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Water Contents and Seasonal Changes of the Brain-weight in Shrews

[With 7 Tables and 3 figures]

The absolute and relative (in percentages of brain weight) lipids and fat-free dry rest contents in the brain of *S. araneus* were determined. The water content in the brain was determined from the difference between the sum of the above values and the weight of the fresh brain. Seasonal and age variations in the weight of the brain were found to occur realy in material which had not been fixed. Variations in the weight of water, lipids and dry rest were stated. These indices are smaller in the winter than in the summer by respectively 23.7%, 11.8% and 6.8%. The water content exhibits a relation in direct proportion to the mass of brain, i.e. a significant loss in the winter (of 3.8%) and repeat increase in old adults (in spring) was found. The dry rest is in reverse proportion to variations in water content. The lipids content is lowest in young adults in the summer, increases in the winter and spring, then decreases in old adults in the summer and autumn. These data indicate that seasonal variations in the brain weight of shrews are conditioned primarily by variations in water content, and also in fat-free dry rest and lipids contents.

I. INTRODUCTION

The phenomenon of seasonal variability in shrews, discovered by Dehnel (1949), has become a starting point for many elaborations, both morphological and physiological. The mechanism of seasonal variations in the height of the brain-case has been explained in studies by Pucek (1955; 1957). The suggestions made by this author (1955) that variations in the skull constitute a secondary phenomenon directly dependent on seasonal differences in the capacity of the brain-case, and in consequence in the volume of the brain, were confirmed in further studies of *Sorex minutus* Linnaeus, 1766 (Caboń, 1956) and *Sorex araneus* Linnaeus, 1758 (Bielak & Pucek 1960). Many authors have confirmed the occurrence of seasonal changes in the skull of shrews from different geographical areas and for the commoner species of the genus *Sorex* Linnaeus, 1758. The study by Pucek (1963) contains references to the above. Although the causes of seasonal variations in shrews have not as yet been explained, attempts have been made at elucidating these specific properties of those mammals (Dehnel, 1949; Mezhzherin, 1964).

The far-reaching variations in the weight and volume of the brain in shrews form an inducement to undertake more detailed and exhaustive research on the brain of these animals as a whole, and the morphological structure and biochemical composition in particular.

The aim of the present report is to trace the seasonal and age variations in the concentration of water and lipids and in fat-free dry rest contents in relation to the brain of shrews.

II. MATERIAL AND METHODS

A total of 456 common shrews, *Sorex araneus* Linnaeus, 1758, caught over a period of three full annual cycles (1961—1964) in the Białowieża National Park, were used for the investigations. The animals were usually dead, but fresh, when brought to the laboratory. Some of the shrews were alive, and these were anesthetized with ether pro narcosis. The animals were dissected as soon as possible after death, but this period might be as much as 6 hours in the cases in which dead shrews were brought from the forest.

The prepared brains were transferred on to a Petrie dish with 0.9% saline solution, both to rinse the brain clear of blood and to prevent the organs from drying up. After drying the excess fluid with blotting paper the brains were weighed on a semi-automatic analytical scale with accuracy of 1 mg, then fixed in 96% ethyl alcohol, in which they were kept at room temperature for a considerable period (not less than 1 month). The alcohol was not changed during this time. On account of the small dimensions the brains were not crushed for later extraction.

The procedure used to extract lipids from the brain was as follows: the brains were transferred to weighing glasses containing a mixture of absolute alcohol and benzol with ratio of 1:4 (Kreiner, 1954) and extracted at a temperature of 40°C for 48 hours. This proved to be sufficient time to dry the brains and determine their weight. Several extractions were made of one series of brains (N — 20) but no significant loss in weight of the dried brains was found after successive extractions. It was therefore taken that a single extraction of lipids in the mixture given above is sufficient for organs of their size.

The alcohol from the test tubes in which the brains were fixed was poured into separate glasses, the test tubes throughly rinsed with 96% alcohol which was added to that previously poured into the glasses. The whole was evaporated in a thermostat at a temperature of 40°C. The sediment constituted the main mass of lipids, to which the sediment sometimes remaining on the bottom of the glasses after extraction of the brains in alcohol with benzol was added. The weight of lipids (L) and dry rest (DR) obtained in this way, subtracted from the weight of the fresh brain (BW) made it possible to calculate the water content (CW) according to the formula:

$$CW = BW - (DR + L)$$

The material from all the study years was treated jointly and considered during the life cycle of the shrews, separately for young adults and old adults [1]). For certain comparisons 3 groups were distinguished: 1 — young adults from the summer (June—August) aged 1—3 months, 2 — young adults from the winter (January—March) — aged from 6—10 months, old adults from the summer months (June—August) aged from 10—15 months. This division made it possible in certain cases to use a greater amount of material for comparing results. There is, however, no doubt that this arrangement of the material reduced the differences between the mean values of the various groups in comparison with the mean values for the extreme months. Statistically significant results were, however, obtained. The significance of the differences was checked by the t-Student test of the differences in mean values for two independent groups.

III. RESULTS

1. Seasonal Variations in Absolute Values

The absolute values of the weight of fresh brain, water, lipids and dry rest are shown in Fig. 1 and Table 1. These data primarily permit of confirming the seasonal variations in brain weight described earlier, using material preserved in alcohol (Bielak & Pucek, 1960). It is, of course, well known that fixation in alcohol causes significant and not always uniform variations in the weight of internal organs (M. Pucek, in litt.). In the material described, although the character of the seasonal variations in the weight of the shrews' brains is preserved, yet the extent of the variations is different in the two cases. Thus the loss in weight of the brains fixed from the summer to the winter was, in the case of young shrews, 30% and increase from winter to summer 15.4% (Bielak & Pucek, l.c.). These differences are far smaller for fresh brains, the corresponding values being 20.9 and 5.3%. It is worthy of note that in both cases the differences between the weight of the fresh and fixed brain are non-uniform.

The curve of variations in weight of water contained in the brain tissue of shrews (Fig. 1) takes an almost identical course to that of the curve of weight of the fresh brain.

The absolute weight of lipids and dry rest differs from this. In particular the increase in dry rest in the shrews from June to September, while other indices decrease during this period, is interesting. Thus the absolute values of the mass of all the above-mentioned components of the brain exhibit significant seasonal and age variations, which, as is apparent later on, are not always in proportion to the size (weight) of the brain. This is clear even from the comparison of increases in percentage of the absolute

[1]) The authoress distinguished two main age groups: 1) young adult — caught from June, through the winter, to March, 2) old adults — which had lived through the winter, born the previous calendar year, and caught from April to December.

values of different indices between the summer (young adults) and the winter, and between winter and summer (old adults) (table 2) which are not uniform in all cases.

One hundred individuals were chosen at random from the three seasonal groups mentioned in the introduction (summer — young adults, winter — young adults, summer — old adults), and calculation made for these individuals only of the coefficients of correlation between the absolute values of weight of the brain components (Table 3). This table shows that the highest degrees of correlation are observed for water, especially in the

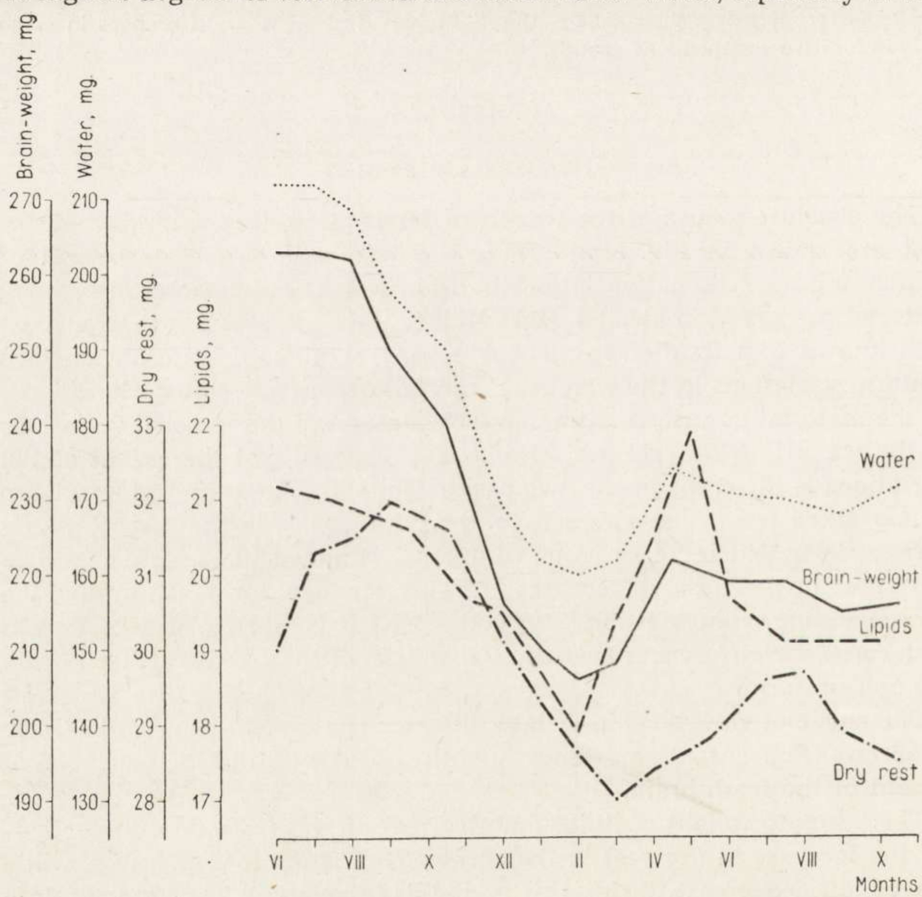

Fig. 1. Variations in mean monthly values of weight of brain, water, dry rest and lipids during the life cycle of the shrew.

young adults from the summer months (r = 0.92). Relatively the smallest connections exist between the weight of the fresh brain and of the dry rest in old adults (r = 0.44), and between the dry rest and lipids. In this latter case, in material from all three groups jointly r = 0.44 and in different seasons was: summer — young adults r = 0.569; winter — young

Table 1.
Variations in absolute values of weight of brain, water, dry rest and lipids.

Period and age group	N	Min.	Max.	Avg.	S. D.	V
Brain weight, mg						
VI - VIII, Young adult	71	219	318	263	19.39	7.4
I - III, Young adult	79	174	237	208	12.37	5.9
VI - VIII, Old adult	62	201	246	219	10.50	4.8
Water weight, mg						
VI - VIII, Young adult	68	170.5	253.0	211.3	17.0954	8.51
I - III, Young adult	75	133.4	183.8	161.2	9.6026	5.96
VI - VIII, Old adult	61	150.1	196.0	171.0	9.9779	5.84
Lipids weight, mg						
VI - VIII, Young adult	68	17.1	27.1	21.1	2.1112	3.20
I - III, Young adult	75	10.7	23.8	18.5	2.4519	13.21
VI - VIII, Old adult	61	16.3	24.3	19.5	1.8738	9.61
Dry rest weight, mg						
VI - VIII, Young adult	68	23.8	37.9	30.8	10.1159	32.84
I - III, Young adult	75	23.5	32.9	28.7	6.0289	20.99
VI - VIII, Old adult	61	26.0	34.0	29.1	5.5688	19.12

Table 2.
Variatitons in absolute weight of fresh brain, weight of water, dry rest and lipids (Percents of increases).

Difference between :	Brain	Water	Dry rest	Lipids
Summer, Young adult → Winter, Young adult	- 20.9	- 23.7	- 6.8	- 11.8
Winter, Young adult → Summer, Old adult	+ 5.3	+ 6.2	+ 1.4	+ 4.8
Summer, Young adult → Summer, Old adult	- 16.7	- 19.0	- 5.5	- 7.6

Table 3.
Coefficients of correlation for components of the brain (absolute values). Underlined values are statistically non-significant.

Period and age group	N	Brain / Water	Brain / Lipids	Brain / Dry rest	Dry rest / Lipids
VI - X, Young adult	100	0.92	0.48	0.16	
XI - III, Young adult	100	0.78	0.62	0.11	0.44*
IV - XI, Old adult	100	0.76	0.54	0.44	

* All groups together, n = 90.

adults r = 0.544; summer — old adults r = 0.081. From the above it will be seen that the relations between the mass of components of the brain and the weight of the fresh brain are variable within wide limits, depending on the age group and kind of component. In certain cases (e. g. dry rest in young adults from the summer and winter) they are statistically non-significant.

Calculation was next made of the indices which should characterize the relations between different components of the shrews' brain. The mean values of the weight of these components in different seasonal-age groups were taken as the basis for calculations. As can be seen from table 4, only the ratio of dry rest to lipids is ± a constant value in all the seasons. The

Table 4.
Reciprocal proportions of the components of the brain.

Index	Summer, Young adult N = 68	Winter, Young adult N = 75	Summer, Old adult N = 61
Water / Dry rest	6.85	5.61	5.88
Water / Lipids	10.00	8.66	8.77
Dry rest / Lipids	1.46	1.54	1.49

relation between water and lipids and between water and dry rest, on the other hand, exhibits considerable differences, the highest values being observed in the group of young adults from the summer. Differences between young adults from the winter and old adults are smaller. These results suggest that there must be seasonal variations in the percentage of water content on the one hand, and of lipids and dry rest on the other.

2. Variations in the Percentage of Water and Lipids Contents

Table 5 contains a comparison of the most important data characterizing seasonal fluctuations in the percentage of water, lipids and dry rest contents in the brain tissue of shrews. The course taken by curves of variability of these elements in different months of the shrews' life cycle is illustrated by Fig. 2. The material presented makes the following observations possible.

W a t e r. The concentration of water in the brain exhibits seasonal and age variations almost indentical with the variations in the weight of the fresh organ. The mean water content varies within limits of 80.23% (youn adults — summer) to 77.21% (young adults — winter). Both values differ by 3.76%, if we take as 100% the value for young adults from the

Table 5.
Variations in contents of water, fat-free dry rest and lipids (in %), depending on the season and age of the shrews.

	Month	Water						Lipids						Dry rest					
		N	Min.	Max.	Avg.	S.D.	V	N	Min.	Max.	Avg.	S.D.	V	N	Min.	Max.	Avg.	S.D.	V
Young adult	VI	31	77.98	83.67	80.50	1.5086	1.87	31	6.93	9.65	8.02	0.8077	10.07	31	9.07	13.65	11.39	1.0139	8.90
	VII	26	77.19	82.38	80.23	1.3434	1.68	26	6.28	9.30	7.76	0.7838	10.10	27	10.13	14.71	11.85	1.0545	8.90
	VIII	11	76.93	81.27	79.50	1.7321	2.18	11	7.20	10.94	8.56	0.3472	4.06	11	10.92	13.10	11.88	0.7836	6.60
	IX	46	75.28	82.80	78.80	3.1543	4.00	46	6.62	11.26	8.28	0.9004	10.87	47	10.54	14.10	12.62	0.8023	6.26
	X	22	76.47	80.88	78.41	1.0193	1.30	21	7.55	9.67	8.41	0.5827	6.93	22	12.23	14.72	13.20	0.6901	5.23
	XI	25	77.28	80.38	78.86	0.9522	1.21	25	6.87	9.16	8.06	0.6602	8.19	25	12.01	13.76	13.00	0.5416	4.17
	XII	16	75.48	79.31	77.38	1.3102	1.69	16	7.94	10.63	8.92	0.9152	10.26	19	12.73	15.17	13.65	0.7435	5.45
	I	29	75.71	80.60	77.12	1.2654	1.64	29	7.10	10.45	9.03	0.6853	7.59	31	12.43	15.20	13.88	0.5254	3.78
	II	30	75.04	79.88	77.40	1.3222	1.71	30	7.06	10.68	8.67	0.9706	11.19	30	13.06	15.67	13.83	0.6425	4.64
	III	16	74.15	79.66	76.95	1.3686	1.78	16	7.81	12.19	9.20	0.4743	5.16	16	12.53	14.91	13.62	0.7019	5.15
Old adult	IV	23	75.64	79.66	77.46	1.1474	1.48	23	7.81	11.58	10.98	1.0227	9.31	28	12.33	15.09	13.04	0.8057	6.18
	V	14	76.58	80.41	78.00	1.3445	1.72	14	8.01	10.60	9.52	0.7126	7.48	14	11.33	14.49	12.59	0.7641	6.07
	VI	36	74.81	79.65	77.86	1.1504	1.48	36	7.31	11.37	8.97	0.3118	3.48	37	11.93	14.74	13.04	0.6243	4.79
	VII	6	76.26	79.83	77.85	1.0266	1.32	5	7.58	10.08	8.71	0.1575	1.81	7	12.23	14.47	13.51	0.6728	4.98
	VIII	17						17						17					
	IX	32						32						32					
	X	4	76.54	79.96	77.88	0.9353	1.20	5	6.53	10.23	8.76	0.8456	9.65	6	12.09	14.08	13.20	0.4744	3.59
	XI	3						3						3					

summer, and like those between winter and summer (old adults) are highly statistically significant (Table 6). The water content in the brain of old adults which had lived through the winter period and were in the phase of sexual activity (June — August) is higher than in the winter (I—III), but lower in comparison with the mean values for young adult shrews from the corresponding period.

D r y r e s t. The dry rest, treated here as the dry mass of brain minus lipids, exhibits almost exactly the reverse behaviour to the water content (Fig. 2). The mean monthly values are lowest during the summer in young

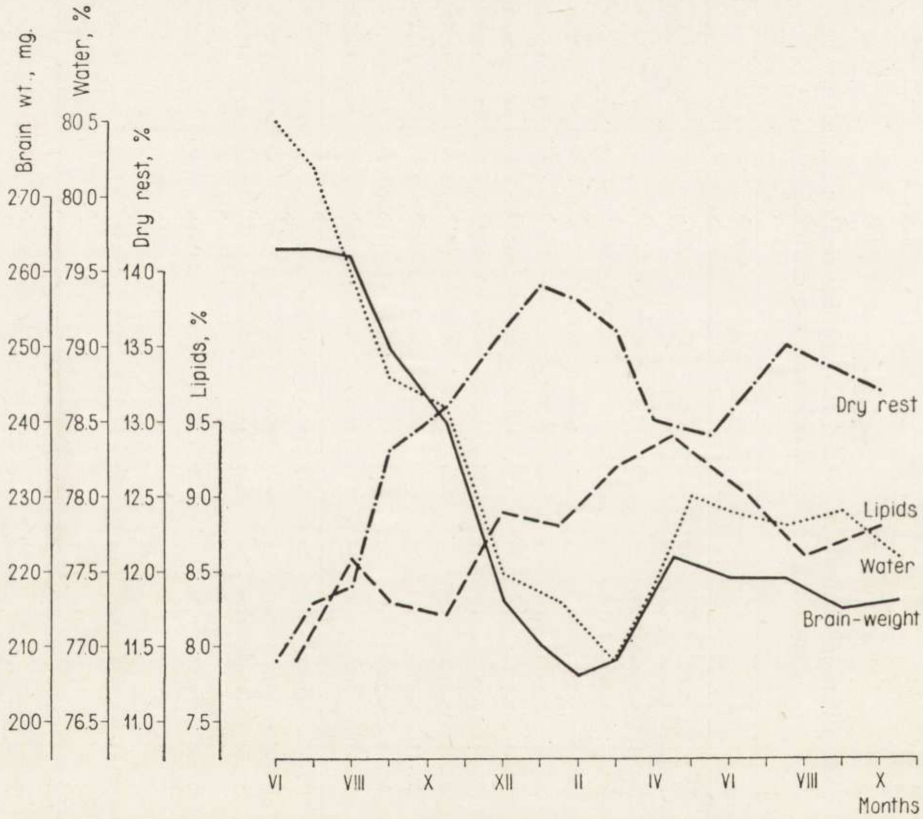

Fig. 2. Variations in the mean monthly values of contents of water, lipids and fat-free dry rest during the life cycle of the shrew.

adults (11.4—11.9%), increase in the winter (13.6—13.9%) then decrease in old adults in the summer (13.0—13.5%). These differences are always statistically significant (Table 6). The contrariety of these variations in relation to the weight of the fresh brain is evidenced by the differences expressed in approximately the same values of increase or decrease but in the reverse direction (Table 6).

Lipids. The concentration of lipids does not exhibit such distinct seasonal differences as were observed in the case of water content and dry rest. The lowest values are noted in young adults in the summer (7.7—8.6%), followed by an increase of lipids content, only interrupted during the period from September to November. Maximum values are attained in the old adults in the spring, in March, April and May. The respective monthly means are then 9.2, 9.4, and 9.5%. This increase does not take place evenly, as is indicated by the bend in the curve in Fig. 2 in different months. It is, however, obvious that during the winter no decrease is observed here in the lipids content in the brain tissue of shrews, in fact the very opposite, there is an increase of 11.5% in relation to the young adults from the summer (Table 6). In old adults, as from

Table 6.
Variations in the weight of the fresh brain (g) and contents of water, dry rest and lipids (%).

Difference between :	Brain		Water	
	%	t	%	t
Summer, Young adult ⟶ Winter, Young adult	- 20.9	$t > P_{0.001}$	- 3.76	$t > P_{0.001}$
Winter, Young adult ⟶ Summer, Old adult	+ 5.3	$t > P_{0.001}$	+ 0.84	$t > P_{0.01}$
Summer, Young adult ⟶ Summer, Old adult	- 16.7	$t > P_{0.001}$	- 2.95	$t > P_{0.001}$
	Lipids		Dry rest	
	%	t	%	t
Summer, Young adult ⟶ Winter, Young adult	+ 11.11	$t > P_{0.001}$	+ 18.63	$t > P_{0.001}$
Winter, Young adult ⟶ Summer, Old adult	- 0.11	$t < P_{0.05}$	- 4.34	$t > P_{0.01}$
Summer, Young adult ⟶ Summer, Old adult	+ 10.99	$t > P_{0.001}$	+ 13.48	$t > P_{0.001}$

June, the concentration of lipids in the brain decreases and in the autumn is only 8.7% (Fig. 2, Table 5). It may therefore be stated that the lipids content in general increases with the age of the shrews, but only up to a certain period. Individual variations in the lipids content are relatively great, as is also expressed in the highest coefficients of variation (circa 11%, Table 5). In relation to the variability of water content the values of this coefficient for lipids are almost 6 times higher, and in the case of dry rest — twice higher. Thus no very close relation is obtained between the concentration of lipids and weight of the fresh brain (Fig. 3, Table 7).

Thirty individuals were selected from each seasonal-age group and diagrams made illustrating the relation between weight of the fresh brain and percentage contents of water, dry rest and lipids (Fig. 3). This is of course a simplification in relation to analysis of the whole material, which

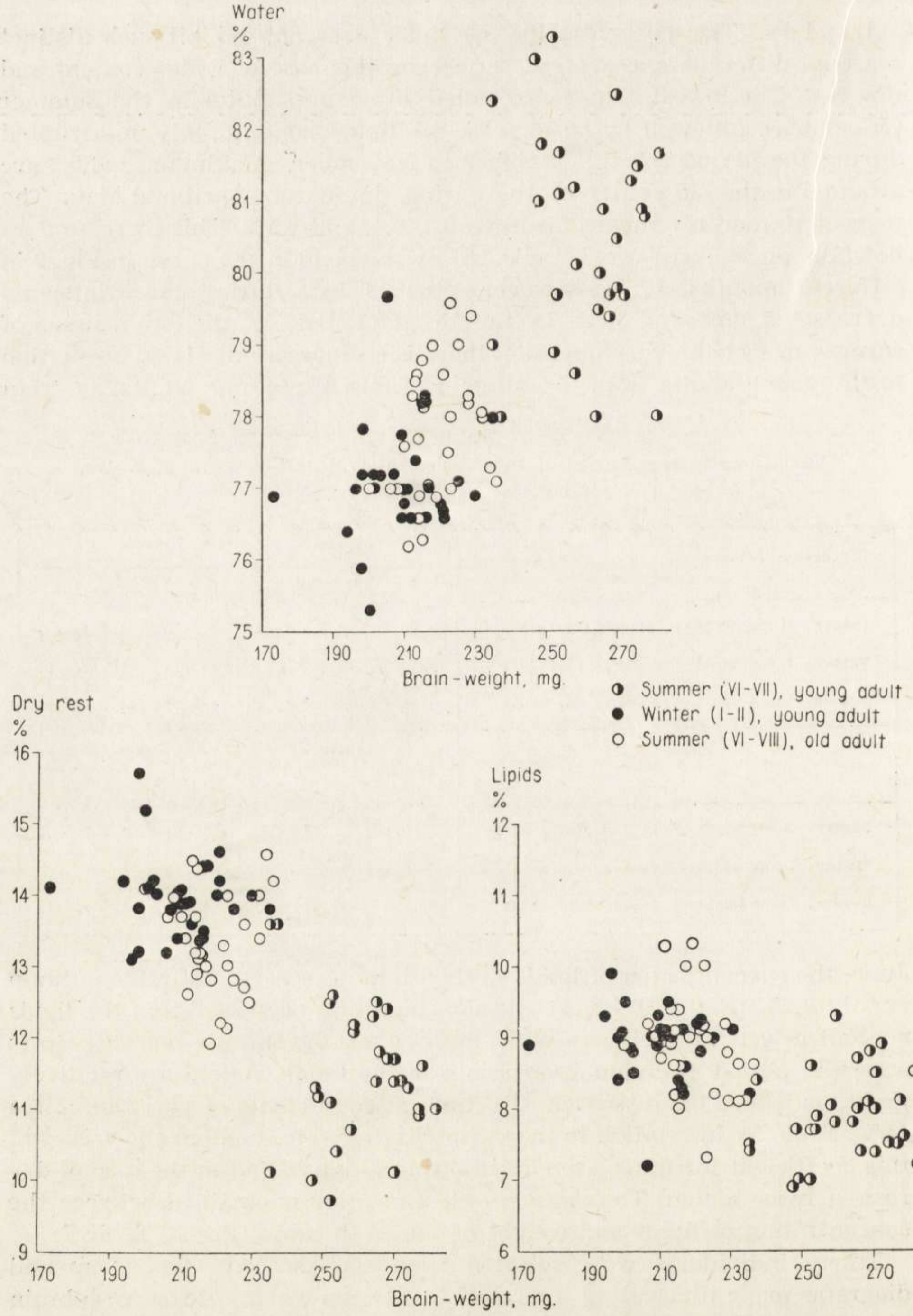

Fig. 3. Dependence of water, dry rest and lipids contents on the weight of the fresh brain.

in our case was extensive. It can be seen from the diagrams given that in all three cases the various groups, especially the young adults from the summer, are clearly distinct from each other. Within each of the groups correlation is far smaller than for the whole of the material (all three groups jointly) and in almost all cases non-significant (cf. Table 7). From this it is clear that despite the general positive or negative dependence of concentration of the various components of the grain on the weight of the

Table 7.

Values of the coefficient of correlation between the percentage of content of different components of the brain and the mass of fresh brain.

Period and age group	N	Water / Brain	Lipids / Brain	Dry rest / Brain
VI, VII, Young adult	30	- 0.05	0.20	- 0.05
I, II, Young adult	30	0.19	- 0.16	- 0.09
VI, VII, Old adult	30	0.31	- 0.40	- 0.04
All groups together	90	0.867	- 0.581	- 0.721

fresh organ, we are chiefly concerned here with the effect of seasonal variations. These variations affect to different degrees the various components, as is evidenced by the different strength of the connection which exists between them and the mass of the brain. The highest degree of dependence is exhibited by water content. The coefficient of correlation for all the age groups jointly ($N = 90$) is: $r = 0.867$. The dry rest and lipids content are in reverse proportion to the weight of the fresh brain and exhibit a lesser degree of correlation. Coefficient r is respectively: —0.721 and —0.581 (Table 7, Fig. 3).

IV. DISCUSSION

The results presented throw a certain light on the problem of seasonal variations in the brain of *Sorex araneus*. The method accepted is somewhat rough, not too precise from the biochemical point of view (alcohol extracts different lipids and most probably also washes out certain non-lipid substances), yet it nevertheless makes it possible to draw the attention of research workers to the direction in which further research on the causes of such deep seasonal variations in shrews should be made.

The whole question has two aspects, since 1 — seasonal variations and 2 — age variations are interrelated here. It is impossible to exclude one of them in the case of animals living in the wild state. The young adults from the winter are undoubtedly at least a half a year older than the young adults from the summer and simultaneously remain under the influence of the action of the habitat conditions in this period. The case is similar with the old adults.

The present investigations indicate that the seasonal variations in the weight of the brain and possibly, of other internal organs also are due primarily to the dehydration of these organs during the winter. Dehydration of the brain here is reversible, since in the spring we observe a signifacant increase in the whole body of the shrews and, in many of the internal organs, including the brain. The increase in the weight of the fresh brain is not, it is true, as great as in the case of body weight, and as a result the relative weight of the brain decreases in old adults in comparison with young adults (Pucek, 1965). The water content in the brain tissue is also found to be greater in spring than in winter but lower than in young adults from summer (Fig. 2).

These variations agree to a considerable extent with the results obtained by Górecki (1965). This author showed that the percentage of water content in the tissues of shrews (samples from whole animals) is lowest in the winter together with the early spring (64.79%), slightly higher in the autumn (66.94%) and highest in the summer (69.10%). The differences between summer and winter would undoubtedly be higher if this author had distinguished between young and old adults. In the latter, as shown by the results presented, the total concentration of water is certainly lower than in young adults.

Dehydration of the tissues was also found in *Peromyscus leucopus noveboracensis* (Fischer, 1829), living under natural conditions (Sealander, 1951). Losses in the percentage of water content in the tissues of this species were, however, slight. In the case of laboratory animals, such as rats or hamsters, acclimatised to cold, completely opposite results were obtained, i. e. an increase was noted in the relative water content in the tissues (Héroux, 1961; Barnett, 1965, giving appropriate references). The statement made by Barnett (1965) that it would be difficult to connect seasonal variations with the results obtained for animals acclimatised to cold under artifical conditions, would appear justified.

The results presented here in relation to variations in water content create a real basis for the hypothesis put forward earlier by Dehnel (1949) who suggested that seasonal variations in the body weight of shrews may be due, among others, to loss or intake of water by the tissues.

It might be concluded that the curve of content of fat-free dry rest and lipids, in reverse proportion to water, is merely the result of the variations which take place in water content. This is not, however, the case. Variations in water content are of course most correlated with variations in the weight of fresh brain, but other components of the brain tissue, that is, lipids and fat-free dry rest, which are absolutely less in the winter than in the summer, are also subject to seasonal variations (Fig. 1, Table 1).

It would seem that the lipids content in the brain tissue of shrews increases during the winter period only as the result of its dehydration. Similar results were also obtained in experimental work on rodents acclimatised to cold (H é r o u x, 1961; B a r n e t t, 1965). On the other hand it may be possible that this increase of the lipids contents is connected with myelinisation of the brain tissue with age (K r e i n e r, 1954). The increase in fat-free dry rest content during the winter is partly connected with the ash content, which was determined in shrews by G ó r e c k i (1965). This author showed that in the winter the tissues of shrews, treatly jointly, contain more mineral substances per gramme of body than in the summer and autumn, both in young and old adults. This points to the fact that in the winter not only does dry mass content as a whole increase but also mineral substances and certainly also protein content, and once again suggest general dehydration of the tissues in shrews. Hence the increase in the caloric value of the shrew's tissues in the autumn and winter (G ó r e c k i, l.c.) is understandable. It is a characteristic fact here that the quentitative ratio of different components of the brain tissue to water is disturbed during the winter and does not return in old adults to the state observed in young adults.

The ratio of dry rest to lipids, the most fundamental elements of the brain on account of its physiological functions, remains constant throughout the shrew's whole life. This would point to an absence of variations which might restrict the functions of the brain. It may, however, be assumed that the shrew's organism as a whole functions less intensivelly during the winter. This is borne out by G ę b c z y ń s k i's (1965) investigations in which he showed that during the winter the general level of the shrew's metabolism is lower than in the summer. Bearing in mind the amount of oxygen consumed per gramme of body it was found that the mean values of this index run parallel to the variations in the weight of the brain, that is, are highest in young adults in the summer, and lowest in the winter. In old adults they do not attain the level they do in young adults, but are higher than in the winter. It would therefore seem that the morphological variations observed in the weight of the brain or in other organs are a reflection of physiological transformations, the general expression of which is the level of metabolism of these animals. Dehydration of the tissues in shrews during the winter is greater than might be expected from the variations connected with the age of these animals. Dehydration of the tissues may therefore be an expression of the specific reaction of these small animals to the conditions of the winter period, a process enabling them to survive the winter over the area of a very wide geographical range with great amplitude of climatic conditions.

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ZAWARTOŚĆ WODY A SEZONOWE ZMIANY CIĘŻARU MÓZGU U RYJÓWEK

Streszczenie

Oznaczano absolutne i względne (w procentach masy mózgu) zawartości lipidów i suchej pozostałości poekstrakcyjnej w mózgu *S. araneus*. Z różnicy między sumą wymienionych wartości a ciężarem mózgu świeżego — określano koncentrację wody w mózgu. Potwierdzono występowanie sezonowych i wiekowych zmian ciężaru mózgu na materiale nie utrwalanym. Wykazano zmiany ciężaru wody, lipidów i suchej pozostałości. Wskaźniki te są w zimie mniejsze niż latem odpowiednio o: 23.7%, 11.8% i 6.8% (Ryc. 1, Tabele 1, 2, 5).

Procentowa zawartość wody wykazuje zależność wprost proporcjonalną do masy mózgu, tj. istotny ubytek (o 3.8%) w zimie i ponowny wzrost u przezimków (Tab. 6).

Sucha pozostałość zachowuje się odwrotnie proporcjonalnie do zmian koncentracji wody (Ryc. 2, 3).

Zawartość lipidów jest najniższa u zwierząt młodych latem, rośnie u ryjówek zimą i na wiosnę, poczym maleje u przezimków z lata i jesieni (Ryc. 2).

Dane te wskazują, że sezonowe zmiany ciężaru mózgu ryjówek są uwarunkowane przede wszystkim wahaniami koncentracji wody, a także suchej pozostałości i lipidów.