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Tissue Metabolism in the Common Shrew and the Bank Vole*

[With 3 Tables & 3 Figs.]

Examination was made of oxygen intake rate by homogenates of the liver, kidneys, heart, skeletal muscles and brown adipose tissue (*BAT*) in the common shrew *Sorex araneus* L i n n a e u s, 1758 and in the bank vole *Clethrionomys glareolus* (S c h r e b e r, 1780). The animals investigated were divided into 5 seasonal and age groups: young in summer, autumn and winter, old adults in spring and summer; and differential microrespirometers were used for the experiments. Season and age variations were found in oxygen intake (μl O_2/1 mg of dry mass hour) in different tissues in both species of animals. The course taken by variations in this index differs in the tissues examined and is different in each species. Maximum metabolic activity (*MA*) of the organs (ml O_2/kg $^{0.75}$ hour) is exibited in shrews in winter, but in voles in spring. *BAT* in the two species has a different course of *MA* variations than in the other tissues. The average value of *MA* of the organs is higher in shrews than in voles: it is 8.9% higher for the liver, 23.2% higher for kidneys, 36.1% higher for the heart and 64.8% higher for *BAT*. A correlation was found between the indexes obtained and other morphological and physiological parameters obtained in earlier studies. The connection between tissue metabolism and variations in general metabolism is discussed.

I. INTRODUCTION

Data are to be found in literature on the value of metabolism in shrews. P e a r s o n (1948) assumed that metabolism is higher in shrews than in other mammals of similar body size and weight. Later studies (H a w k i n s, J e w e l l & T o m l i n s o n, 1960) failed to reveal any fundamental differences between the metabolism of the shrew, and that of mice or voles, but G ę b c z y ń s k i (1965, 1971) found that the metabolism of shrews is in fact higher than might have been expected on the strength of the known relation between the size of an animal and its metabolic rate. In addition he drew attention to seasonal variations in the metabolism of shrews, directly connected with the individual's

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life cycle. Seasonal and age variations in the metabolism of shrews are correlated with variations in morphological and physiological indexes specific to this species (P u c e k, 1965, 1970). Variations in different biomorphological indexes and metabolism in voles have been discussed *inter alia* by G r o d z i ń s k i (1961), K u b i k (1965), V i s i n e s c u (1965).

The whole complex of morphological and physiological variations may be considered as the expression of adaptational processes enabling the two species of animals to occur over so broad geographical range. As adaptation is manifested in all levels of organization of the animal organism it should also be reflected at the tissue level. It is a known fact that the metabolism of an animal constitutes the sum total of the metabolism of its cells or tissues and that the metabolic activity of different tissues is not uniform, in consequence of which the participation of the various tissues in the metabolism of the whole animal is not in direct proportion to the participation of the mass of the given tissue in the organism. Considerable similarity was found between the metabolism of tissues *in vitro* and the metabolism of the whole animal, expressed both in similar dependence of the metabolic rate of the tissues of a given animal on body size, and also in the considerable similarity in the sum total of tissue metabolism and basic metabolism (J u s i a k & P o c z o p- k o, 1969). As long ago as 1948 P e a r s o n suggested that the higher metabolic rate in shrews as compared with other mammals of similar size is connected with high tissue metabolism, although this was not confirmed later (R e d m o n d & L a y n e, 1958).

It was therefore decided to examine the rate of oxygen intake by the tissues of shrews and voles *in vitro* and to compare the metabolic octivity of the organs of these animals. Endeavour was made to find the answer to the question as to whether the metabolic activity of tissues is also subject to seasonal and age variations, and whether there is a correlation between these indexes and the other morphological and physiological parameters which have been studied previously.

II. MATERIAL AND METHOD

The animals used for the experiments were caught in the Białowieża National Park from the summer of 1970 to the summer of 1972. Trapping areas were set up in the following biotopes: *Tilio-Carpinetum* and *Fraxino-Ulmetum*. A total of 111 individuals of *S. araneus* and 102 of *C. glareolus* were caught and used for the studies. After arrival in the laboratory the animals were placed in cages and given food and water *ad libitum*, and were used for the experiments from 1—2 days after their capture. When dividing the animals into seasonal and age groups their biology was taken into consideration, as the seasonal changes in the organism of these animals coincidental with age changes affect the indexes examined. The following were distinguished for both species: young individuals caught in summer

(July-August), autumn (September-October) and winter (December-February) and sexually mature old adults caught in spring (April-May) and summer (July-August) of the following calendar year.

The animals were anaesthetized with ether, weighed and their age and sex determined, after which they were dissected and the liver, kidneys, heart, skeletal muscles of the whole hind leg and brown adipose tissue (*BAT*) isolated. After the blood had drained from them the tissues were weighed. Krebs-Ringer solution was used as an incubation medium, composed as follows: 100 parts of 0.9% NaCl solution+4 parts of 1.15% KCl and 3 parts of 1.22% $CaCl_2$+1 part of 3.82% $MgSO_4$+ + 12 parts of 0.10 M phosphate buffer with pH 7.4. The tissues were homogenized with the addition of the incubation solution, using 0.5 ml to 100 mg of fresh mass of tissue, in a Potter homogenizator at a temperature of about 0°C for 1—3 minutes (1000 revs. min). The homogenates were kept at a temperature of approx. 0°C until measurements were begun. 0.3 ml of the homogenate was taken for measurements, *i.e.*, about 50 mg of wet mass of tissue.

Measurements were made by means of differential microrespirometers of the Drastich type as modified by Klekowski (Klekowski, 1968). During the measurements the microrespirometers were immersed in a water bath at a temperature of 37±0.1°C. After the thermostat had operated for 10 minutes recordings were made of oxygen consumption by the homogenates every 5 minutes for 45 minutes. Results were converted to standard conditions *i.e.* 0°C and 760 mm Hg. On completion of the measurements the dry mass of the samples was determined by drying at a temperature of 105°C for 24 hours. Results were converted to µl O_2/l mg of dry mass/hour (Q_{O_2}). In order to compare the metabolic activity (*MA*) of the organs of the two species of animals the results obtained were then calculated for the interspecies metabolic unit of body weight and given in ml O_2/kg $^{0.75}$ hour.

Comparison of the statistical significance of differences between average values of Q_{O_2} and average values of *MA* of all the shrew and vole tissues examined in seasonal and age groups was made by means of variance analysis and a new multiple range test (Oktaba 1966). Comparison of the *MA* of organs between the species was made using the Student *t* test.

III. RESULTS

1. Variations in Weight of Body and Internal Organs

Table 1 contains averages, standard deviations and coefficients of variaton of body weight and relative weights of the internal organs of shrews and voles. In general no deviations from the variation of the parameters previously described (Pucek, 1965) were found in the case of shrews, but the very high absolute and relative weight of *BAT* is remarkable. The maximum index of BAT occurs in young summer shrews, but the highest average values of the indexes for kidneys and heart were found in young shrews in winter with simultaneous minimum average body weight. The liver index underwent the smallest variations. The voles used for the experiments were heavier than the weights given by Kubik (1965) for animals caught between 1946—1955. Maximum body weights were found in adult voles in the spring. Young voles in winter have slightly reduced body weight (by 2.8%) in relation to the body weight of young in autumn. Average relative organ weights of voles in seasonal and age groups are also subject to variations. The highest index for liver and heart is found for young voles in winter, for the kidneys — in old adults in spring, but for *BAT* in old adults in summer. Within the groups of the two species examined the relative

Table 1

Seasonal and age variations in body weight and relative weights of internal organs (in per cent of gross body weight).

Season & age	Body wt., g Avg.±S.D. (n) CV	Relative weights of organs: Liver Avg.±S.D. (n) CV	Kidneys Avg.±S.D. (n) CV	Heart Avg.±S.D. (n) CV	*BAT* Avg.±S.D. (n) CV
			Sorex araneus		
Summer young ad.	7.95±0.85 (40) 10.7	7.63±1.62 (20) 21.2	1.84±0.23 (25) 12.3	1.12±0.16 (20) 14.7	8.53±4.87 (23) 56.9
Autumn young ad.	7.09±0.86 (25) 12.1	7.24±1.03 (24) 14.2	1.66±0.40 (20) 24.4	1.19±0.20 (22) 16.8	3.38±1.72 (24) 50.9
Winter young ad.	6.24±0.57 (18) 9.1	7.60±0.99 (16) 13.1	2.16±0.39 (17) 18.1	1.26±0.17 (16) 10.8	2.32±0.91 (12) 39.3
Spring old ad.	8.79±1.39 (18) 15.8	7.52±1.16 (17) 15.4	1.89±0.27 (18) 14.5	1.17±0.04 (18) 3.2	2.07±1.04 (15) 50.1
Summer old ad.	10.97±1.04 (10) 9.7	7.11±0.68 (10) 9.5	1.65±0.06 (10) 3.8	1.14±0.14 (10) 12.1	2.90±0.93 (10) 32.2
			Clethrionomys glareolus		
Summer young	13.39±1.71 (27) 12.7	6.48±0.73 (15) 11.3	1.67±0.18 (15) 10.7	0.77±0.13 (15) 16.8	0.68±0.25 (15) 39.6
Autumn young	15.47±1.82 (19) 11.8	6.26±0.12 (17) 19.0	1.32±0.17 (17) 13.6	0.76±0.08 (18) 10.5	1.05±0.43 (16) 40.7
Winter young	15.03±1.29 (22) 8.6	7.83±0.94 (22) 12.0	1.40±0.19 (22) 13.9	0.91±0.04 (22) 4.4	0.95±0.34 (22) 25.7
Spring adult	19.95±4.10 (19) 20.6	7.15±1.21 (19) 16.9	1.71±0.22 (19) 12.9	0.83±0.09 (19) 10.8	0.61±0.37 (19) 54.1
Summer adult	18.44±2.12 (15) 11.5	6.02±0.87 (10) 14.4	1.64±0.21 (10) 12.0	0.59±0.05 (10) 8.5	1.97±0.39 (10) 18.0

weight of *BAT* is characterized by the greatest individual variation, whereas the relative weight of the heart is the smallest.

Despite the greater body weight and absolute weights of organs in voles as compared with shrews, the average relative weights of organs are higher in shrews in all the seasonal and age groups.

2. Variations in Tissue Metabolism

The greatest differences between average values for Q_{O2} of the various tissues, in both shrews and voles, occur in young individuals in summer, and the smallest differences, in the case of shrews, in old adults in spring, and voles — in winter (Fig. 1A). It is possible to distinguish three groups of tissues according to the course taken by seasonal and age variations in Q_{O2} in the shrew tissues examined (Tab. 2):

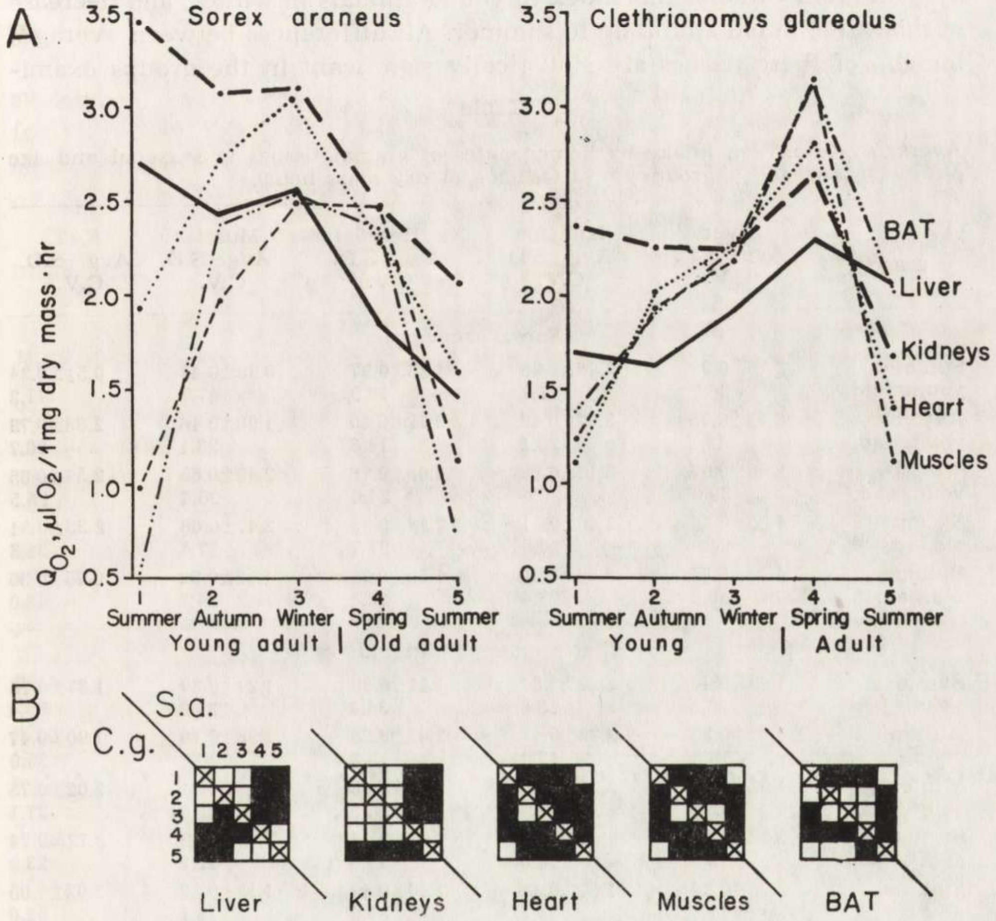

Fig. 1. Seasonal and age variations in oxygen intake rate (Q_{O_2}) by tissues of both species of animals in seasonal and age groups (A) and comparison of statistical significance of differences between average Q_{O_2} values for seasonal and age groups of shrews tissues (*S.a*) and vole tissues (*C.g.*) (B). Significant differences are indicted in black, with $\alpha=0.05$.

(1) Liver and kidneys: with maximum average value of Q_{O2} in young animals in summer, reduction in this value in autumn, then a slight increase in winter, and abrupt decrease in old adults in spring until the minimum value of Q_{O2} is reached in old adults in summer. The maximum statistically significant difference between average values of Q_{O2} for

these tissues occurs between young animals and old adults in summer (Fig. 1B);

(2) Muscles — heart and skeletal: these are characterized by rapid increase in the value of Q_{O2} in young animals from summer to winter, by maximum value of this index in young animals in winter, and decrease in this value in old adults up to summer. All differences between averages for Q_{O2} of these tissues are statistically significant in the groups examined, apart from young animals and old adults in summer, and in the case of skeletal muscles, apart from the difference between young animals in winter and old adults in spring;

Table 2

Average rate oxygen intake by homogenates of animal tissues in seasonal and age groups (in µl O_2/1 mg of dry mass hour).

Season & age	Liver Avg.±S.D. C.V.	Kidneys Avg.±S.D C.V.	Heart Avg.±S.D. C.V.	Muscles Avg.±S.D. C.V.	*BAT* Avg.±S.D. C.V.
			Sorex araneus		
Summer young ad.	2.70±0.98 36.2	3.46±0.96 27.7	1.93±0.37 18.9	0.98±0.47 47.7	0.51±0.24 47.2
Autumn young ad.	2.43±0.75 31.1	3.07±0.62 20.1	2.72±0.40 14.6	1.98±0.46 23.1	2.38±0.73 30.7
Winter young ad.	2.56±0.97 38.0	3.10±0.88 28.4	3.08±0.76 24.6	2.49±0.65 26.4	2.54±0.65 25.5
Spring old ad.	1.85±0.46 24.8	2.46±0.51 20.5	2.28±0.50 21.7	2.47±0.68 27.4	2.35±0.81 34.3
Summer old. ad.	1.45±0.74 50.9	2.06±0.48 23.4	1.59±0.37 23.4	1.12±0.38 34.2	0.75±0.36 48.0
			Clethrionomys glareolus		
Summer young	1.69±0.40 23.5	2.38±1.01 13.8	1.11±0.39 35.4	1.24±0.39 31.9	1.37±0.76 55.4
Autumn young	1.62±0.30 18.5	2.25±0.41 18.2	2.02±0.25 12.3	1.93±0.40 20.7	1.90±0.47 25.0
Winter young	1.92±0.44 22.6	2.24±0.49 21.9	2.27±0.60 26.5	2.18±0.51 23.6	2.02±0.75 37.1
Spring adult	2.30±0.32 13.9	2.64±0.61 23.0	2.81±0.42 14.8	3.15±0.42 13.2	3.12±0.74 23.9
Summer adult	2.06±0.24 11.8	1.67±0.38 23.1	1.40±0.49 35.2	1.12±0.22 18.1	2.02±1.05 52.0

(3) *BAT:* exhibits a high average value of Q_{O2} in: autumn, winter and spring periods and low value in summer in young animals and old adults. No statistically significant differences were found between average values of Q_{O2} in young animals and old adults in summer, but highly significant differences occur between Q_{O2} for these two groups and Q_{O2} in the other groups of shrews.

In voles the maximum averages for Q_{O2} of all the tissues examined occur in old adults in spring. On account of the course taken by variations in this parameter it is possible to distinguish 2 groups of tissues:

(1) Liver and kidneys: are characterized by reduction in value of Q_{O2} in young animals in autumn in relation to summer (in the case of kidneys until the winter). Maximum values for tissue metabolism are attained in spring, followed by a repeat reduction in this index in summer. No statistically significant differences were found between averages for Q_{O2} for these tissues in young voles. The metabolism of kidneys differs significantly only when old adults in summer are compared with averages of Q_{O2} for all the remaining groups;

(2) Muscles and *BAT:* metabolism increases in young animals to reach maximum values in old adults in spring. This is followed by an abrupt

Table 3

Metabolic activity of animal organs in seasonal and age groups (in ml O_2/kg $^{0.75}$ hour). S. a. — *Sorex araneus*, C. g. — *Clethrionomys glareolus*, *P* — comparison of statistical significance of differences between species in groups using the Student *t* test: — $P>.05$ + $.01<P<.05$, ++ $.001<P<.01$, +++ $P<.001$.

Season & age		Liver Avg.±S.D.	*P*	Kidneys Avg.±S.D.	*P*	Heart Avg.±S.D.	*P*	*BAT* Avg.±S.D.	*P*
Summer	S.a.	17.90±5.99		6.12±2.10		1.71±0.61		6.24±4.84	
young	C.g.	11.09±2.95	+++	4.28±2.17	+	0.68±0.34	+++	0.81±0.48	+++
Autumn	S.a.	17.77±7.91		4.43±1.39		2.72±0.72		8.63±3.69	
young	C.g.	11.57±2.93	++	3.23±1.01	++	1.43±0.44	+++	2.30±0.93	+++
Winter	S.a	20.37±6.63		7.03±2.17		3.71±1.08		8.44±3.76	
young	C.g.	17.38±4.61	—	3.28±0.80	+++	2.08±0.53	+++	2.50±1.15	+++
Spring	S.a.	16.81±3.66		4.83±1.52		2.77±0.80		6.70±4.68	
adult	C.g.	21.27±5.49	+	5.85±1.18	+	2.45±0.30	—	2.32±1.23	+++
Summer	C.g.	10.19±3.23		3.35±0.83		1.61±0.31		2.82±1.21	
adult	C.g.	15.23±3.18	++	3.88±1.92	—	0.88±0.57	++	5.09±3.80	—
Total	S.a.	17.22±6.72		5.35±2.11		2.55±1.06		6.91±5.35	
	C.g.	15.69±5.67	—	4.11±1.47	+++	1.63±0.80	+++	2.43±2.00	+++

decrease in the value of this index in old adults in summer. No statistically significant differences were found between averages of Q_{O2} of these tissues in young voles and old adults in summer. In general it may be said that the most highly statistically significant differences for averages of Q_{O2} for the groups of voles examined were found in the case of muscle tissues.

3. Metabolic Activity

Owing to formulation of results of oxygen intake by organs in ml O_2/kg$^{0.75}$ hour, which has been termed metabolic activity (*MA*), it is possible to compare these values, regardless of differences in the body weight of the two species of animals (Table 3). The ratio in percentages of the average *MA* values for the various organs of both species of animals in the seasonal and age groups to the maximum *MA* for each organ is set out in Fig. 2A.

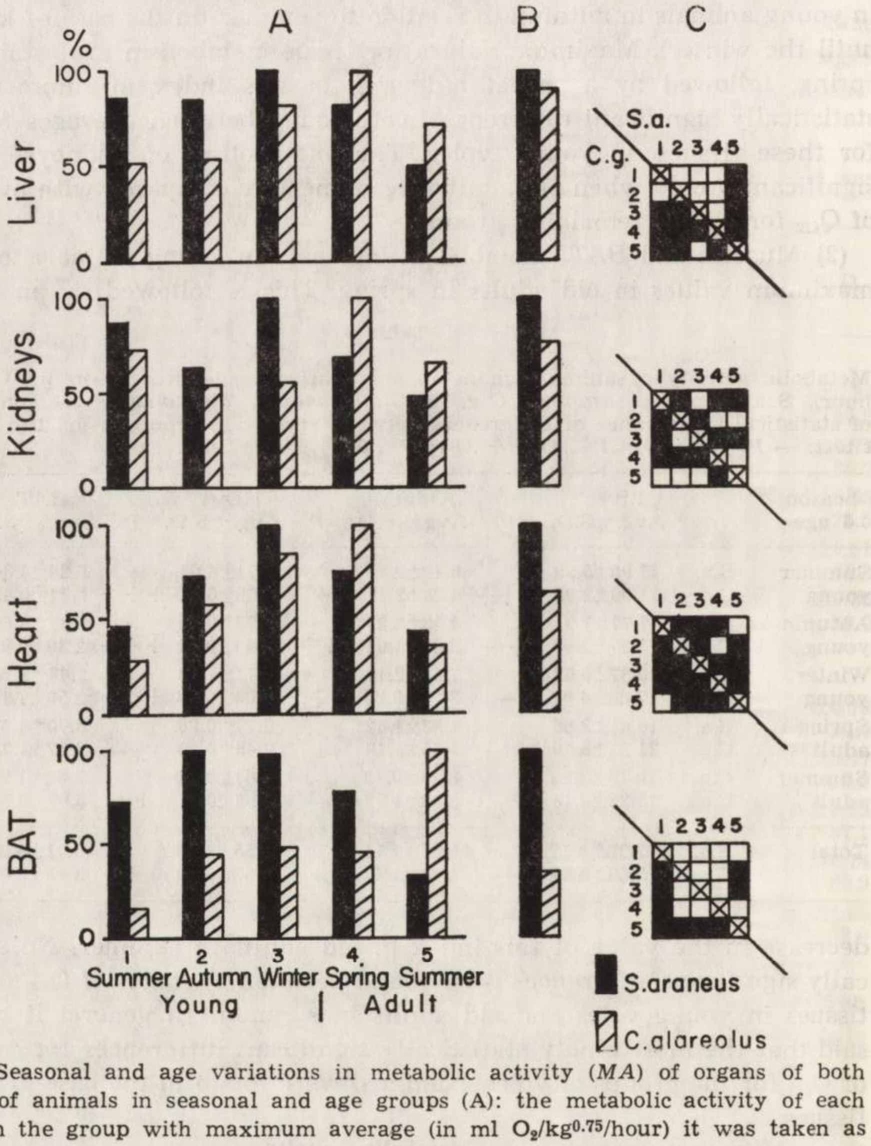

Fig. 2. Seasonal and age variations in metabolic activity (*MA*) of organs of both species of animals in seasonal and age groups (A): the metabolic activity of each organ in the group with maximum average (in ml $O_2/kg^{0.75}$/hour) it was taken as 100%. Comparison of average of *MA* for various organs for all the individuals of *S. araneus* and *C. glareolus* examined (B): *MA* of each organ in shrews taken as 100%. Comparison of statistical significance of differences between average values of MA in shrew and vole organs in the seasonal and age groups (C). Symbols as for Fig. 1B.

Maximum *MA* values for shrew organs occur in young animals in winter (in the case of *BAT* also in young animals in autumn) and decrease in a different rate with the animal's development until the lowest value of this parameter is reached in old adults in summer. The decrease of *MA* values in young animals in autumn, comparing to summer occur in kidneys only. Maximum reductions from these averages of *MA* values of all shrews, occur in old adults in summer (in the case of the liver by 40.8%, kidneys by 37.4%, heart by 36.9% and *BAT* by 59.2%), and maximum increase — in young individuals in winter (for liver by 18.3%, kidneys by 31.4%, heart by 45.5% and *BAT* by 24.9%). The most highly statistically significant differences between average *MA* values for shrew organs in the different groups were found for the heart, and the least for *BAT* (Fig. 2C).

In the case of voles the *MA* of the liver, *BAT* and heart increases as the animal develops. The maximum values of this index for the liver, kidneys and heart occur in old adults in spring, then decrease in different rate in old adults in summer. The metabolic activity of *BAT*, however, increases in young voles in winter in comparison with this value in young animals in summer, then decreases in old adults in spring, to increase very intensively in old adults in summer (maximum value). Maximum increase from average *MA* values of the various organs for all the voles examined takes place in old adults in spring (liver by 35.6%, kidneys by 42.3%, heart by 50.3%) and in the case of *BAT* in old adults in summer (by 109.4%) while maximum decreases occur in individuals in different groups for the various organs (summer, young — liver by 29.4%, heart by 46.1% and *BAT* by 66.7%, autumn, young — kidneys by 21.5%). The most highly statistically significant differences between average *MA* values for the vole organs in the groups studied were found in the case of the heart.

Average metabolic activity for all the organs examined in young individuals is higher in shrews than in voles. In old adults in spring the *MA* of the liver and kidneys is higher in voles, but that of the heart and *BAT* — in shrews, while with old adults in summer only the *M*A of the heart is higher in shrews than in voles.

Comparison of the significance of differences between average values for the various shrew and vole organs in the seasonal and age groups and between averages for all individuals of *S. araneus* and *C. glareolus* are given in Table 3 and Fig. 2. Differences between the *MA* averages of organs for all the shrews and voles examined are highly statistically significant in the case of the kidneys, heart and *BAT* ($P < .001$), but not significant in the case of the liver ($P > .05$). Average metabolic activity is 8.9% higher in shrews than in voles in relation to the liver, 23.2% to the kidneys, 36.1% to the heart and by as much as 64.8% higher in the case of *BAT* (Fig. 2B).

IV. DISCUSSION

The results of this study permit of concluding that the rate of oxygen intake by tissues in vitro in both the species of animals examined is subject to seasonal and age variations.

Tissues playing an important part in metabolism — the liver and kidneys, are distinguished by a high level of Q_{O2} and similar character of variations in this index. It is remarkable that variations of this index for the both tissues are parallel to seasonal and age changes in the general metabolism of the animals (Fig. 3). It is likely that the factors which determine metabolic level *in vivo* are also present in tissues outside the organism, which agrees with the suggestions made by Kleiber (1941). After making allowance for seasonal and age changes in the body weight of the animals and absolute weights of the liver and kidneys it was found that the *MA* values of these organs are also subject to similar changes. Higher metabolic activity was found for these two organs in shrews than in voles, but it must be emphasised that the *MA* values of these organs are higher in shrews in the young individuals of this species, but in voles, in the sexually mature individuals. Young shrews have maximum *MA* of the liver and kidneys in winter, and old adults voles in spring. These results can be compared with the other indexes of these organs which were examined previously, and which can be dependent upon or may affect changes in metabolic rate. Hyvärinen (1968) found maximum activity of alkaline phosphatase in the kidneys of shrews in winter, but in the kidneys of voles in spring. The activity of this enzyme was, however, higher in shrews over the course of the whole year. Redmond & Layne (1958) also found that the metabolic rate of the kidneys is lower in *Reithrodontomys humulis* than in *Cryptotis parva*. The results obtained by Hyvärinen (1972) on changes in copper content in the liver of shrews over the yearly cycle are also interesting. This author observed an increase in Cu content from September to December-February, followed by an abrupt decrease in subsequent months. As copper in the organism is an activator of many enzymes (including cytochromic oxydase) differences in the contents of this microelement in the liver may be connected with changes in metabolic activity. The cytochrome c content in very active tissues is a good indicator of their metabolic rate. Hyvärinen & Pasanen (1973) stated that the cytochrom c content in the liver and kidneys of shrews is twice as great as that in voles and is subject to seasonal variations in a similar way to the other indexes discussed. Variations of many indexes of the liver and kidneys are probably closely connected with the specific changes in the general metabolism specific to each of the species examined.

The other tissues from shrews and voles exhibit seasonal and age changes in metabolism of a different character from those of the liver and kidneys. In the case of the heart, the directly proportional agreement of changes in relative weight, Q_{O2} and *MA* in shrews and Q_{O2} and *MA* in voles is remarkable. All the indexes obtained for the heart in each seasonal and age group of the animals are higher in shrews than in voles.

The rate of oxygen intake by the skeletal muscles is similar in voles to the Q_{O2} of the organs (heart and *BAT*), but in the case of shrews such

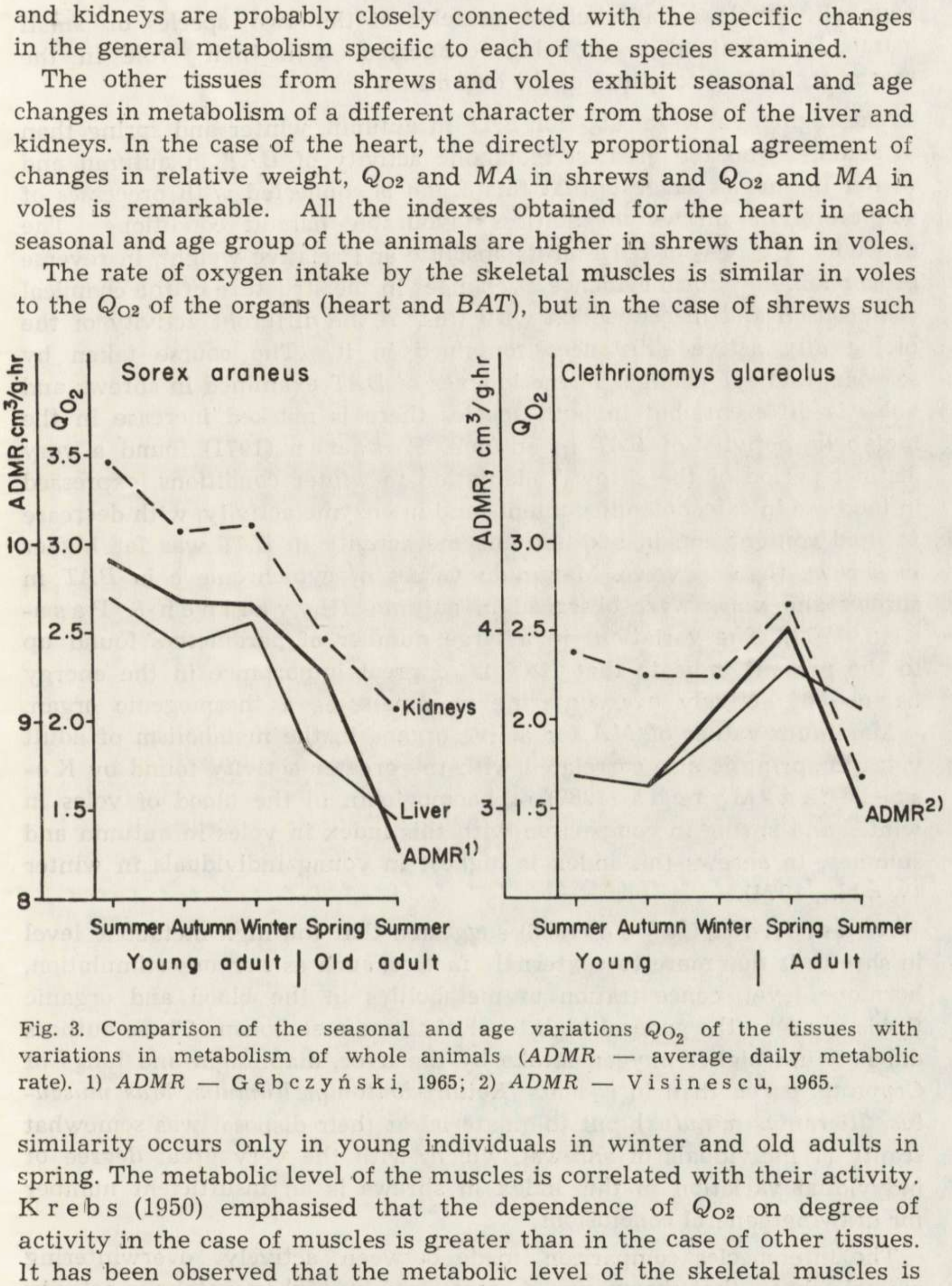

Fig. 3. Comparison of the seasonal and age variations Q_{O_2} of the tissues with variations in metabolism of whole animals (*ADMR* — average daily metabolic rate). 1) *ADMR* — Gębczyński, 1965; 2) *ADMR* — Visinescu, 1965.

similarity occurs only in young individuals in winter and old adults in spring. The metabolic level of the muscles is correlated with their activity. Krebs (1950) emphasised that the dependence of Q_{O2} on degree of activity in the case of muscles is greater than in the case of other tissues. It has been observed that the metabolic level of the skeletal muscles is higher in small than in large rodents (Isaakjan, Makarova & Ščeglova, 1968), hence it may be concluded that in general the high metabolic level of the skeletal muscles of the two species of small mammals examined is probably connected with their role in the thermoregulating reactions of the organisms.

The higher values of Q_{O2} for *BAT* in autumn, winter and spring than in summer and the greatest metabolic activity of *BAT* in autumn and winter in shrews suggests that this organ is connected with processes of adaptation of shrews to the less favourable habitat conditions. The dependence of Q_{O2} of *BAT* on its absolute and relative weight, in reverse proportion, may form evidence of changes in the structure of the chemical composition and in connection with this, of the different activity of the biologically active substances contained in it. The course taken by seasonal and age changes in the indexes of *BAT* examined in shrews and voles is different, but in both species there is marked increase in the metabolic activity of *BAT* in autumn. Pasanen (1971) found a very distinct period of the shrews' adaptation to winter conditions, expressed in increase in catecholamin contents and in enzyme activity, with decrease in lipid content and in addition enzyme activity in *BAT* was far higher in shrews than in voles. Maximum values of cytochrome c in *BAT* in shrews and voles were observed in autumn (Hyvärinen & Pasanen, 1973). The variations in a large number of parameters found up to the present indicate that *BAT* is of great importance in the energy balance of actively overwintering mammals, as a thermogenic organ.

Maximum values of *MA* for active organs in the metabolism of adult voles in spring is also correlated with the greater activity found by Kostelecka-Myrcha (1967) of haemoglobin in the blood of voles in winter and spring in comparison with this index in voles in autumn and summer. In shrews this index is highest in young individuals in winter (Wołk, 1974).

Redmond & Layne (1958) suggested that the high metabolic level in shrews is due more to »external« factors, such as nervous stimulation, hormone level, concentration of metabolites in the blood and organic fluids, than by the general high level of tissue metabolism. These authors did not find higher oxygen intake by the liver, diaphragm and lungs of *Cryptotis parva* than in rodents (*Reithrodontomys humulis, Mus musculus, Micromys minutus*), but the material at their disposal was somewhat scanty (7 individuals of shrews), which, with the very great degree of indyvidual variation in this index in shrews is an insufficient number for drawing general conclusions.

The interspecies comparison made between actively overwintering animals shows that shrews are characterized by higher metabolic activity of organs *in vitro* than are voles. It must be emphasised that the greatest difference in metabolic activity occurs in *BAT*, which is of great importance in the organism's energy balance.

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METABOLIZM TKANKOWY U *SOREX ARANEUS* LINNAEUS, 1758 I *CLETHRIONOMYS GLAREOLUS* (SCHREBER, 1780)

Streszczenie

Dokonano analizy zmienności tempa pobierania tlenu (Q_{O_2}) przez homogenaty tkanek (wątroby, nerek, serca, mięśni szkieletowych i brunatnej tkanki tłuszczowej) ryjówki akasmitnej *S. araneus* i nornicy rudej *C. glareolus* w aspekcie sezonowo-wiekowym. Zwierzęta badano w 5 grupach: młode latem, jesienią i zimą, przezimki wiosną i latem. Doświadczenia przeprowadzano przy pomocy mikrorespirometrów różnicowych. Stwierdzono zmienność sezonowo-wiekową Q_{O_2} (μl O_2/1 mg suchej masy/godz.) badanych tkanek u obu gatunków zwierząt (Tab. 2, Ryc. 1). Wyodrębniono grupy o podobnym przebiegu zmienności Q_{O_2}. Podkreślono różnice w przebiegu zmienności Q_{O_2} grup tkanek u ryjówek i nornic.

Przeprowadzono również analizę zmienności aktywności metabolicznej (*MA*) organów (ml O_2/kg$^{0.75}$/godz.) obu gatunków zwierząt (Tab. 3, Ryc. 2). Maksymalną wartością *MA* organów charakteryzują się młode ryjówki zimą, natomiast nornice przezimki wiosną. Brunatna tkanka tłuszczowa różni się pod względem przebiegu zmienności *MA* od innych tkanek. Średnia wartość *MA* jest wyższa u ryjówek w porównaniu z nornicami w przypadku wątroby o 8.9%, nerek o 23.2%, serca o 36.1% i *BAT* o 64.8%.

Otrzymane wyniki są skorelowane z wcześniej otrzymanymi parametrami morfologicznymi i fizjologicznymi u obu gatunków zwierząt. Zmienność Q_{O_2} wątroby i nerek jest równoległa do zmian sezonowo-wiekowych metabolizmu ogólnego tych zwierząt (Ryc. 3). Przedyskutowano zależność między metabolizmem tkanek a zmiennością metabolizmu ogólnego, specyficzną dla każdego gatunku. Podkreślono rolę brunatnej tkanki tłuszczowej jako organu mającego istotne znaczenie w ekonomice energetycznej organizmu aktywnie zimujących ssaków.