	1960	%	94.75 ± 1.64		1.077 ± 0.032
	5	♀♀	1960	%	85.50 ± 2.18		1.120 ± 0.135
Sorex cinereus	?			‰	2.9 – 4.0		16.6
Sorex minutus Jamal	9	♂+♀	YA, 1957	‰			15.6 ± 0.59
Sorex arcticus	16	♂+♀	YA, 1957	‰			14.5 ± 0.72
Jamal	15	♂+♀	YA, 1958	‰			11.1 ± 0.62
Sorex daphenodon	11	♂+♀	YA	‰	5.26 ± 0.176		13.1 ± 0.44
Jamal	8	♂+♀	OA	‰	8.32 ± 0.621		12.9 ± 0.733
Sorex araneus							
Jamal	24	♂+♀	YA	‰	7.17 ± 0.138		11.8 ± 0.105
	10	♂+♀	OA	‰	10.44 ± 0.092		10.6 ± 0.732
	4	♀	YA	‰	10.7 ± 0.457		8.6 ± 0.460
Kuragan Palat.	?	♂♂	YA (?)	‰	10.0		9.65
Białowieża	142	♂+♀	YA	%	6.88	3.77 ± 0.0578	1.08 ± 0.0168
	97	♂+♀	YA	%	5.60	3.81 ± 0.0672	1.28 ± 0.0242
	124	♂+♀	OA	%	11.10	2.04 ± 0.0511	1.06 ± 0.0300
Neomys fodiens							
Kuragan Palat.	?	♂♂	YA (?)	‰	19.0		9.8
Bielorussia (?)	14			%	16.8		1.076
Crocidura russula	9	♂♂		‰	8.74		9.48
	6	♀♀		‰	10.07		9.72
Mus musculus dom.	36	♂♂	Y?	%	10.43	3.84	0.706
Germany	37	♀♀	Y	%	10.15	3.88	0.750
Apodemus sylvaticus	27	♂♂	Y?	%	11.50	4.87	0.901
Germany	47	♀♀	Y	%	11.06	5.09	0.929

of *Soricidae* as *Neomys anomalus* Cabrera, 1907 is approximately 22% higher that that of a representative of rodents — *Pitymys subterraneus* (de Selys-Longchamps, 1835). Gębczyńska & Gębczyński (1965) measured the metabolism of both species, in shrews (*Soricidae*) and in other representatives of *Insectivora* and *Rodentia.*

Liver	Kidneys	Spleen	Author, Remarks
			Hesse /1921/, All seasons
5.620 ± 0.122	1.000 ± 0.020	0.950 ± 0.040	Fateev /1962/, All seasons
5.760 ± 0.200	1.11 ± 0.03	0.99 ± 0.06	
5.676 ± 0.177	1.218 ± 0.045	1.258 ± 0.077	
6.050 ± 0.610	1.440 ± 0.125	1.430 ± 0.176	
			Morrison et al. /1959/
64.6 ± 4.98	10.6 ± 0.245		Schwarz /1962/
55.6 ± 3.13	9.65 ± 0.454		Schwarz /1962/
73.5 ± 3.45	9.48 ± 0.454		
60.7 ± 2.92	8.88 ± 0.246		Schwarz /1962/
65.9 ± 4.04	8.0 ± 0.65		
64.0 ± 1.7	10.0 ± 0.252		Schwarz /1962/
68.1 ± 3.98	8.2 ± 0.326		
74.0 ± 10.3	8.0 ± 0.61		Sexualy active young adult females
60.3	11.0		Schwarz /1955/
7.81 ± 0.170[1/]	2.09 ± 0.0361[4/]	1.28 ± 0.0543	Pucek /this paper/, Summer
6.36 ± 0.260[2/]	2.08 ± 0.0295	0.34 ± 0.0409	Winter
7.11 ± 0.210[3/]	1.80 ± 0.0451	1.12 ± 0.0712	Summer [1/] VIII - IX, n=109; [2/] IV, n=43; [3/] n=76; [4/] Both kidneys were weighed
56.0	14.5		Schwarz /1955/
5.743	1.581		Nikicenka /1961/
			Hesse /1921/, Autumn, Winter /X - XII/
5.92	1.483	0.409	Acc. to Nord /1963/, All seasons. [5/] Body weight groups 6.0 - 12.0 g.
5.93	1.495	0.563	
7.09	1.734	0.524	Acc. to Klemmt /1960/, All seasons. [6/] Body weight groups 7.0 - 14.0 g.
7.77	1.838	0.572	

animals with the same body weight, and in the same apparatus. The results they obtained may therefore be taken as fully comparable.

The higher level of shrews' metabolism as compared with rodents is evident in the relatively higher morpho-physiological indices of these animals, and specially in the greater relative weights of the organs directly participating in physiological changes (Schwarz, 1956). It would seem that comparison of this kind cannot be made directly without taking into consideration the class of body size, since it is well known that the level of metabolic changes increases with a decrease in the dimensions of the body. Similarly, the relative size of certain organs in general increases with a decrease in the dimensions of the animal. Better comparability of results may therefore be obtained by considering animals of the same size and same body weight. In many cases this is completely out of the question, and comparison of animals of the same weight but, for instance, young and adults may be burdened by certain errors. The material so far accumulated by different authors is not always comparable, both on account of the different methods used and frequently because incomplete. It is therefore impossible as yet to draw final conclusions.

Despite this fact, table 15 sets out the material available, both for different species of shrews varying in size, and for other insectivores and for certain representatives of rodents, which were in fact taken into consideration completely fortuitously. In this last case comparison was made of mean values calculated from certain classes of body weight only, hence rodents and shrews of similar mean body weight were compared. The differences between the two species of rodent referred to (*M. musculus* and *A. sylvaticus*) are very considerable. *M. musculus*, as a synanthropic animal, differs distinctly from the wild forms (Frick & Nord, 1963) and is not a very good example here. It is therefore more correct to compare shrews with the free-living *Apodemus sylvaticus* (Linnaeus, 1758). It will be found that the heart index in shrews is only slightly higher than in *A. sylvaticus*. The kidney index is almost the same, and even smaller in the case of shrews from Jamal. The liver index of shrews is also equal to or even slightly lower than in *A. sylvaticus*, while the spleen index is twice as high as shrews.

The heart index of representatives of the genus *Crocidura* Wagler, 1780 is almost the same as in mice. In the case of water shrews this index is particularly high even in comparison with other *Soricidae*. The important influence of their way of living in and out of water is undoubtedly marker in these mammals. In a similar way the heart and kidney indices in the mole are as high as in *S. araneus* that is, in animals 10 times smaller. Here also specific adaptations to subterranean life and intensive work exert a distinct influence.

Within the genus *Sorex* L. variations in the heart index exhibit regular distribution in reverse proportion to the body weight of different species. The extreme values in this comparison (16.6 %), although probably not yet the minimum ones in mammals, are those of *Sorex cinereus cinereus*

(K e r r, 1792). The results of the present investigations show that seasonal differences in the value of the heart index may be of the order of differences between various species completely differing from each other as to body size (e.g. *S. araneus* and *S. daphenodon*).

Young adult shrews from the Białowieża population have the same heart index as old adults, although these two age groups differ greatly in body size.

Attention has also been drawn to the adaptive properties of the morpho--physiological indices (S c h w a r z, 1962). This author states, for instance, that shrews living in the north (Jamal peninsula) have greater heart and liver indices than these living in areas further to the south (Kuragan Palatinate). It is worthy of note that data for old adults from Białowieża are identical with those given by S c h w a r z (1962) for Jamal Peninsula, although Białowieża is situated about 12° of geographical latitude to the south and 47° — to the west. It may, however, be expected, in view of some data (C o u l i a n o s & J o h n e l s, 1962; J u d i n, 1962) that the microclimate of the immediate habitat of the shrews (nest, burrows, subnivean air space) will be similar in both cases when the snow covering is abundant, and this will tend to balance any possible differences.

Relative weight of liver and kidneys do not exhibit such regular variation as the heart index. The kidney index is relatively high in young adult shrews, in summer and winter, and markedly lower in old adults. No regular differences are observed between different species.

On the other hand there are no data for comparison of the spleen index in different species of shrews. Seasonal differences, expressed by indices four times smaller in winter than in summer, result in this index being similar in summer to the values obtained for other insectivores (e.g. the mole), and in winter closer to the corresponding data for rodents.

The data given in this study on brain weight and its relation to body weight are probably proper to the whole genus *Sorex* L. (P u c e k, 1963). They may be of importance to the comparative research so far carried out on the degree of cephalisation in *Insectivora* and the conclusions drawn on this basis as to the evolution of this group (S t e p h a n, 1959; S t e p h a n & A n d y, 1963; B a u c h o t & S t e p h a n, 1964). Different results may be obtained depending on choice of material from the seasonal and age aspect. It is sufficient to point out that the brain index of old adult shrews from summer is 46% smaller than that for young animals (Table 1).

3. Seasonal Variability of Internal Organs

Seasonal changes in the weight of internal organs in shrews form the crucial point in these investigations. Not all organs are, of course, subject to seasonal rhythm, nor are they all so subject to a uniform degree. This section discusses an attempt at interpreting changes in certain organs. An analysis has been made of the occurence and the rate of autumn regression and spring jump in growth. Changes in absolute and relative values have been compared here, which enables a fuller analysis of the material, and critical assessment of the results to be obtained.

3.1. An Attempt at Interpretation of Changes in Some Organs

Neither the cause nor the mechanism of the physiological processes causing such important seasonal changes in shrews have as yet been fully explained. It would seem that it is a question here of a group of phenomena superimposed on each other, resulting from the adaptation of these animals to life in the conditions of the external habitat determined by the season. With the knowledge we possess at present of the biology and physiology of these animals it would be difficult to say which of the factors is more decisive, particularly as these changes may, under certain conditions (e.g. laboratory conditions, cf. Pucek, 1964) deviate to some degree from the normal course in nature. Analysis of the effect of different factors on seasonal changes in shrews is more important.

Dehnel (1949) in describing seasonal variation in body dimensions and weight and the height of the skull in shrews put forward the hypothesis, that the mechanism of seasonal shrinkage of shrews may consist in the dehydration of the shrews' body in winter. This hypothesis, appearing highly probable in the light of research presented by Slonim (1961), has recently obtained factual confirmation in studies by Górecki (1965) and M. Pucek (1965). Górecki *(l. c.)* showed that the concentration of water in shrews' tissues is lower in winter and early spring than in summer. The concentration of ash exhibits reverse proportions. M. Pucek *(l. c.)* found that seasonal changes in the brain weight of shrews are connected with fluctuations in the concentrations of water and lipids in the tissues of the organ. In winter water content decreases, while that of lipids and dry rest after extraction increases, although there is absolutely less of these components than in summer. The ratio of dry rest to lipids is constant, while all proportions in relation to water exhibit significant seasonal changes. Thus the change in the concentration of water in the brain tissues would seem to be of fundamental importance to seasonal differences in the weight of this organ.

The decrease in concentration of water in the shrews' tissues may also be responsible for the decrease in their body weight in winter, since it is a known fact that in rodents dehydration may cause a loss in body weight of 30 to 50% (cf. Chew, 1965). In addition dehydration is always connected with a decline in the level of metabolic processes. Decrease of metabolism in winter was found in shrews by G ę b c z y ń s k i (1965). Changes of this kind must undoubtedly affect the water metabolism in shrews and the weight (= indices) of organs connected with it (e.g. kidneys). It is true that distinct correlations have not always been found, for instance it has been shown that the proportions of the cortex and medulla of the kidneys, indicating their function, are the same in the white rat as in *Dipodomys*, an animal adapted to life with a scanty water supply (cf. S c h m i d t - N i e l s e n, 1964; C h e w, 1965). It is also known that the kidney index forms a better indicator of metabolic functions than, for instance, the heart index (S c h w a r z, 1960). In shrews, on the other hand, a decrease in the absolute — and lack of change in the relative kidney weight are observed with a decrease in metabolism, dehydration of tissues, reduction in dimensions and weight of the body in winter. Analogical deviations are observed in old adults when the intensification of metabolic processes in relation to winter and sudden jump in growth in spring are accompanied by a drop in the relative kidney weight.

It may be assumed that the dehydration of shrews' tissues in winter is due to a change in their food. In the case of *Rhombomys opimus* L i c h t e n s t e i n, 1823, it was shown that water concentration in tissues of animals kept on a dry diet (43—47% water) was lower than it a group fed with moister food (73—76% water), S l o n i m (1961). It is possible that in winter shrews reduce their water intake, both of drinking water and water contained in their food. Studies by M e z h z h e r i n (1964) and K i s i e l e w s k a (1963) show that the food regime of shrews varies considerably over the year. Representatives of *Gastropoda, Araneida* and *Heteroptera* are found in shrews' stomachs more often and *Coleoptera* rarely in winter than in summer. This indicates the possibility of changes in the water metabolism of shrews during the winter.

The liver, as is known from earlier data given by R i b o i s s i e r e (1903), cited after R e n s c h (1948), reacts primarily to a change in diet. It is smaller in herbivorous than in carnivorous animals (S c h w a r z, 1960). It would be difficult to assume that shrews consume more plant food in the winter (J u d i n, 1963). It is not, however, known to what degree a change in the chemical composition of the invertebrates consumed affects the weight of the shrews' liver. On the other hand we know that in rats adapted to cold (H é r o u x, 1961) or in other mammals living in the subarctic (S c h w a r z, 1963) the liver weight is relatively higher, undoubtedly as a result of the glycogen stored in it. Reverse relations in shrews are found during the winter. The methods used in this studies were not accurate enough to show changes in liver weight depending on accumulation of glycogen. It may be, however, assumed that in the case of animals caught and remaining in traps or cylinders until they died, the reserve substances in the liver were used up more rapidly in winter when there was no natural food in the traps.

The relative weights of internal organs are considered as reflecting the latters' function in animals' organisms. Changes in the heart index are particularly interesting. Small animals, as is well known, with a higher metabolic rate, have relatively larger hearts. Animals living in mountainous areas, sub-arctic forms of widely-spread species and finally more active animals, whether those naturally so or as the result of appropriate exercise, also have a higher heart index (cf. Quiring, 1946; Rensch, 1948; Schwarz, 1949; 1960; Class, 1961). Hypertrophy of the heart is also observed in rats in winter (Héroux, 1961). In the light of these general rules, to which of course there are some exceptions, the seasonal changes in the heart index of the common shrew are unusual.

In winter the shrews' heart index rises from 10.5‰ in young animals in summer to 12.9—13.6‰. Judging by the regularities so far discovered and using only the relative values of heart weight, as is done by, *inter alia*, Schwarz, a rise in metabolism, activity and chemical thermoregulation should be expected in winter. More recent investigations decidedly refute such an assumption. Gębczyński (1965) showed that the average daily metabolism rate (*ADMR*, cm O_2/gm. hr) is lower in shrews caught in winter than in summer or spring, both in young and old adults. These differences are not in fact as great as in rodents, nevertheless they are statistically significant. Chemical thermoregulation is lower in winter (by about 15.5%). The hitherto unpublished data collected in our laboratory show that the locomotory activity, measured by the number of times the shrews move from the nesting box to the run, and run to feeding box, is 46% lower in shrews caught in winter when compared with young adults examined during the period July—August (Hejwowska, *in litt.*). Thus all the processes referred to which might provide an explanation of the increase in heart weight of shrews in winter take place on a lower level.

Analysis of changes, both in body weight (Fig. 1), and absolute heart weight (Fig. 4) make it possible to imagine the probable mechanism of variations in the index of this organ. As the absolute heart weight does not undergo regression in winter and body weight as a whole decreases, there is an increase in the heart index. On the other hand it would be difficult to imagine that the heart muscle undergoes regressive changes. In any case processes of this kind undoubtedly take place "more easily" in parenchymatous organs. Studies by Morisson *et al.* (1959) show that the heart rate of *S. cinereus* is only 60% of that expected for so small an animal. These authors assume that this is compensated by the relatively large dimensions of the heart (16.6‰ of body weight). When the data obtained are compared with the observations of the above authors it may be assumed that the maintenance during the winter of the same absolute dimensions of the heart as in summer permits the shrews' heart rate to be reduced. This would be advantageous on account of the lower winter level of metabolism. Any eventual thermoregulation deficiencies due to this are physically regulated, since in winter the number of hairs per unit of body surface increases in shrews (Borowski, 1958) and the isolation value of the skin and fur increase considerably (Gębczyński & Olszewski, 1963). The considerable reduction in the spleen index in winter may also be conneceted with the circulation of a larger amount of blood through the circulatory system.

It is clear from the above that in the case of the seasonal changes in shrews there is a lack of concurrence between activity, chemical thermoregulation and metabolism and relative heart weight. Regardless of the cause of this, the fact of its being evident suggests that care is required in interpreting the values of indices, at any rate of certain organs.

The mechanism of seasonal variations in adrenal weight can be traced in the light of Siuda's studies (1964). This authoress demonstrated that seasonal changes take place in the thickness of the adrenal cortex (*zona reticularis* and *zona fasciculata*). Involution begins from October onwards, attaining a minimum during the winter months. The spring increase in thickness of the adrenal cortex in shrews is very distinct in females, and faint in males. These changes are completely parallel to the fluctuations in the weight of these organs described above. The mechanism of these changes is therefore similar to that observed in other animals (Christian, 1963). To character of the changes in the adrenals of shrews indicates that it differs greatly from the observed in rodents, for instance in the case of the muskrat the adrenal weight was found to increase in autumn (Beer & Meyer, 1951 — after Christian, 1963; Schwarz & Smirnoff, 1960). These changes, similarly to the case of *Microtus montanus* (Peale, 1848) can be interpreted as reactions to social factors (Christian, 1963), or as Schwarz & Smirnoff (*l. c.*) maintain — to cold autumn weather. Changes take a different course in shrews. While the thickness of the adrenal cortex and the weight of these glands increase in summer, from June to September, rapid involution of these organs begins as early as October. The increase in adrenal weight occurs in spring, and earlier in males (March) than in females (April). These observations coincide to a considerable extent with the course taken by other processes in the shrews' organism, particularly with changes in the gonads. Intensification of all regressive changes as from October is also characteristic. Changes in the adrenals prove that it is a case here of processes governed by the activity of the endocrine system.

An attempt may be made at interpreting changes in adrenal weight from the standpoint of the stress theory (Christian & Davis, 1964). In addition to the endogenous seasonal rhythm, the decrease in intensity of individual contacts within the population of these mammals may also be responsible for reduction in adrenal function during the winter, since it is a known fact that shrews are less active in winter (Gębczyński, 1965; Hejwowska, *in litt.)*. This is also expressed by the feeding on invertebrates included in the nests fauna (Kisielewska, 1963). Although we have no direct proof the above facts point to reduction in individual contacts and to the shrews' tendency to migrate in winter. In spring, on the other hand, migrational tendency intensifies during the oestrus, activity and frequency of contacts increase in both sexes. The adrenal weight of males decreases markedly immediately after the first phase of intensive rut (Fig. 15), whereas in females it continues to increase in connection with pregnancy and lactation.

The mutual relations between adrenals-thymus have frequently been discussed (Bachmann, 1954; Christian, 1963). The figures (Fig. 14 and 15) show that involution of the thymus begins immediately after the shrews leave the nest, and that by September—October it is in principle completed. The adrenals, however, function intensively until September, than later exhibit involutionary changes. This shows that the two processes take place more or less independently of each other in shrews.

3.2. Time and Rate of Autumn Regression

Weight regression in internal organs begins relatively early, in fact as early as the summer. Absolute weights of organs such as kindneys, liver, spleen, adrenals behave similarly to body weight, i.e. increase in weight (or do not exhibit any significant changes) up to September inclusively. As from October however they decrease rapidly, within 3 months, and reach the state of winter depression. Exceptions to the above are formed by the brain, which after increasing slightly up to July, decreases in weight, particularly intensively as from October—November, and the thymus and *BAT* which attain maximum dimensions in young shrews after leaving the nest. The heart weight does not exhibit any changes up to the winter inclusively.

The time of occurrence of seasonal changes in the relative weights of internal organs varies greatly. Complete synchronisation is present only in the case of the liver and spleen. Regression of the adrenal index begins earlier, in August—September. The brain index decreases slightly during this period, but later returns to the dimensions peculiar to young shrews in summer. The relative weights of thymus and *BAT* decrease as from July, as to their absolute values.

As can be seen from the above, regressive changes in certain organs are manifested relatively early. The rate of these changes rises as from October. In other cases this point forms the start of regressive changes. These observations are in considerable agreement with the data given by other authors. It was found that as from October the resorption processes of the bones of the skull arch intensifies, and are connected with the more rapid changes in volumne and weight of the brain during this period (Pucek, 1955; 1957; Caboń, 1956; Bielak & Pucek, 1960). Changes in the blood tissue leading to specific erythropoiesis are manifested in young shrews at the age of 5—6 weeks and are maintained through the whole life of these animals (Perkowska, 1963). Thyroid function is intensified in October and the period following it (Dzierżykray-Rogalska, 1952). Involution of the thymus (Bazan, 1952) and adrenal cortex (Siuda, 1964) is hastened beginning with October. Metabolism is reduced almost to winter level (Gębczyński, 1965). It is clear that we have here complete synchronisation of the whole complex of physiological and morphological changes leading the shrews to the winter depression.

3.3. Spring Jump in Growth

Spring growth is manifested in March, in almost all internal organs, and fully corresponds to the changes in dimensions and body weight recorded in this period. These changes usually take place earlier in males than in females, due to the earlier sexual maturation of the former. Particularly distinct dimorphic differences are evident in brain weight, which does not exhibit progression in females until April. Increase in relative weights is marked only in certain organs, spleen — in March, adrenals — in April and liver — in May. Indices of the remaining organs, as we have seen, exhibit tendencies to decrease to a level similar to that in young animals (heart, *BAT*), or lower (brain, kidneys).

The rate of spring growth is even greater than that of autumn regression. Increase in mean weights of organs in March are negligible, but in May almost all the organs attain the maximum, or almost maximum, values of their weight in old adults. The whole spring growth therefore takes place in principle, on the population scale, within about 2 months. The picture given above is also in agreement with earlier observations of the functions of gonads, parathyroid glands, adrenals, changes taking place in the brain, skull and postcranial skeleton. The function of the thyroid gland also intensifies and the level of the shrews' metabolism rises (Brambell, 1935; Dzierżykray-Rogalska; 1952; 1955; Pucek, 1957; Dolgov, 1961; Siuda, 1964; Gębczyński, 1965; M. Pucek, 1965).

The question arises incidentally to those observations as to what is the stimulator of such intensive growth changes, comparable in extent to the spring growth in certain generations of rodents (S c h w a r z *et al.*, 1964). Is the stimulator merely the sexual maturation process? In an earlier study (P u c e k, 1960) it was shown that sexual maturation of young shrews in the year of their birth does not involve increase in weight and body measurements (except in individuals in late pregnancy or intensive lactation). This standpoint was criticised by S c h w a r z (1962) who holds that sexual maturation in young adult shrews causes an intensification in growth in summer and autumn in the first year of their lives. Without solving the question in general it must be emphasised that in the light of data so far obtained, no justification can be found for this state-

Table 16.
Relative weights of organs (in percentages) of young females of *S. araneus*, sexually active in year of birth.

Coll. no.	Date	Body wt., g.	Absolute organ weight, mg.							Sexual condition
			Brain	Heart	Liver	Kidneys	Spleen	Adrenals mg.100/g	Thymus	
31903	17.VI.63	7.3	-	-	-	-	-	-	-	Uterus greatly, enlarged
28145	19.VI.62	6.2	237.5	79.6	614.5	152.4	128.6	118.4	12.7	Gravid, 5 E
28163	20.VI.62	7.8	268.2	-	-	-	-	-	-	Gravid, 6 E
32002	21.VI.63	9.2	-	-	-	-	-	-	large	Gravid, 7 E
25032	23.VI.61	10.4[1]	232.3	82.1	581.2	185.6	145.0	79.1	-	Gravid, 6 E[1]
32140	28.VI.63	8.2	237.3	80.7	673.3	161.6	164.5	80.5	30.0	Gravid, 4 E
28234	30.VI.62	7.2	267.8	-	-	-	-	-	medium	Lactating
25164	11.VII.61	8.9	254.9	83.3	669.4	163.2	89.6	127.8	-	Gravid, 6 E and lactating
Young adult	Summer VI–VIII Averages	5.5 – -8.5[2]	256	72.9	530	142	87	79.8[2]	45.1	Non active
Old adult	Summer VI–VIII Averages	8.5 – -15.5[2]	220	112.0	760	196	120	57.2[2]	-	Gravid or lactating

[1]) Before parturition. Total weight of uterus with large embryos = 2.180 g. (After alcohol fixation).
[2]) Females only.

ment. In young adult shrews maturating in the year of birth, including captive animals, normal (skull, organs) or accelerated (thymus) regressive changes are observed in autumn (P u c e k, 1960; 1964). The weight and measurements of the postcranial skeleton (pelvis, scapula) exhibit no progressive changes and are maintained within the limits of variation of these dimensions in young adult shrews (D o l g o v, 1961). Comparison of the weights of internal organs in young, sexually active female shrews (Table 16) fully confirms the remarks made above. Young shrews which attain sexual activity in the first year of life do not therefore undergo a jump in growth such as observed in old adults.

The spring jump in growth leads to reconstruction of the internal proportions of the shrews' organism, expressed in changes in the morpho-physiological indices. The period of intensive function in summer does not cause further structural changes. As soon as the reproductive functions cease regressive changes can be observed in the values of the indices, some of which are manifested relatively early. Thus, for instance, the oxygen consumption level in old adults in June and July is decidedly lower than the spring maximum (Gębczyński, *l. c.*). There are no changes of any sort intended to prepare the animal for survival through the succeeding winter, for instance, there are no moulting changes (Borowski, 1963). The shrews die a natural death under such conditions.

4. Stages of postnatal Development of Shrews

The results of studies, presented in this paper, in comparison with earlier studies of variation in many morpho-physiological indices over the whole life cycle of shrews make a more exact description of the postnatal period of their ontogenesis possible. It is a question here particularly of the kind and rate of changes in different stages of postnatal development. It would seem here that the character of these changes, although examined primarily in *S. araneus*, is a feature common to at least all the representatives of the genus *Sorex* L. (Pucek, 1963).

In addition to the results of this study observations of the course and mechanism of changes in the skull were taken as the chief basis (Dehnel, 1949; 1950; Pucek, 1955; 1957; 1963; 1964), of seasonal changes in brain weight in *S. minutus* and *S. araneus* (Caboń, 1965; Bielak & Pucek, 1960; Pucek M., 1965) and also differences in the proportions of the postcranial skeleton in young adult and old adult shrews (Dolgov, 1961). Histo-morphological investigation, throwing light on the function of certain endocrine organs such as the thymus (Bazan, 1952; Pucek, 1964), thyroid gland (Dzierżykray-Rogalska, 1952) and parathyroid (Dzierżykray-Rogalska, 1955), adrenals (Siuda, 1964) are very important here. A valuable contribution to them is formed by studies made recently enabling more accurate findings to be given on physiological changes in the shrew's organism, that is, investigations of metabolism Gębczyński, 1965), diurnal activity rhythm (Crowcroft, 1957; Gębczyński, *l. c.;* Hejwowska, *in litt.*) the structure of blood tissue (Perkowska, 1963) and changes in blood indices (Kunicki-Goldfinger & Kunicka-Goldfinger, 1964). Analysis of these data gives a fairly complete picture of the morpho-physiological changes taking place in shrews' organism over the whole life cycle.

Seven phases can be distinguished in the postnatal development of shrews of the genus *Sorex* L.:

I. Development in the nest
II. Summer stabilisation phase in young adults
III. Autumn regression

IV. Winter depression
V. Spring jump in growth
VI. Summer stabilisation phase in old adults
VII. Senile regression.

The above should be treated as stages in the complex changes taking place over the shrews' life cycle, and not as stadia in the physiological sense. A description of the changes taking place in each period is given below.

I. Development in the nest, from birth to about the 21—22 days of life (Dehnel, 1952) intensive growth of the whole body leading to attainment of "adult" dimensions (particularly of the skeleton) on leaving the nest.

II. Summer stabilisation phase in young shrews. From June to September the weight of the body and certain internal organs (liver, spleen, kidneys, adrenals) increases slightly in mean values. This increase applies both to absolute and relative values. The skull, brain, *BAT*, thymus, and gonads already exhibit depressive changes, the heart remains unchanged. Indices such as level of metabolism, water concentration in the brain, are highest in June—July and exhibit regressive changes early on. The thyroid, parathyroid and adrenal glands function evenly, even manifesting some progressive changes (adrenals). Erythropoietic changes are manifested in the blood tissue in animals 5—6 weeks old and gradually intensify in the population in autumn. The number of erythrocytes in the blood increases slightly. This picture is slightly blurred by the continuous entry into the population of young shrews which have different indices from animals which have lived in the forest for several weeks.

III. Autumn regression. From October to December there is rapid regression of morphological and physiological indices. Metabolic level and locomotory activity decrease, as do body measurements and weight. All organs except the heart and *BAT* decrease in weight. Resorption of the bones of the skull arch and regression in the height of the brain case is hastened. Involution of the thymus reduces this organ to the rudimentary state. The thyroid functions more intensively, particularlly during the autumn moult occurring at that time; parathyroid secretion is inhibited up to February inclusively. *Zonae fasciculata* and *reticularis* of the adrenal cortex undergo rapid involution. The number of erythrocytes in the blood decreases. In November almost 100% of the individuals in the population exhibit erythropoietic changes in the blood tissue, which are maintained to the end of the shrews' life.

IV. The winter depression phase covers the period from December to mid-March, i.e. until the spring jump in growth takes place.

Regressive changes in organ weights intensify slightly (mean values) and reach their minimum values. No changes are found in the bones of the skull arch or sutures. Thyroid function is highly specific, only part of the gland secretes. The parathyroid is in the degeneration phase. The thickness of the adrenal cortex is the smallest it ever is during the shrews' lifetime. Oxygen consumption per unit of body weight and also locomotory activity are both on a low winter level.

V. Under the conditions at Białowieża the spring jump in growth begins in the second half of March. The mean March values of certain components are by that time decidedly higher than in February, and by May the maximum values of all morphological indices are almost attained. The shrews then enter the sexual activity phase, and therefore development of the gonads, oestrus and pregnancy are observed. The first births take place during the first ten days of May. Progressive changes occur in body weight and dimensions, absolute and sometimes relative weights of internal organs. The brain, heart, kidney and *BAT* indices do not increase. The different growth rate of these and the other organs leads to a change in the body proportions of old adults. Sudden regenerative processes are observed in the skull, leading to growth of new bone tissue on the margins of *ossa parietalia* and *occipitointerparietale*. The skeletal dimensions increase (pelvis, scapula, spine). Metabolic level and concentration of water in the tissues increase. Thyroid function is uneven, states of great activity of this gland (oestrus) alternate with regeneration periods. Parathyroid activity distinctly increases. Thickness of the adrenal cortex increases in females to the state observed in young shrews, whereas increase is only slight in males. Regeneration of the thymus, a frequent phenomenon in rodents (Schwarz *et al.*, 1964) is not observed during this period.

VI. The summer stabilisation phase in old adults covers the period from June to August—September. Morphological indices are maintained on a more or less even level. Oxygen consumption is far lower than during the spring growth period. Thyroid function is similar to that in the spring, while the parathyroids exhibit senile changes.

VII. Senile regression. Regressive changes are observed in old adults in the autumn, that is, during the same period as in young shrews. The processes take place slowly and are undoubtedly senile in character. Histological pictures of the thyroid are similar to the winter state. The cells and nuclei of the parathyroid glands gradually grow smaller. Sexual activity ceases and gonad weight decreases in males from October—November onwards. There are no data available on the structure of the adrenal cortex. The weight of these organs increases in autumn

(October—November) both in absolute and relative values in comparison with summer. The concentration of water in the brain decreases.

5. Uneven Rate of Postnatal Development of Shrews as an Expression of Adaptive Processes

It can be seen from the above review that the postnatal development rate of shrews is uneven. Periods of intensive growth (nest development, spring jump in growth) alternate with phases of relative stabilisation (both summer periods) in young shrews and old adults, and also sharp autumn regression and winter depression. As a result the duration of different development stadia differs in comparison with other mammals, including other insectivores. Intensive nest development brings young shrews up to the proportions proper to fully-grown individuals. There is therefore no typical juvenis stage (Dehnel, 1950). Shrews can be classified as subadultus (= young adults) immediately they leave the nest. This stage lasts relatively long, i.e. from 6—9 months of active life in the open. The time of sexual maturity in many mammals coincides with or precedes the period of attainment of general physical maturity, whereas in shrews, with a few exceptions [1]) this stage occurs relatively late, in the second half or even in the final third part of their lives, when they are 7—10 months old. The periods of sexual activity and senile regression which follow later (adults and senex) taken jointly do not last longer than 6—10 months. These very specific proportions of the duration of different stadia of postnatal development in shrews clearly distinguish them from other small mammals.

Analysis of the facts presented provides confirmation of Dehnel's hypothesis (1950) that the pause in the sexual development of shrews is the expression of the adaptation of these forms to life in circumpolar and polar areas. Developing this assumption even further it may be concluded that as a result of this adaptation the uneven rate of the postnatal development specific to shrews has been formed. Functioning of the most important vital processes has been limited to relatively short periods favourable from the climatic and food aspects. Thus the atainment of full physical development of both — skeleton and, in principle, the main body dimensions has been intensified and concentrated into 21—22 day period of nest development. The phase of intensive growth and sexual maturation of all individuals in the population has been "shifted" to the spring of the following calendar year.

As the result of adaptation to survival through the difficult conditions

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[1]) There have been, of course, cases of earlier sexual maturation of young shrews in the year of their birth. This phenomenon, depending on population dynamics, applies to a definite percentage of young females (Pucek, 1960; Stein, 1961; Schwarz, 1962). Spring reproduction is however of decisive importance to the species, irrespective of the role of earlier reproduction.

of the long winter period in the best possible condition specific physiological adaptive mechanisms have been formed, which are reflected in the far-reaching changes in many of the morpho-physiological indices.

Phylogenetic adaptation to survival under different climatic conditions may be either physiological, behavioural or morphological (P e a r s o n, 1962). These phenomena are manifested to a different degree in different species of mammals. It is also known that changes in the level of metabolism within a population of individuals of the same species do not involve changes in tissue metabolism, but in the whole organism of the animal (B e r t a l a n f f y & P i r o z y n s k i, 1953). Changes then take place in morphological structures without altering basic physiological processes (S c h w a r z, 1959b). In the light of studies so far discussed of the seasonal changes in shrews it would appear probable that it is primarily a question here of morphological adaptation in these small mammals.

Seasonal changes in shrews do not correspond to the processes observed in rodents adapted to cold (cf. H é r o u x, 1961; B a r n e t t, 1965). Adaptation to cold under laboratory conditions causes, e.g. increase in calorie production, and in consequence increase in food consumption and hypertrophy of certain internal organs. No such changes were observed in either shrews or rodents living under natural conditions (H é r o u x, 1961; S l o n i m, 1961; P e a r s o n, 1962). Shrews differ significantly from rodents in this respect. The winter reduction in metabolism in shrews is relatively slight (G ę b c z y ń s k i, 1965), which is probably the result of the considerable disturbance of ratio of bady surface to volume. With reduced body dimensions and weight in shrews in winter this ratio is less favourable and makes a change in the organism's energy requirements necessary. Energy losses are thus reduced to a minimum from both physical (B o r o w s k i, 1958; G ę b c z y ń s k i & O l s z e w s k i, 1963) and physiological aspects. Locomotory activity is reduced. Dimensions of body and organs decrease, which in consequence leads to favourable reduction of the relative food requirements (M e z h z h e r i n, 1964).

Are these changes, however, due only to food adaptation? It would be difficult to accept so simple an explanation of such universal seasonal changes, although this question has frequently been studied and discussed already (D e h n e l, 1949; M e z h z h e r i n, 1964). Depressive changes in shrews are manifested relatively early (in brain and skull — in July) when food conditions have not yet undergone any visible changes. It is not only a question here of the amount and quality of food, but also of its accessibility. This last factor may be decisive in causing the shrews to change a different kind of food, possible more energetic, in winter. This might balance to some degree insufficiency of food due both to the altered activity of invertebrates and to the decreased migratory activity of the shrews themselves in winter. It is thus clear that there are many aspects of this problem, which cannot be solved without accurate data on calorie values and abundance of the shrews' prey, and the degree to which these animals make use of their natural food supply. The question as to whether and to what degree food can determine processes of seasonal adaptation in shrews therefore requires further study.

Analysis of the seasonal changes presented shows that it is undoubtedly a question here of more complicated processes. The rhythm of the changes, governed by endogenous processes, is the expression of the seasonal changes taking place in the external habitat. Specific adaptations, mainly morphological, must be developed during the phylogenetic development of shrews which enable them to live over a wide geographical range.

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Zdzisław PUCEK

SEZONOWE I WIEKOWE ZMIANY CIĘŻARU NARZĄDÓW WEWNĘTRZNYCH U RYJÓWEK

Dokonano analizy zmienności względnych i absolutnych ciężarów dziewięciu narządów wewnętrznych ryjówki aksamitnej, *Sorex araneus* Linnaeus, 1758, w aspekcie indywidualnym, wiekowym i sezonowym. Liczny materiał (n = 655 okazów), z trzech kolejnych generacji 1960/61 — 1963/64, pochodził z jednego terenu — Białowieskiego Parku Narodowego. Narządy były ważone w stanie świeżym i odnoszone do ciężaru ciała brutto.

Indywidualna zmienność względnych ciężarów narządów jest różna (współczynniki zmienności wahają się w granicach 7—52%), i zależy od sezonu i wieku zwierząt (Tabele 1—8). Serce, nerki, wątroba są mało zmienne (V = 9—14%), zaś śledziona, nadnercza i brunatna tkanka tłuszczowa (BAT) są bardzo zmienne (V = 22—52%). Zmienność śledziony i nadnerczy jest dwukrotnie wyższa zimą niż latem. Na ogół poszczególne narządy są bardziej zmienne u przezimków niż u młodych.

Zależność względnego ciężaru narządu od ciężaru ciała uwidacznia się tylko w niektórych przypadkach (mózg, serce, nerki, wątroba — u młodych). Indeksy pozostałych narządów nie wykazują żadnych prawidłowych zależności od ciężaru ciała (Tabela 14).

Dymorfizm płciowy uwidacznia się tylko we względnych ciężarach mózgu i nadnerczy u młodych ryjówek (Tabela 14).

Ciężar ciała młodych ryjówek wzrasta latem, poczem maleje, od września do lutego o 32%. Wiosenny wzrost od lutego do maja-czerwca wynosi: u samców — 100%, a u samic — 129% (Ryc. 1).

Absolutne ciężary wątroby, nerek, śledziony, nadnerczy wykazują latem niewielkie przyrosty, poczem tracą na ciężarze. Niektóre narządy podlegają zmianom regresyjnym wcześniej (mózg, grasica BAT, gonady) lub nie zmieniają się aż do zimy (serce) — Ryc. 17.

Regresja jesienna absolutnych ciężarów narządów wyraźnie przyspiesza się od października.

Depresja zimowa w ciężarze śledziony, nadnerczy i wątroby jest silniej wyrażona

niż w ciężarze ciała (odpowiednie różnice wynoszą: 77, 52 i 34%). Mózg, nerki, BAT są zimą lżejsze o 20—23% (Tabele 1—8).

Wiosenny wzrost obejmuje wszystkie narządy, lecz uwidacznia się w różnym stopniu. Największe przyrosty wykazuje śledziona (49%) i wątroba (123%), mniejsze — nerki (70%), serce (59%), BAT (30%) i mózg (8%). Nadnercza osiągają prawie taką samą wielkość jak u młodych (samice) lub pozostają mniejsze (samce) — Ryc. 15, 17. Młode ryjówki, dojrzałe w pierwszym kalendarzowym roku życia nie podlegają skokowi wzrostowemu. Nie zawsze więc dojrzewanie płciowe jest stymulatorem wzrostu (Tabela 16).

Szybkie tempo regresji jesiennej i wiosennego skoku wzrostowego sprawia, że każdy z tych procesów w skali populacyjnej, trwa tylko około dwu miesięcy. Jesienne zmiany regresyjne, a zwłaszcza wiosenny wzrost przebiegają w różnych narządach bardzo synchronicznie.

Względne ciężary narządów (indeksy) wykazują większą różnorodność zmian sezonowych. Wskaźniki serca i BAT wzrastają w okresie zimowym a wiosną wracają do proporcji właściwych dla młodych. Mózg i nerki u młodych ryjówek, od lata do zimy, nie wykazują większych zmian, wiosną zaś tracą na względnym ciężarze. Indeksy wątroby, śledziony i nadnerczy zmniejszają się w okresie zimowym a u przezimków latem znów mają wartości zbliżone do takich u osobników młodych (Ryc. 18). Stwierdzono, że korelacje między ciężarem poszczególnych narządów a ciężarem ciała oraz między narządami, ulegają zmianom, zależnie od wieku zwierząt. Na ogół są one mniejsze u przezimków niż u młodych. Wyjątkowo współczynniki korelacji dla mózgu i BAT są wyższe u przezimków (Tabela 10). Wskazuje to na fakt, iż na przestrzeni życia ryjówek zmieniają się wewnętrzne proporcje organizacji ich ciała. Może to być wyrazem adaptacji tych ssaków do życia w określonych sezonem warunkach środowiskowych.

Stwierdzono istnienie różnic między poszczególnymi generacjami. Są one wyraźniej zaznaczone w ciężarze niektórych narządów wewnętrznych (wątroba, nerki — 10—12%; BAT — 25%; śledziona — 35%), intensywniej reagujących na warunki środowiskowe i populacyjne, niż w ciężarze ciała — 3—6% (Tabela 12). W generacji 1963/64 depresja zimowa zaznaczyła się najsilniej (Tabela 12).

Dyskutowane są różnice między wartościami wskaźników narządów u różnych gatunków *Soricidae* oraz przedstawicieli innych owadożernych i gryzoni (Tabela 15). Podkreślono ewentualne konsekwencje wykazanych zmian sezonowych dla wnioskowania o ewolucji *Insectivora,* na podstawie indeksów mózgu.

W oparciu o analizę sezonowych zmian ciężaru narządów wewnętrznych a także wyniki wcześniejszych prac, dotyczących zmienności wymiarów i ciężaru ciała, czaszki, mózgu, BAT, niektórych gruczołów układu dokrewnego jak też pewnych wskaźników fizjologicznych (metabolizm, aktywność, krew) wyróżniono siedem faz rozwoju postnatalnego ryjówek: I — rozwój gniazdowy; II — faza względnej stabilizacji letniej młodych; III — regresja jesienna; IV — depresja zimowa; V — wiosenny skok wzrostowy; VI — faza stabilizacji letniej przezimków; VII — faza regresji starczej. Jak widać, okresy intensywnego wzrostu przeplatają się z fazami stabilizacji a także gwałtownej regresji.

Czas trwania poszczególnych stadiów rozwojowych u ryjówek jest inny niż u pozostałych *Micromammalia.* Brak wogóle stadium, które można by nazwać *juvenis.* Stadium *subadultus* trwa bardzo długo, 6—9 miesięcy. Dojrzewanie płciowe następuje więc w drugiej połowie życia ryjówek. Stadia *adultus* i *senex,* trudne do wydzielenia, trwają nie dłużej niż 6—10 miesięcy. Ta nierównomierność rozwoju postnatalnego ryjówek jest, zdaniem autora, wynikiem specyficznej adaptacji, sezonowej, utrwalonej w rozwoju filogenetycznym