A C T A T H E R I O L O G I C A

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Variations in the Hematological Parameters of Shrews

[With 5 Tables & 7 Figs.]

Examination was made of the morphological parameters and also the blood volume and osmotic resistance of erythrocytes in 548 representatives of 5 species of the sub-family *Soricinae (Insectivora)* caught from 1969—1972 in the Białowieża National Park, and also the hematological parameters of 22 nestlings of *Sorex araneus* Linnaeus, 1758, born in the laboratory. Nestling shrews are characterized by intensive increase in the number, and simultaneous decrease in the diameter, of erythrocytes. After leaving the nest Hb, *RBC* and Hct values continue to increase for about 5 weeks of independent life, *i.e.*, until the time when these parameters attain the values characteristic of physiologically mature individuals. From October to January and February there is an increase in Hb, *RBC* and Hct values and in the total number of erythrocytes. The winter depression in the body weight of shrews is also accompanied by reduction in absolute blood volume. A marked increase in the total number of erythrocytes and absolute blood volume is observed in old adults in spring. Relative blood volume is a constant value in shrews throughout their life. The diameter of blood cells and their consequent volume and *MCH* value are greatest in summer and smallest in winter. The osmotic resistance of erythrocytes reaches maximum values in summer and minimum in winter. In addition to characteristic changes due to season and age, the blood of shrews is distinguished by a high hemoglobin level and a number of erythrocytes constituting a record among mammals. This number decreases with increase in the average body weight of the various species of shrews, with simultaneous increase in the diameter of *RBC*.

1. INTRODUCTION

The numerous studies made in recent years of the blood of small mammals, particularly rodents, have dealt with the family *Soricidae (Insectivora)*, to a slight degree only. Schwarz (1955) and Koržuev & Koreckaja (1962) obtained results on the blood morphology of several individuals of *Sorex minutus*, *Sorex araneus* and *Neomys fodiens* caught in summer, and Kostelecka-Myrcha (1973) examined 19 individuals of *Sorex araneus* from November. The blood of single representatives of the *Soricidae* family: *Blarina brevicauda*, *Sorex fumeus*, *Sorex cinereus* and *Cryptotis parva* was examined by Sealander (1964) and Dunaway & Lewis (1965). An attempt was made at grasping seasonal variations in the hematological parameters of *Sorex araneus* by Kunicki-Goldfinger and Kunicka-Goldfinger (1964) but these authors did not as a rule give the age of the animal or the season in which they were caught.

The question of variations in the blood of shrews is extremely important in view of the exceptional character of the ecological and physiological properties of these animals. In connection with the phenomenon of seasonal and age morphological variations which has been found in shrews (Dehnel, 1949, 1951; Pucek, 1963, 1965, 1970) the question arises as to how such blood parameters as number and size of *RBC*, hemoglobin level, and blood volume, synchronize with such variations. Shrews are amongst the smallest mammals, but their metabolism is higher than could be expected to result from the relation between this index and the size of the animal (Morrison & Pearson, 1946). Gębczyński (1965) considers that the cause of this phenomenon is to be found in the very small body measurements of shrews and in the kind of food they consume. On the strength of the close connection between the level of metabolism and the respiratory function of hemoglobin, a higher hemoglobin content might be expected in these animals, or the existence of other mechanisms requiring its respiratory function.

The purpose of the study was therefore to investigate seasonal and age regularities in variations in the hematological parameters of shrews and water shrews belonging to the sub-family *Soricinae*, with particular emphasis on one representative, namely *Sorex araneus*, and also description of the morpho-physiological picture of the blood in these primitive mammals, which have not as yet been thoroughly investigated from the hematological aspect.

2. MATERIAL AND METHODS

Studies were made of a total of 473 individuals of *Sorex araneus* Linnaeus 1759, including in this number 22 young animals still in the nest (8 produced by females covered in the laboratory and 14 by females already pregnant when brought in from the forest), while the remainder represented all periods of the life cycle of shrews (354 young animals and 97 old adults). Details of the hematological parameters in selected periods of the life cycle of the remaining species of *Soricinae* were obtained for 31 individuals of *Sorex minutus* Linnaeus, 1776, 1 individual of *Sorex caecutiens* Laxmann, 1788, 13 individuals of *Neomys anomalus* Cabrera, 1907 and 42 individuals of *Neomys fodiens* (Pennant, 1771). *S. caecutiens* and *N. anomalus* are species most infrequently trapped in the Białowieża Forest, and consequently only a small number of individuals were obtained for these studies. The animals were segregated into young and old adults, depending on the appearance of the coat, degree of wear of the teeth and degree of development of the gonads (Dehnel, 1949; Pucek, 1960).

The animals were caught in the Białowieża Primeval Forest, chiefly in a stand of *Tilio-Carpinetum* (Traczyk, 1962) during the period from August 1969 to July 1972, using metal pitfalls and live traps, the latter, containing bait in the form of bread fried in oil, being used mainly in winter. The animals were caught in every month in the year, although the greatest difficulty was encountered in winter. Despite this 78 common shrews and 7 lesser shrews were caught during the period from December to the end of February. As we had no winter method of catching water shrews, this deficiency was partly remedied by keeping the group of five individuals caught earlier through the period from November or December until February in cages out of doors, thus ensuring that there was access to natural climatic conditions (Wołk, 1969).

The animals were taken directly after capture to the laboratory, placed in cages in which the bottom was covered with moss and given food in the form of minced beef, chiefly liver, spleen and lungs, with the additioʊ of chicken meat, fish, eggs and sprouting wheat, also water *ad libitum*.

The interval between catching the animal and beginning studies on it varied from several hours to well over a day, but only exceptionally was 3—7 days. Endeavour was made to reduce stress-creating factors to a minimum when carrying out the studies (Wołk, 1970a). The sex and age of animals and their body weights were determined at the time blood was taken from them.

The degree of parasitization of the shrews was also ascertained taking into consideration the macroscopically visible parasites of the body cavity and, when blood volume was determined, also parasites of the alimentary tract. Since, however, no connection was found between the state of parasitization and level of blood parameters (cf. Bezubik & Turner, 1964) this problem was omitted when elaborating results, as it was accepted, after Kisielewska (1970), maintenance under natural conditions of the balance between the host and parasite populations as the best form of specificity attained by the given »host-parasite« synecological system.

Blood was taken between 8.30 and 11.00 a. m. in order to avoid 24-hour variations in the morphological composition of the blood, and from animals anaesthetized with ether and always from the jugular vein. Hemoglobin content (Hb, g%) in 100 ml of blood was determined by means of a Zeiss hemometer. In order to calculate the number of erythrocytes (*RBC*, mln/mm^3) blood samples $^2/_5$ times smaller in volume than usually were taken, then diluted with Hayem's reagent, and when calculating results allowance was made for the necessary correction for dilution of the blood. This technique was used for a very large number of *RBC*. The diameter of erythrocytes (2R, μ) was measured with a Zeiss micrometric eye-piece on smears stained by Pappenheim's method. Fifty red blood cells were measured for each individual after establishing that there were no important differences between the averages calculated for different groups of 50 cells from preparations of the blood of 3 animals. The hematocrit index (Hct, %) was determined by the microhematocrit method, centrifuging blood taken into heparinized tubes for 9 min. at 6,500 revs. per minute.

On the basis of data obtained by the methods given above and after establishing the homogeneity of the erythrocyte population calculation was next made, using Wintrobe's formulae (1944) of: average hemoglobin content in a blood cell (*MCH*, $\gamma\gamma - 10^{-12}$g), average concentration of hemoglobin in a blood cell (*MCHC*, %) average volume of blood cell (*MCV*, μ^3) and average thickness of cell (μ).

In addition total blood volume was defined in 77 individuals of *Sorex araneus* (59 young and 18 old adults) by the extraction method, expressing it in millilitres (absolute volume) and in millilitres per 100 g of body weight (relative volume). The extraction method is based on comparison of the amount of hemoglobin in the peripheral blood and in a known volume of filtrate obtained by compressing the chopped carcass of the animal.

The resistance of *RBC* was determined in 30 common shrews, composed of 17 young and 13 old adults, in 6 young water shrews and in 4 old adults of lesser shrews, by the classic method, using a large number of hypotonic solutions of sodium chloride in concentrations decreasing every 0.02%. Two concentrations of NaCl were taken into consideration: (a) that in which hemolysis begins (minimum resistance) and (b) in which total hemolysis has taken place (maximum resistance).

Changes in hematological parameters in nest period of *Sorex araneus*, from 1 to 9 days old, were traced in 22 animals. On account of their small dimensions (the body weight of newborn common shrews is about 300 mg), and the consequent small amount of blood, these studies did not include all parameters in each individual. The relation between the value of the various parameters and the age of the animals was defined by means of linear regression equation. The significance of deviations of regression lines from the axis on which the age of the shrews was plotted was checked by means of the *t* test.

In the case of mammals, the life span of which under natural conditions is at most 18 months, and which in addition attain sexual maturity in the second calendar year of life (Dehnel, 1949, Borowski & Dehnel, 1953) it is practically impossible to distinguish between age and seasonal variations as they overlap, and consequently these kinds of variations were considered jointly.

Variations in blood parameters in common shrews from field conditions were examined in samples from populations distributed in accordance with the animals' life cycle (cf. Dehnel, 1949, Borowski & Dehnel, 1953), *i.e.*, from June one year in which the first youngs appear in traps, through autumn and winter until September of the following calendar year. The term young adult was applied to animals caught between June to the end of February, *i.e.* before the onset of the spring jump in growth and the first phase of sexual maturation. From March to Decembre they were termed old adults, *i.e.* animals born the previous year. Only 3 old adults were obtained during the period from October to December, since this is the period during which natural death takes place.

The average values of blood parameters calculated in principle for the various months, were taken as a basis for comparison of seasonal variations in the blood of common shrews. The data obtained on young adults in August and September and in January and February were combined, as there were no significant differences between them. On account of the small number of animals data for old adults in June and July and in August and September were also combined.

The average values were defined using confidence intervals and coefficients of variation. The generally small confidence intervals show that the number of individuals was sufficient for statistical calculations. Average values were compared by means of the Student t test for two independent groups.

3. RESULTS

3.1. Description of Blood in Nestlings

Variation in the morphological parameters of blood in nestling shrews (Table 1) consists in gradual and significant ($.01 < P < .02$) increase in the number of *RBC* (Fig. 1 A) and in marked ($P < .001$) reduction of their diameter (Fig. 1 B). In newborn animals the number of erythrocytes (4.29 mln/mm^3) is about five times smaller than in adults. The small number of *RBC* in 2 five-day old individuals (Fig. 1A), the mother of which died 5 days later, is remarkable. It is possible that the female's poor condition caused anaemia in its young.

Table 1

Variations in morphological blood indices for the nestlings of the common shrew. Number of samples is given in brackets.

Age, days	Hb g%	*RBC* 10^6/mm^3	Hct %.	*RBC* diam. μ	*RBC* thick, μ	*MCV* μ^3	*MCH* $\gamma\gamma$	*MCHC* %
1	—	4.29(3)	41.8 (3)	7.88 (3)	1.87 (3)	95.07 (3)	—	—
3	—	3.17 (1)	—	7.87 (3)	—	—	—	—
		4.32 (1)						
5	—	5.27 (4)	46.0 (4)	6.62 (4)	2.09 (3)	84.54 (4)	—	—
8	—	6.07 (5)	32.0 (3)	5.66 (3)	2.19 (3)	53.45 (3)	—	—
9	12.2 (1)	6.28 (1)	—	5.66 (1)	—	—	19.43 (1)	—
	13.8 (1)	—	39.0 (1)	5.85 (1)	—	—	—	35.38 (1)

The diameter of these cells, which is approx 3 μ greater in one-day old shrews than that of cells in adult individuals (cf. Table 1 and 2) rapidly decreases during the first nine days of life. As the thickness of cells does not in principle change, although it is slightly greater than in adult individuals (cf. Tables 1 and 2), the decrease in the volume of erythrocytes is due to the decrease in their diameter.

Numerous nuclear forms of juvenile *RBC* and polychromatic erythrocytes occur in blood smears from one-day old shrews.

3.2. Seasonal and Age Variations in the Morphological Composition of Blood

No differences were found in the morphological composition of blood between males and females in young common shrews during the period after leaving the nest, but certain differences, which are discussed below, were found in old adults.

Young common shrews in June, after leaving the nest, are characterized by more than double the number of erythrocytes found in nine-day old young animals still in the nest. As the diameter of *RBC* decreases by over 1 μ during this period, their volume and *MCH* value also decreases, while Hb level increases very slightly during the second half of the time spent in the nest (cf. Tables 1 and 2). When considering further changes in different hematological parameters the low values of Hb, Hct and

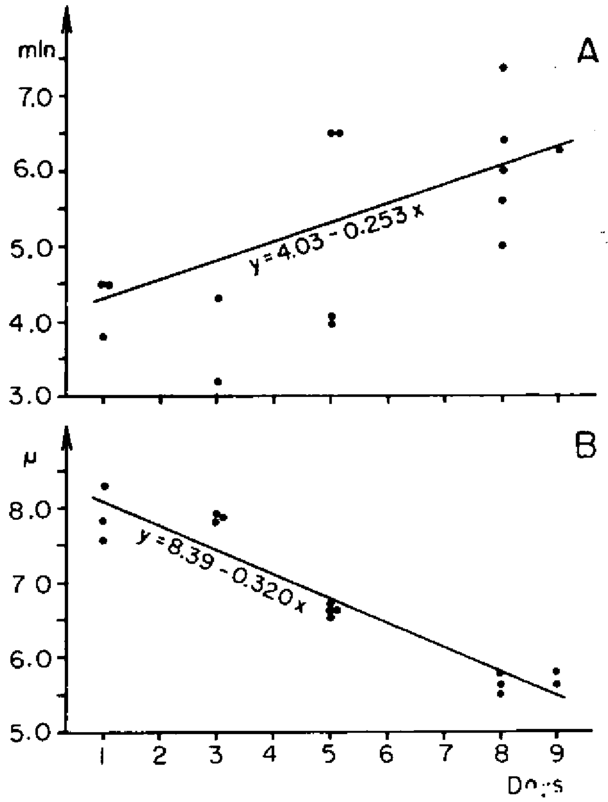

Fig. 1. Changes in number of erythrocytes (A) and in diameter of erythrocytes (B) in *Sorex araneus* during nest life.

number of *RBC* in the group of the youngest animals from June leading an independent way of life (Fig. 2, Table 2) in relation to the group from July ($P<.001$) are striking. In July these values are already high, but decrease in August and September, although not to the level of the June values. The differences between animals from July and August–September are statistically significant ($P<.001$). In October *RBC* attain a level

Table 2

Seasonal and age changes of blood parameters of *Sorex araneus*. The description includes means, confidence intervals (C. I.) and coefficients of variation (C. V.).

Item	Young ad. June		July		Aug., Sept.		Oct.		Nov.		Dec.	
	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I	C.V.
Hb, g/100 ml	13.0±1.1	19.5	16.3±.4	8.8	14.7±.4	11.8	15.5±.8	14.1	16.8±.4	7.7	16.6±.4	7.3
RBC, 10^6/mm^3	15.01±1.3	19.0	19.23±1.0	12.7	17.15±1.0	20.6	19.00±1.2	17.3	21.48±1.1	12.6	23.16±1.3	16.0
Hct., %	42.1±3.3	17.8	49.4±1.3	10.8	45.1±1.5	13.7	49.9±2.6	14.6	52.8±1.8	10.9	55.4±1.7	9.0
RBC diam., μ	4.56±.1	4.7	4.57±.06	1.8	4.46±.09	9.7	4.51±.08	4.9	4.47±.06	4.0	4.30±.05	3.2
MCV, μ^3	26.6±2.1	12.0	26.1±.8	7.8	26.3±1.1	11.7	24.5±1.2	9.9	25.2±.9	7.3	25.0±1.2	11.0
MCH, γγ	8.8±.4	10.3	8.2±.4	12.4	8.2±.4	13.0	7.4±.3	8.5	7.4±.2	6.8	7.3±.3	14.5
MCHC, %	31.6±1.1	8.1	31.9±1.6	11.9	31.3±.8	6.7	30.6±1.2	7.9	29.4±.7	4.8	29.2±.9	7.1
RBC thick., μ	1.74±.13	16.2	1.81±.08	10.6	1.80±.09	12.8	1.62±.10	12.2	1.67±.08	9.3	1.70±.08	10.7
N	22		66		69		34		41		37	

Item	Young ad. Jan., Feb.		March	Old ad. April		May		June, July		Aug., Sept.	
	$\bar{X}\pm$C.I.	C.V.	$\bar{X}$	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.	$\bar{X}\pm$C.I.	C.V.
Hb, g/100 ml	16.7±.5	8.3	15.7	♂ 16.8±.8	9.4	16.5±.8	9.3	16.7±.8	9.3	17.4±.9	10.7
				♀ 15.5±.8	6.3						
RBC, 10^6/mm^3	23.34±1.0	11.0	19.59	20.50±1.9	23.2	19.98±2.1	19.3	17.92±1.1	12.8	16.20±1.5	14.9
Hct., %	57.4±2.4	11.2	51.2	♂ 55.0±2.7	9.3	54.4±4.5	14.5	50.0±2.7	11.7	50.6±2.8	9.3
				♀ 50.9±2.5	6.9						
RBC, diam. μ	4.19±.06	3.6	4.22	4.22±.08	5.0	4.55±.16	6.3	4.58±.11	5.2	4.65±.13	5.1
MCV, μ^3	23.8±.7	6.7	25.1	26.6±2.0	18.4	26.6±1.9	12.8	29.1±2.0	14.6	30.8±2.3	10.5
MCH, γγ	7.2±.3	11.2	8.3	8.5±.8	22.8	8.4±.7	14.4	9.5±.7	16.6	10.7±1.0	15.3
MCHC, %	29.3±.9	7.4	30.4	30.6±.6	5.1	30.5±1.3	7.2	33.4±1.5	9.3	33.9±1.3	6.4
RBC thick., μ	1.76±.08	10.7	1.81	1.86±.2	26.1	1.67±.2	22.9	1.75±.09	10.7	1.89±.05	13.8
N	29		5	27		15		19		17	

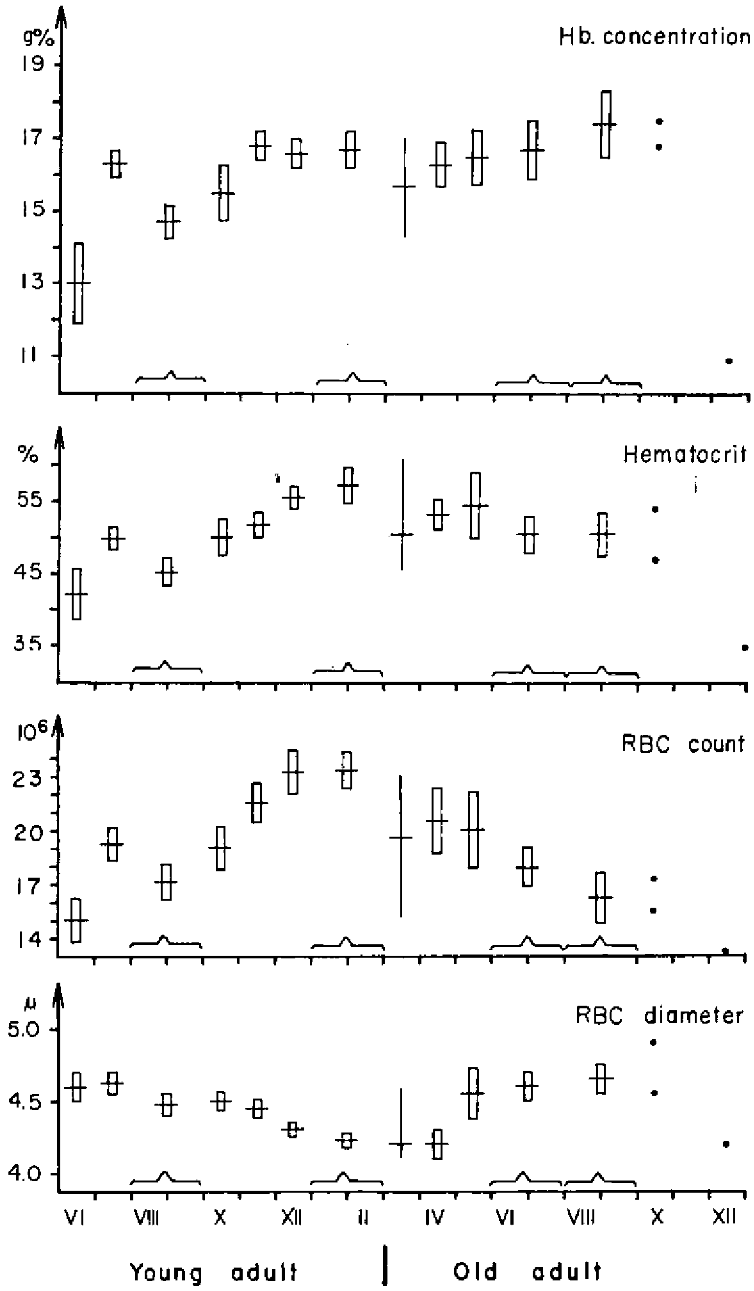
g%
19
17
15
13
11
Hb. concentration
%
55
45
35
Hematocrit
10^6
23
20
17
14
RBC count
μ
5.0
4.5
4.0
RBC diameter
VI
VIII
X
XII
II
IV
VI
VIII
X
XII
Young adult
Old adult

Fig. 2.

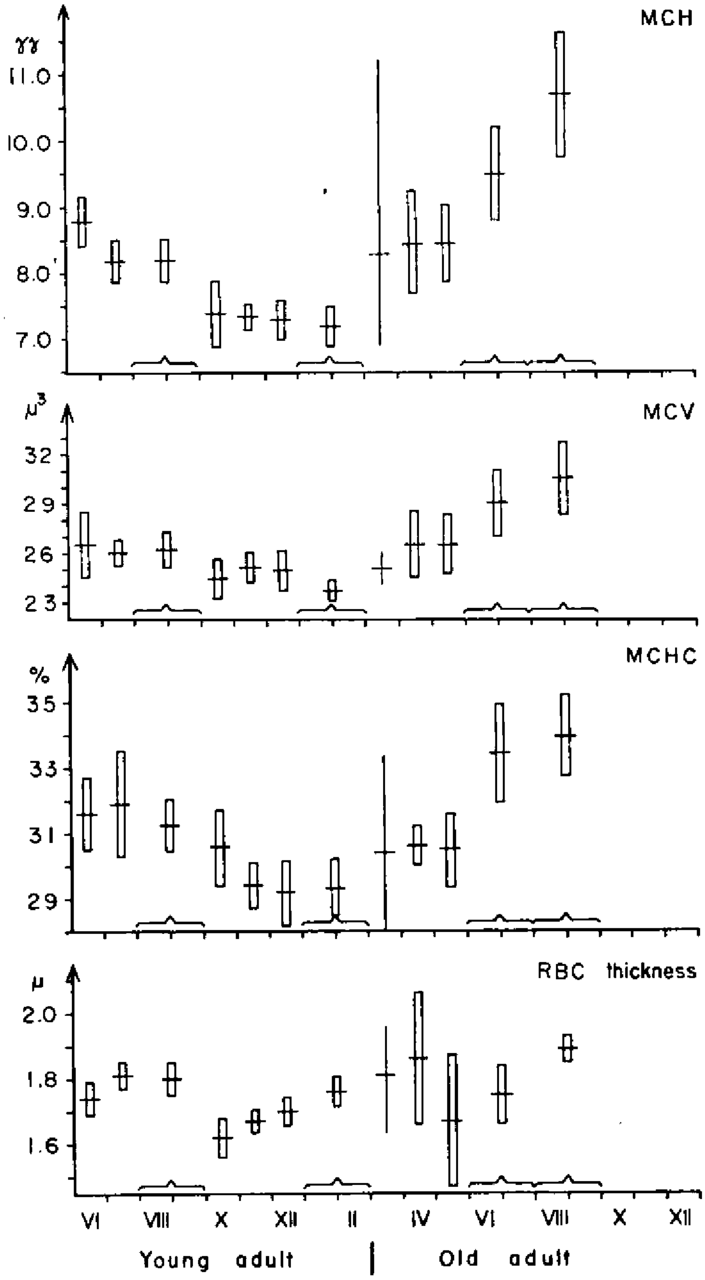

Fig. 2. Seasonal and age changes in basic blood parameters in *Sorex araneus*. Average values and confidence intervals (or average and observed ranges for the series from March, n=5) are given. Data for single individuals are marked by dots.

similar to that in July, after which they increase regularly up to December, and remain in the same high level of over 23 million *RBC* in 1 mm³ of blood during the winter. The difference between *RBC* values in October and January-February is highly statistically significant ($P<.001$). In old adults in early spring, in March and April, before reproduction begins, there is a decrease in *RBC* value, as there is in other basic blood parameters in comparison with data for shrews from the winter (Table 2, Fig. 2). The difference between *RBC* values in January-February and April is significant ($.01<P<.02$). During the period from April to August-

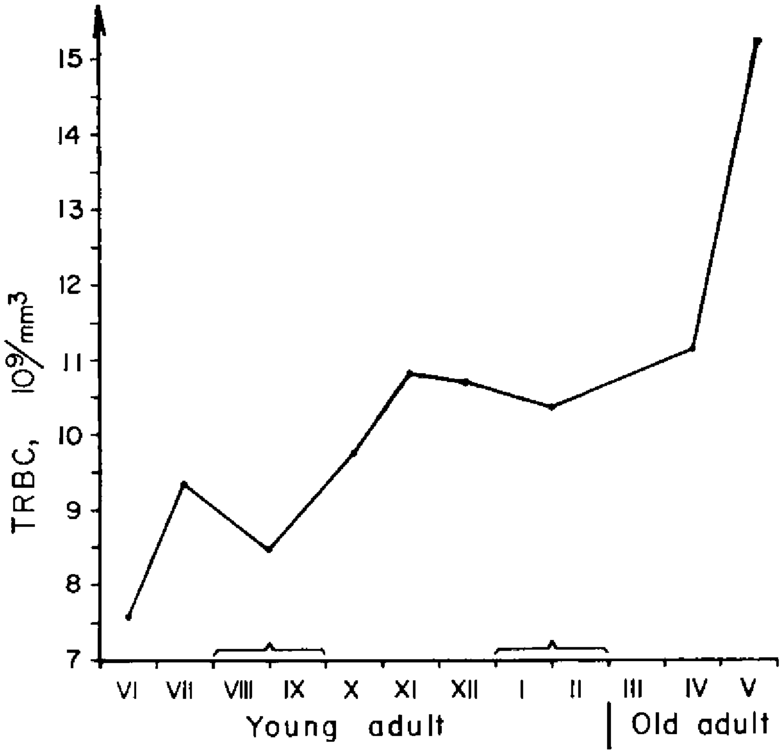

Fig. 3. Seasonal and age changes in total number of erythrocytes (*TRBC*) in *Sorex araneus*. *TRBC* values were obtained by multiplying average *RBC* values (Table 2) and absolute blood volume (Table 3) for corresponding periods but for different series of animals.

-September *RBC* value continues to decrease from 20.50 to 16.20 million/ /mm³ ($P<.001$) and has a tendency to decrease up to the end of the animal's life (Fig. 2).

In order to ascertain whether the fluctuations found in the number of *RBC*/mm³ of blood are compensated for by changes in the absolute volume of blood (see Section 3.3, Table 4) or whether it is a case here of real increase or decrease in the number of erythrocytes, calculation was made of the total number of *RBC* circulating in the animal's organism (*TRBC*). The data obtained indicate that the lowest *TRBC* value occurs in young shrews in June, after which this value increases fairly regularly, except that there is a decrease in August and September, compatible with the decrease of basic hematological parameters during this period (Fig. 3).

Hemoglobin, on the other hand, attains a maximum value of 16.8 g/100 ml of blood in November, and continues on an unchanging level until June of the following year (Fig. 2), the difference between Hb value in October and November being significant with $.001 < P < .01$. The apparent lack of agreement between increase in winter of the number of erythrocytes and the stability of Hb level can be easily explained when tracing the changes in the diameter of *RBC* (Fig. 2), since this value decreases significantly in the winter months in relation to July ($P < .001$). In connection with these opposite processes leading to increase in the number of smaller *RBC* in the middle of winter, the *MCH* index decreases significantly during this period (Fig. 2) in comparison with the value characterizing young shrews in June ($P < .001$). In old adults as from June onwards the Hb level rises slightly, attaining a maximum of 17.4% in August and September (Fig. 2). Differences in the Hb content in old adults in May and in August and September are significant ($.02 < P < .05$).

Changes in Hct index, which attains a maximum (55.5%) in the middle of winter, take an analogical course to that of changes in *RBC*. The difference between average values of this index in samples from October and January+February is statistically significant ($P < .001$). In old adults Hct is maintained on the same level up to the autumn this level being slightly lower than in young adults in winter. The difference between Hct values in January+February and in April is statistically significant ($.01 < P < .02$). Significant differences ($.02 < P < .05$) were found in Hct values and also in Hb level between males and females in April: they are lower in females. There are, however, no differences in the values of the other parameters in old adults in April, and material from other months consists mainly of males.

A distinct decrease in Hct value, like that of *RBC* and Hb, occurred in a senile individual caught in December (Fig. 2). The phenomenon of Hct value being maintained in old adults on an unvarying level, with simultaneous decrease in *RBC*, can be explained by the significant increase in the diameter of erythrocytes ($P < .001$) from 4.22 μ in April to 4.65 μ in August and September (Fig. 2). This process of increase in diameter compensates for the decrease in the number of *RBC* and also explains the increase in Hb level during this period.

There are no differences in the thickness of *RBC* in young adult shrews in June and July. This values decreases from July to October ($.001<P<.01$), and after which it rises slightly, although not to a statistically significant extent (Fig. 2). The decrease in volume of *RBC* in winter (Fig. 2) is therefore due to the decrease in their diameter at this time. Differences between values of the volume of erythrocytes in July and in the middle of winter are highly statistically significant ($P<.001$). As differences in thickness of *RBC* in old adults from spring to autumn are not significant, their increase in volume from 26.5 μ^3 to 30.8 μ^3 ($.02<P<.05$) is due solely to increase in their diameter and reduction in the number of erythrocytes. *MCH* obviously also increases during this period (Fig. 2; $.01<P<.001$).

MCHC index in young adult shrews in June, July and August+Sep-

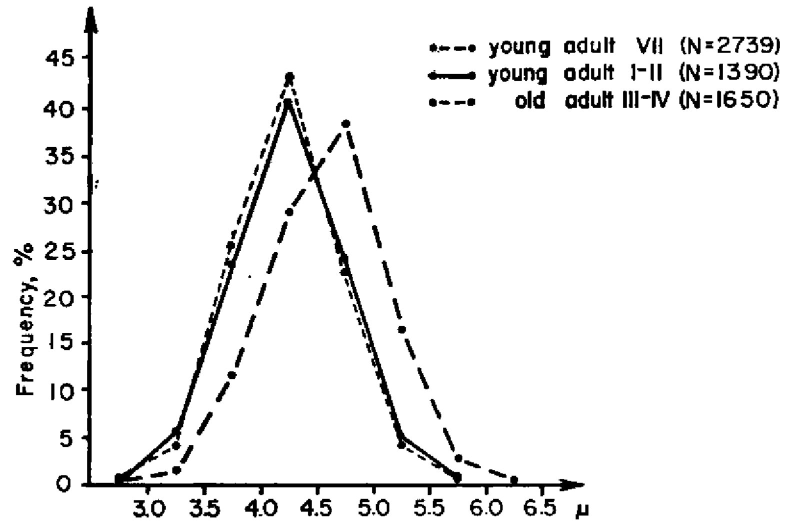

Fig. 4. Anisocytosis curves for *Sorex araneus* in different seasons. N indicates the number of measurements made of erythrocyte diameters.

tember does not differ despite the considerable differences in Hb and Hct levels, as these values change proportionately during this period. From October onwards, as Hct value rises, Hb level hardly alters, resulting in decrease in *MCHC* in winter (Fig. 2). Differences between *MCHC* values in July and December are statistically significant ($.001<P<.01$). *MCHC* index for old adults in April is higher than that for young adults in winter ($.02<P<.05$), and although it increases slightly from April to September (Fig. 2), as Hb values increases while Hct remains constant, this increase is not statistically significant ($.05<P<.1$).

Anisocytosis of erythrocytes in shrews was examined in three seasonal groups: in young adults in July, young adults in winter and old adults in March and April. In all the groups examined anisocytosis is slight, and the distribution of values of cell diameters are close to normal. The curves for anisocytosis for shrews in winter and spring almost completely coincide, but that for shrews caught in July is shifted to the right, as the diameters of erythrocytes are greater in summer (Fig. 4).

Hematological data for the other species of shrews and water shrews are available for some seasons for *S. minutus* and *N. fodiens*, and permit of tracing certain tendencies in variations (Table 5). The increase in the number of *RBC* and Hct value in the lesser shrew in winter, analogical to that observed in the common shrew, is remarkable. The blood parameters found in five water shrews in February are similarly very high, but it must be remembered that this group cannot be fully representative as it is composed of animals which, although living out of doors from November or December, were kept in captivity and therefore the food they consumed and their way of life undoubtedly differs from that of a natural population. Strikingly low coefficients of variation for all blood indexes were found in this group (*C. V.* within limits from 2.2 — 9.6% — Table 5).

The diameter of erythrocytes does not, however, alter in the lesser shrew and water shrew (Table 5), but in the former there is a difference between the average thickness of *RBC* in winter and in the other periods. Erythrocytes of individuals caught in winter have significantly lesser thickness than animals in autumn and spring ($.02<P<.05$), and consequently their volume and *MCH* is smaller during the winter. The winter depression in *RBC* dimensions is thus manifested in a different way in this species to that in the common shrew.

It must be said in general, however, that seasonal changes exhibiting certain common characteristics and tendencies occur in the representatives of *Soricinae* examined.

3.3. Blood Volume

Absolute (in ml) and relative (in ml per 100 g of body weight) blood volume was determined in series of 5—10 common shrews representing almost the whole life cycle of these animals (Table 3). When comparison is made of the absolute blood volume in young adult shrews from summer (from June to September) and winter (from December to February) it was found that this value decreases by 0.047 ml, *i.e.*, by 8.1%. This difference is not statistically significant. But the difference between blood volume in young adults in winter and old adults in March and April is statistically significant ($.02<P<.05$). Far greater (by as much as 30%) increase in absolute blood volume in spring was found when the group of young adults from the winter was compared with old adults from May and June ($P < .001$; Table 3). Increase in absolute blood volume in shrews is thus a progressive process, beginning with the spring increase in body weight and attainment of sexual maturity by these animals in March (Fig. 5). Average values of relative blood volume were calculated for the same age and seasonal groups for which the absolute values described above were determined. These values do not differ

Table 3

Blood volume of common shrew (average values and confidence intervals are given of averages for the groups compared).

Month	Young ad.							Old ad.	
	J	J	A+S	O	N	D	J+F	M+A	M+J
Absolute, ml	0.506	0.499	0.494	0.510	0.502	0.462	0.445	0.555±.05	0.809±.1
	(0.503±.03)			(0.506±.04)		(0.456±.07)			
Relative, ml/100 g	6.98	6.70	6.47	6.96	6.86	6.99	6.87	6.73	7.18
N	7	5	9	10	10	10	6	10	6

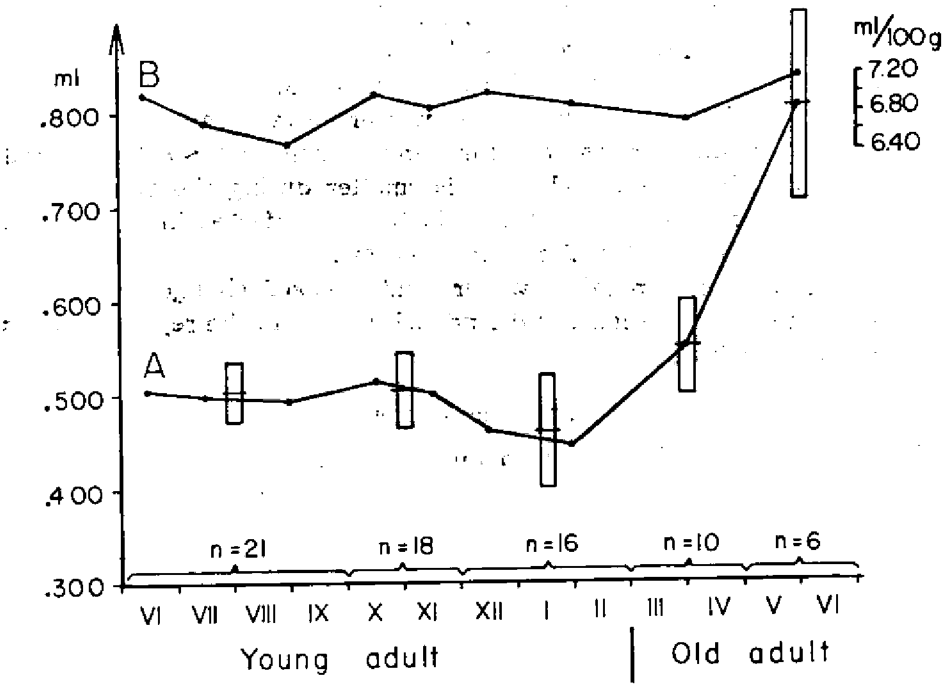

Fig. 5. Seasonal and age changes in absolute (A) and relative (B) blood volume in *Sorex araneus*. Average values and confidence intervals are given for absolute blood volume. Number of animals examined for relative blood volume are given in Table 3.

statistically and vary on an average from 6.44 ml/100 in August and September in young adults to 7.18 ml/100 g in May and June in old adults (Table 3, Fig. 5).

There are no differences in either absolute or relative blood volume between males and females.

In order to ascertain the interrelation between blood volume and hemoglobin content, absolute and relative blood volume was correlated with Hb content in young and old adults. A very low and non-significant correlation was found between relative blood volume and Hb in young animals, but in old adults we found a significant negative correlation with coefficient $r=-0.50$ between relative blood volume and Hb content ($P<.001$).

3.4. Osmotic Resistance of Erythrocytes

Examination was made of the osmotic resistance of erythrocytes to different concentrations of hypotonic NaCl solutions in three groups of common shrews: in young adults from June and August, in young adults from October, November and December and in old adults from March and April, and also in old adult individuals of *Sorex minutus* from the spring and in young adults of *Neomys fodiens* from the autumn (Table 4).

Table 4

Seasonal variations in osmotic resistance of shrews ($\bar{X}$ — average values, C. I. — confidence intervals and C. V. — coefficients of variation are given).

Species, age	Month	N	Min. resistance $\bar{X}\pm$C.I.	C.V.	Max. resistance $\bar{X}\pm$C.I.	C.V.
Sorex araneus, juv. ad.	June, Aug.	8	0.522±.03	6.3	0.434±.02	5.8
Sorex araneus, juv. ad.	Oct., Nov., Dec.	9	0.592±.02	3.5	0.454±.02	6.8
Sorex araneus, old. ad.	March, April	13	0.559±.02	4.9	0.441±.02	7.7
Sorex minutes, old. ad.	April, May	5	0.545±.05	5.5	0.490±.04	8.5
Neomys fodiens, juv. ad.	Oct., Nov.	6	0.570±.03	4.9	0.427±.02	3.5

Average values of maximum and minimum osmotic resistance of the *RBC* of shrews was from 0.52—0.43 to 0.59—0.45% NaCl in different seasons.

The erythrocytes of young common shrews have a lower osmotic resistance from October to December than those of animals from the summer months. Hemolysis of *RBC* of shrews was thus begun in autumn in higher concentrations of NaCl (Fig. 6). This difference, in relation to the starting point of hemolysis (minimum resistance) is highly statistically significant ($P<.001$), but the time of complete hemolysis (maximum resistance) does not significantly differ in the three seasons examined, although it is also shifted in the direction of higher concentrations of

NaCl in shrews from the autumn. Minimum resistance of *RBC* of old adults in March and April occupies an intermediate place between analogical data for young adults from summer and autumn (Fig. 6) and differs significantly both from the corresponding value obtained for shrews from summer ($.01<P<.02$), and those from autumn ($.001<P<.01$).

3.5. Hematological Parameters within the Sub-family *Soricinae*

The values of hematological parameters for the representatives of the sub-family *Soricinae* which we examined have been arranged in order of increasing average body weight for the various species (Table 5). The average number of erythrocytes markedly decreases as the body weight of the different species of *Soricinae* increase, from a very high value of 25.6 mln/mm^3 in young lesser shrews in winter to 9.6 mln/mm^3 in young water shrews in spring and summer. The reverse relations can

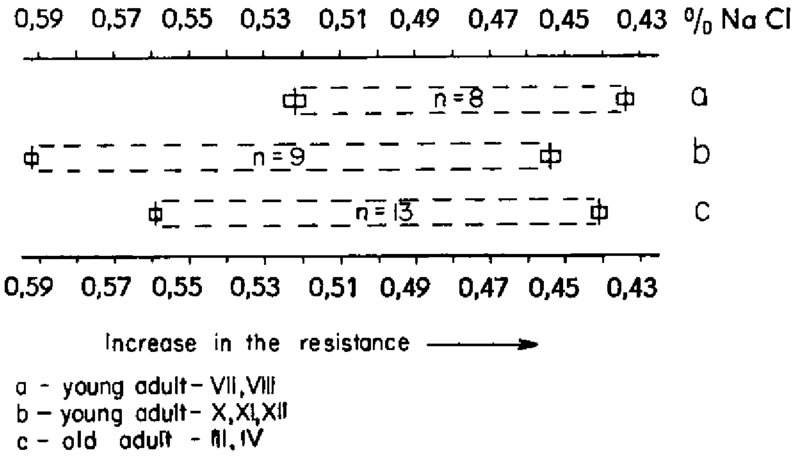

Fig. 6. Seasonal variations in osmotic resistance of erythrocytes in *Sorex araneus*. Zones of cell hemolysis and average values and also confidence intervals of minimum and maximum resistance are shown.

be observed in the size of erythrocyte diameters, which are smallest in the smallest species of shrew, *S. minutus* (4.2 μ) and greatest in *N. fodiens* (5.4 μ) (Fig. 7). Trends in variations in the mean cell volume (*MCV*) and mean hemoglobin content in blood cells (*MCH*) obviously take an analogical course. The thickness of erythrocytes in the different species does not differ significantly, except for the markedly lesser thickness of these cells in the lesser shrew in winter. *MCHC* value calculated for representative numbers of animals varies on an average from 31.9% in old adults of *Sorex minutus* to 35.4% in old adults of *Neomys fodiens* (Table 5).

Hemoglobin content in representative groups of *Soricinae* is maintained on a fairly even and high level, from which only the lower Hb values in old adults of *N. anomalus* and the high values in young in winter and old adults of. *N. fodiens* differ.

4. DISCUSSION

4.1. Description of Blood in Nestlings

Changes in the morphological composition of the blood in small mammals during the period they live in the nest have been investigated by a large number of authors. In rodents living in the wild state, relatively easily reproducing under laboratory conditions, this problem has not presented any great difficulty (Kalabukhov & Radionov, 1934; Müller, 1963; Kostelecka-Myrcha, 1966, 1967; Ro-

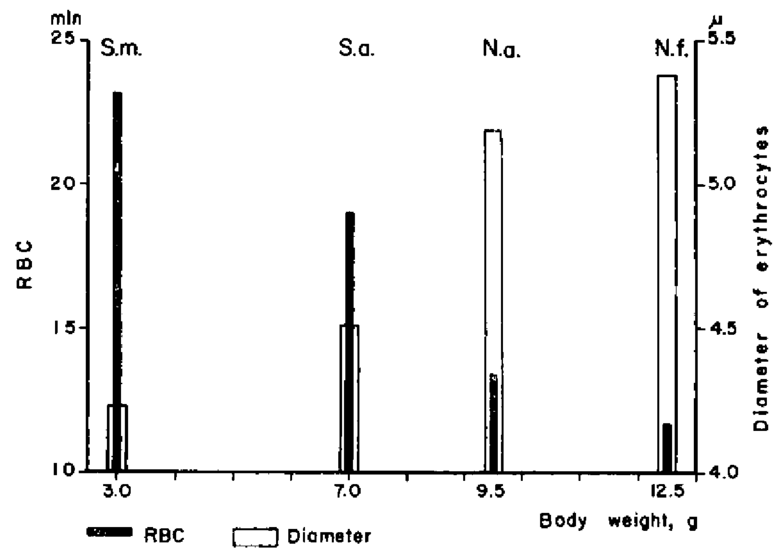

Fig. 7. Relation between average body weight of different species of *Soricinae* and *RBC* values and cell diameter. Samples from October, only *N. anomalus* from July and August. (*S. minutus* 7 specimens, *S. araneus* 34, *N. anomalus* 3 and *N. fodiens* 16).

gatko, 1970; Wołk, 1970). The basic difficulty in examining the early stages of the ontogenesis of shrews is to obtain young under laboratory conditions and then to keep them alive for the 21 days of their nest life. This difficulty accounts for the small amount of material which has been obtained only for the period of the first nine days of the shrews' life. The second difficulty is obtaining a sufficient amount of blood from such small animals.

Hematological data for common shrews in the nest period point to a very wide range of values for the number of *RBC* in newborn and adult individuals. The number of erythrocytes on the first day of life is approximately as high as that found in one-day old *Microtus oeconomus* (Wołk, 1970b) and slightly smaller than in *Pitymys subterraneus* and *Clethrionomys glareolus* (Kostelecka-Myrcha, 1966b, 1967). Towards the end of the first month of life outside the nest the *RBC* value is, however, about 8 mln/mm^3 higher than in the other representatives of *Microtidae* mentioned. The *RBC* of newborn shrews have a larger diameter than those of newborn voles, whereas in adult individuals this value is smaller than in pine voles, which are characterized by the smallest diameter of erythrocytes among *Microtidae*. Both these processes — reduction in the diameter of *RBC* and increase in their number — are thus very intensive in young shrews. It is also interesting to note that Hb level in nine-day old shrews is already close to the value characterizing young animals after leaving the nest (Table 1 and 2), whereas in the root vole, for example, Hb level is not established until after the 20th day of life (Wołk, 1970b). This also points to the intensivity of hematopoietic processes in young shrews. It must, however, be emphasised that Hb value still increases significantly in these animals during the first month of life outside the nest.

4.2. Seasonal and Age Variations in the Morphological Composition and Volume of Blood

Dehnel (1951) found that young shrews, after a relatively long period of nest life (21 days), begin independent life as physiologically mature, although not as yet sexually mature individuals. The low values of hematological parameters of shrews in June, significantly differing from values calculated for the other months, form evidence that the animals have not yet reached the stage of physiological maturity. The shrews examined formed a homogenous group of young adults from the first spring reproduction period. Values of Hb, Hct and *RBC* in young shrews from July, that is, animals which left the nest about 5 weeks previously, are far higher and differ significantly from the values for June. Similarly Vinokurov & Sedališčev (1971) in relation to *Citellus undulatus jacutensis* observed minimum values for Hb and *RBC* in young animals after leaving their burrows. These values rose as the animals changed to an independent way of life and at the end of summer reached the level proper to adult animals.

Perkowska (1963) found a peculiar case of specific erythropoesis in *Sorex araneus*, consisting in morphological changes of erythroblasts in the direction of plasmacell-like forms. Hemoglobin appears very late in erythroblasts, as it only then saturates late orthochromatophiles and the lack of colour in *RBC* is due to delay in accumulation of hemoglobin. Specific changes in erythropoesis begin in the 5—6 week of the animals' independent life and are maintained until natural death occurs. This time coincides with the attainment by shrews of the level of blood parameters characterizing a physiologically mature population (cf. Table 2). This coincidence may form evidence that as from the time the hematogenetic tissue in shrews is adjusted to full production of blood cells, certain morphological changes take place in this tissue connected with the excessive strain placed on it. Lack of colour of cells caused by their late saturation with hemoglobin is probably connected with the production of an unusually great number of erythrocytes in shrews. Support for this hypothesis is provided by the order in which Perkowska (1963) arranged intensification of changes in erythropoesis, from shrews of the genus *Sorex*, through *Neomys anomalus* to *N. fodiens*, in which the lowest percentage of changed cells was observed. As shown above (Table 4) the sequence of decreasing number of erythrocytes agrees with this order, that is, in connection with the far smaller production of *RBC* in *N. fodiens* than in *S. araneus*, the morphological changes in the overworked tissue in water shrews are more faintly manifested.

It can be seen from Fig. 2 that the high July values of hematological parameters decrease transitorily in August and September. This can be explained by the entry into the population of a large number of very young animals from the second litter which had only just left the nest.

As the temperature falls and the day becomes shorter further characteristic processes take place. There is increase in the number of erythrocytes and hematocrit up to the time that maximum values are attained in January and February, the diameter of *RBC* decreases to reach a minimum in winter, while Hb value is maintained as from November on through the winter months on the same level (Table 2, Fig. 2). The significance of these changes for shrews is very great in winter since they lead to considerable increase in the respiratory function of hemoglobin, which, remaining on the same level, is connected with larger number of smaller erythrocytes and consequently the total area of gas interchange is increased. This is of great importance to metabolic processes of shrews in winter, during a period of intensified thermoregulation (Gębczyński, 1971). It may be that the effect of the changes described above in the morphological composition of the blood is the relatively faintly manifested decrease, in comparison with other mammals, of metabolism in shrews (Gębczyński, 1965). It would not, however, appear that increase in the number of erythrocytes was a reaction to the smaller oxygen content in the air under the snow cover. Pichler (1948) has in fact shown that the oxygen content in the layer under the snow cover does not alter depending on the thickness of the snow or the period for which it lies, and does not differ from the normal oxygen content in atmospheric air.

The tendency observed in shrews to maximum increase in Hb, Hct and *RBC* values in winter and their decrease in summer occurs in many species of mammals. It has been reported as occurring in numerous species of rodents (eg. Sealander, 1962, 1964; Newson, 1962; Newson & Chitty, 1962; Kostelecka-Myrcha, 1967; Vidovič, 1967; Lee & Brown, 1970; Kajpbekov, 1971; Vinokurov & Sedališčev, 1971). An increase in oxygen volume of blood, decrease in ambient temperature in winter has also been found by Kozakevič, 1960, in *Citellus pygmaeus*, and by Ševčenko (1968) in *Microtus arvalis*. Analogical changes have been recorded by Erickson & Youatt (1961) and Pearson & Halloran (1971) in the blood of *Ursus arctos* and *Ursus americanus*.

This problem has a different character in the case of the hedgehog, in which a higher level of *RBC* and Hct was found in summer than autumn and winter, whereas Hb level exhibits practically no changes during the course of a year (Kekić, 1970). It would, however, seem that the hedgehog, although systematically close to shrews, differs significantly in respect of ecological and physiological characters, but chiefly in respect of the fact that it hibernates. The rise in hemoglobin value in summer and decrease in winter was found in *Apodemus flavicollis* (Kalabukhov, 1953) and in *Rangifer tarandus* (Afanas'ev, 1963). An exception in seasonal hematological trends is formed by *Clethrionomys rutilus dawsoni*. Sealander (1966) found no changes in Hb and Hct in this species, and connected this with the uniformity of the temperature conditions of the micro-habitat in which these animals live. Seasonal variations in the level of muscle myoglobin have, however, been shown for this species — increase in winter and minimum values in summer (Morrison, Rosenmann & Sealander, 1966).

Further seasonal and age changes in the blood indexes of the common shrew are manifested in a decrease in *RBC*, Hct and Hb values in March and April in relation to winter (cf. Table 2, Fig. 2) which may be a symptom of a certain kind of »development anaemia« connected with the dynamic spring increase in body weight in old adult shrews. The most favourable situation for old adults was in May, when Hct and *RBC* have the highest values for this group of animals. This is a period of full physiological mobilization of the organism for reproduction. In later months, despite the rise in Hb level, the conditions for gas interchange deteriorate as the result of the decrease in the number and simultaneous increase in diameter of erythrocytes.

Seasonal changes in size and shape, i.e., diameter and thickness of *RBC* merit attention. It must be emphasised here that most important are the changes in diameter, as a value directly measurable, characterized in relation to the common shrew by a low coefficient of variation of about 4% (Table 2). Reduction in this value during the period from August+September to February, with almost simultaneous, constant although statistically non-significant increase in thickness (Fig. 2), causes a change in the shape of erythrocytes in shrews in winter to one more similar to spherocytes. This is reflected in the resistance of erythrocytes. Decrease in the diameter of *RBC* in autumn and winter and increase in this value as from spring occurs, as in the case of shrews, also in *Clethrionomys glareolus* (Kostelecka-Myrcha, 1967). Pearson & Halloran (1971) found a significant increase in the diameter of erythrocytes in the brown bear in summer in comparison with spring, but Sealander (1962) did not observe seasonal changes in the diameter of *RBC* in the 5 spieces of rodents he examined.

The course taken by variations in *MCHC*, one of the most constant hematological parameters, is interesting. During the period from July to December its value significantly decreases in young shrews (Fig. 2). Deb & Hart (1956) observed a decrease in *MCHC* in rats kept in low temperatures. A decrease in *MCHC* in winter was also observed in humans (Doupe, Ferguson & Hildes, 1957). Sealander (1966) found an inversely proportional relation in *Clethrionomys rutilus* between *MCHC* and air temperature, with the exception of January and February, when this index distinctly decreased. In the hedgehog a distinct drop in *MCHC* has been shown to occur in summer in relation to spring, and a repeat, although lesser, increase in autumn (Kekić, 1970). No fluctuations in this index were, however, observed in rodents examined by Sealander (1962), Kostelecka-Myrcha (1967) and Lee & Brown (1970). Hb and Hct directly affect *MCHC* value, and indirectly the number and diameter of *RBC* which determine the value of the Hct index. The autumn — winter decrease in *MCHC* in the common shrew is the exponential of the decrease in diameter and simultaneous increase in number of erythrocytes.

Certain data on seasonal variations in Hb, *RBC* and *MCH* in *Sorex araneus* were given by Kunicki-Goldfinger & Kunicka-Goldfinger (1964). They found a rise in the number of erythrocytes and Hb content from the low values at the beginning of spring up to the maximum values in September (no data given for winter). This trend is in general in agreement with the data obtained in the present study, but it did not confirm the autumn decrease in the number of *RBC* and the cause of this discrepancy may perhaps lie in the insufficient amount of material used by these authors.

The changes found in absolute blood volume in shrews point to the connection between this process and the seasonal variations in the body weight of these animals. The winter depression in body weight in young shrews, of as much as 30% of the weight of the animals in September (Pucek, 1965, 1970), corresponds to a certain drop in blood volume (Table 3). As the number of erythrocytes and also Hb value were found to continue during this time on a very high level, the conclusion must be reached that the blood of shrews must become more »dense« in winter, leading to a rise in the respiratory function of hemoglobin, despite the decrease in the absolute volume of the blood. This is also confirmed by the high Hct values in animals in winter (Fig. 2). This is in fact in agreement with the winter dehydration of shrew tissues (Pucek M., 1965; Myrcha, 1969). The occurrence in winter of real increase in the total number of circulating erythrocytes also deserves mention (Fig. 3).

Analogically, the spring increase in the body weight of old adults by over 100% in relation to shrews in winter is accompanied by an increase of about 30% in absolute blood volume, combined with increase in the total pool of circulating erythrocytes (Fig. 3 and 5). The relation between increase in total blood volume and increase in body weight was also found in other mammals by Courtice (1943), Metcoff & Pavour (1944), Lippman (1947).

The increase in the total number of erythrocytes (*TRBC*) in old adult shrews in spring does not, however, completely compensate for the increase in absolute blood volume, since the number of *RBC*/mm^3 is slightly lower than in young shrews in winter. The negative correlation found in old adults between the relative blood volume and Hb content leads to certain interesting conclusions. It is the result of the action of mechanisms aimed at maintaining a constant hemoglobin level in shrews despite the different values of blood volume. In young shrews no significant correlation was found between the Hb level and blood volume. Similarly Mott (1966, 1967) showed that there was no such correlation in immature rabbits.

As a result of changes in body weight and absolute blood volume in shrews, the relative blood volume is maintained on the same level over the whole course of a year (Table 3, Fig. 5). A similar result was obtained by Shield (1971) for *Setonix brachyurus (Marsupialia)*. Murti & Mullick (1961) on the other hand, who examined relative blood volume in Indian buffalo, found that it increased in summer months. Burke (1954) discussed in detail the question of blood volume in mammals and his data, like the values obtained by Courtice (1943) for rabbits, by

Constable (1963) for rats, Kostelecka-Myrcha, Gębczyński & Myrcha (1970) for bank voles and Shield (1971) for Australian marsupials do not in general differ from the relative blood volume calculated for shrews. Koržuev & Koreckaja (1962) obtained similar results for the common shrew, lesser shrew and mole.

The hypotheses of different authors on the autumn or winter decrease in blood volume and totalled volume of erythrocytes are interesting. According to Shield (1971) these phenomena are the result of deterioration in the food conditions of marsupial populations in autumn. Similarly Cameron & Luick (1972) explain the decrease in blood volume and erythrocytes by deterioration in the condition of reindeer. Henschel, Mickelsen, Taylor & Keys (1947) showed that in humans kept on a low-caloric diet for a long period there was an increase in plasma volume at the expense of reduction in cell mass. Ševčenko (1969) found that food conditions affect hemoglobin content in voles. The statistically non-significant winter decrease in absolute blood volume in shrews would appear to be connected more with the phenomenon of depression in body weight rendered permanent by evolution (Mezhzherin, 1965). The increase in winter of such blood parameters as Hb, Hct, *RBC* and primarily the real increase in the total number of erythrocytes refutes the views as to deterioration in food conditions for shrew populations during this period, and this is further borne out by the fact that the absolute weight and size of the stomach in shrews are not subject to general winter depression (Myrcha, 1967).

In summing up the question of seasonal changes in blood morphology in shrews it must be emphasised that the character of these changes consists primarily in the winter increase in combined total area of erythrocytes, due to increase in the number of *RBC* circulating in the organism. The result of these processes is increase in the oxygen capacity of the blood in shrews in winter. The second manifestation of seasonal changes is reduction in the diameter of *RBC* in *S. araneus* and in thickness of *RBC* in *S. minutus* in winter and increase in these values during summer.

It may be that a different mechanism causing reduction in the size of erythrocytes in these two species is connected with the very small diameter of *RBC* in the lesser shrew, which is an extreme value for mammals. Further reduction in this value would undoubtedly be unfavourable on account of the distinct change in the shape of the cell in the direction of a spherocyte.

Age variations in blood parameters of shrews consist, in the most general sense, in intensive increase in the number and decrease in the diameter of cells during the period of nest life, and in further growth in the number of *RBC*, Hb and Hct values in the first month of life outside the nest. Within a few weeks after beginning independent life shrews attain the level of blood parameters characteristic of physiologically adult animals. The total number of erythrocytes and absolute blood volume increases considerably in old adults during the period that the organism is being mobilized for reproduction, this undoubtedly being connected both with intesive increase in body size and weight in this age group of shrews. The senile period of life is connected with reduction in the basic values of hematological parameters.

The foregoing discussion shows that ontogenetic changes in the blood picture of *Soricinae* are connected with the general rhythm of seasonal and age variations in these animals.

4.3. Osmotic Resistance of Erythrocytes and Its Seasonal and Age Changes

As the osmotic resistance of erythrocytes in relation to hypotonic NaCl solutions has hitherto been examined only in domesticated and laboratory mammals (Holman, 1955; Coldman, Gent & Good, 1970), there is no possibility of comparing values obtained for shrews with other species of mammals living under natural conditions. The low values of osmotic resistance of *RBC* in shrews are analogical with those obtained for the small-sized erythrocytes in certain domesticated animals such as sheep and goats (cf. Kolb, 1967).

The significant reduction in the resistance of *RBC* found in shrews in autumn and winter in relation to summer is due to several causes. One of these is undoubtedly the autumn-winter change in the shape of erythrocytes, consisting in reduction of the diameter and increase in thickness (cf. Section 3.2.). It is known from literature that cells similar in character to spherocytes are characterized by lower osmotic resistance (Wintrobe, 1944; Ławkowicz & Krzemińska-Ławkowicz, 1956). In addition Coldman *et al.* showed that the diameter and resistance of *RBC* are correlated with each other in direct proportion. This is confirmed by the lower resistance of *RBC* in shrews in winter than in summer and spring.

Kluczek (1967) drew attention to the connection between resistance of *RBC* of sheep and ambient temperature. He showed that the resistance of erythrocytes decreased at a low temperature, and that it rose with a rise in temperature. Similar observations were made by Stolzmann, Chmiel & Karoń (1957) and Chmiel & Karoń (1958). These authors explain the effect of a rise in ambient temperature on the osmotic resistance of *RBC* by intensification and acceleration of enzymatic processes taking place in the cell, particularly glycolysis. In addition Kluczek (1967) found a decrease in albumin level in blood serum in winter, and it is well known that albumins change the mechanical properties of the surrounding zone of cells during haemolysis, counteracting the penetration of NaCl into the interior of the cell (Katchalsky, Kedem, Klibansky & de Vries, 1960).

In the light of the above considerations the decrease in osmotic resistance of cells in shrews, together with a decrease in temperature and change in the shape of erythrocytes in autumn, is an understandable and normal phenomenon.

4.4. Specific Properties of the Blood in Shrews

Comparison of the blood indexes in the sub-family *Soricinae* (Table 5) shows that one of the smallest mammals, *i.e.*, *S. minutus* is characterized by a number of small blood cells which constitutes a record value in the world of mammals. This figure is almost four times greater than that found in 8 species belonging to 4 orders of free-living small mammals (Youatt, Fay, Howe & Harte, 1961), and about twice higher than the corresponding value in the 5 species of voles kept in the laboratory (Kostelecka-Myrcha, 1966a, 1967; Wołk, 1970b).

The remaining species of shrews and water shrews formed a sequence according to which increase in average body weight of the various species corresponds to decrease in number and increase in diameter and volume of blood cells (Fig. 7). This is a good illustration of the principle formulated by Kostelecka-Myrcha (1973) that the total area of *RBC* within the range of the same hemoglobin level decreases with increase in the body weight of mammals. The total area in fact depends mainly on the number and diameter of erythrocytes.

Larimer (1959) considers that simultaneous decrease in body size and increase in blood oxygen content is an adaptation ensuring a better supply of oxygen to the tissues of small mammals with a high metabolic level. Schmidt-Nielsen & Larimer (1958), in analyzing the curves of oxygen dissociation in different mammals, found that the requirements of a higher metabolic level in small mammals are met by more rapid diffusion of oxygen to tissues. It was also found that the *RBC* of smaller species of animals have a higher enzymatic activity than large ones, which leads to quicker oxyhemoglobin dissociation (Larimer & Schmidt-Nielsen, 1960).

Hb values characterizing shrews confirm the general rule that hemoglobin level is higher in small species distinguished by greater activity and higher metabolic level (Kozakevič, 1959; Sealander, 1964; Burke, 1966; Schwarz, Smirnoff & Dobrinskij, 1968; Koloss & Koloss, 1969).

The high Hb level in the water shrew is presumably connected with the amphibious way of life of this species. The high level of hematological parameters in diving species is a phenomenon which has been frequently described in literature (K o r ž u e v & K o r e c k a j a, 1962; S c h w a r z *et al.*, 1968). The far lower Hb value, and also the smaller number of *RBC* in old adults of the lesser water shrew is therefore even more striking in the light of the foregoing, since according to the opinions expressed by D e h n e l (1951) this species is more closely connected with a water habitat than *N. fodiens*, despite the more weakly formed morphological characters facilitating swimming. The hematological data characterizing these two species would appear to form evidence more of the opposite situation. It is not impossible that there are other mechanism intensifying gas exchange *e.g.* the role of myoglobin of muscles under conditions of reduced oxygen concentration in a water habitat and simultaneous increase in its requirement by the organism is well known (I r ž a k, 1964; S c h w a r z *et al.*, 1968).

The above discussion shows that the hemogram of shrews — animals with specific physiological features characterized by seasonal variations in the morphological parameters of the body and a high metabolic level — has certain features differentiating it from that in other mammals. A very large number, not encountered in other mammals, of small erythrocytes occurs with a high Hb level, which enables shrews considerably to increase the area of gas exchange. The most favourable conditions for it consisting in increase in the total area of *RBC*, occur in shrews in winter under conditions of intensified thermoregulation and in spring during the period of mobilization of the organism for reproduction.

Young shrews after leaving the nest, despite the morphological maturity observed in them, are not fully physiologically mature. They attain this maturity in relation to blood indexes about 5 weeks after leaving the nest.

The characters described here of far-reaching specialization in the blood circulation system of shrews form the expression of evolutional adaptation. These animals, which have extremely small body measurements amongst mammals, are distinguished by intensive metabolism and considerable activity owing to the great oxygen capacity of the blood.

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Elżbieta WOŁK

ZMIENNOŚĆ WSKAŹNIKÓW HEMATOLOGICZNYCH RYJÓWEK

Streszczenie

U 560 ryjówek (*Soricinae*), należących do gatunków *Sorex araneus*, *S. caecutiens*, *S. minutus*, *Neomys fodiens*, *N. anomalus*, złowionych w Białowieskim Parku Narodowym w okresie od sierpnia 1969 do lipca 1972 roku, badano następujące parametry krwi: zawartość hemoglobiny w 100 ml krwi (Hb, g/%), liczbę erytrocytów (*RBC*, mil./mm^3), wskaźnik hematokrytowy (Hct, %), średnicę erytrocytów (μ). Obliczono następnie zawartość hemoglobiny w krwince (*MCH*, $\gamma\gamma$), stężenie hemoglobiny w krwince (*MCHC*, %), objętość krwinki (*MCV*, μ^3), grubość krwinki (μ), a także średnią ogólną liczbę erytrocytów (*TRBC*). Oznaczono ponadto absolutną i względną objętość krwi i oporność osmotyczną erytrocytów.

Zmienność wskaźników krwi u ryjówek aksamitnych *S. araneus* rozpatrywano w próbach z populacji, układających się zgodnie z cyklem życiowym zwierząt, poczynając od okresu gniazdowego aż do okresu senilnego. U pozostałych przedstawicieli *Soricinae* próby pochodziły z wybranych okresów życia zwierząt.

Stwierdzono, że w okresie życia gniazdowego ryjówki charakteryzuje niezwykle dynamiczny wzrost liczby erytrocytów, połączony ze zmniejszaniem się ich średnicy (Tabela 1, Ryc. 1). W okresie od czerwca, tj. od momentu opuszczenia przez młode gniazda, do naturalnego kresu życia ryjówek w końcu następnego roku w obrazie krwi obwodowej zachodzi szereg zmian sezonowych i wiekowych. W początkach życia pozagniazdowego wartości Hb, *RBC*, Hct oraz *TRBC* są u ryjówek niższe, niż w pozostałych grupach sezonowych i wiekowych (Tabela 1 i 2, Ryc. 2). Od lipca począwszy wartości te wzrastają, przy czym obserwuje się ich obniżenie w sierpniu i wrześniu u młodych oraz w marcu i kwietniu u przezimków (Tabela 2, Ryc. 2). Jedynie wartość *TRBC* jest u przezimków na wiosnę wysoka i nadal ma tendencje wzrostowe. Maksymalne wartości Hb występują u młodych w listopadzie, u przezimków w sierpniu i wrześniu, maksymalne wartości *RBC* i Hct u młodych w styczniu i lutym (Tabela 2, Ryc. 2). Średnica i objętość erytrocytów, a także *MCH* osiągają wartości minimalne u młodych w styczniu i lutym, a u przezimków wzrastają (Tabela 2, Ryc. 2). Wskaźnik *MCHC* obniża się istotnie w zimie (Tabela 2, Ryc. 2).

Absolutna objętość krwi zmniejsza się nieco zimą, a istotnie wzrasta na wiosnę u przezimków, a więc zmienia się zgodnie z trendem sezonowo-wiekowej zmienności ciężaru ciała ryjówek (Tabela 3, Ryc. 5). Natomiast względna objętość krwi ma w ciągu życia ryjówek stałą wartość (Tabela 3, Ryc. 5).

Oporność osmotyczna erytrocytów jest najniższa u młodych ryjówek zimą, wzrasta u przezimków na wiosnę, a maksymalne wartości przyjmuje u młodych z lata (Tabela 4, Ryc. 6).

Wraz ze wzrostem średniego ciężaru ciała poszczególnych gatunków ryjówkowatych zaznaczają się charakterystyczne trendy: wzrasta średnica czerwonych krwinek i zmniejsza się ich liczba (Tabela 5, Ryc. 7).

Z przedstawionych materiałów wynika, że młode ryjówki po opuszczeniu gniazda nie są w pełni dojrzałe fizjologicznie, a ich wskaźniki krwi osiągają wartości charakteryzujące osobniki dorosłe dopiero po około 5 tygodniach życia pozagniazdowego. Obniżenie się wartości Hb, *RBC* i Hct w sierpniu i wrześniu jest spowodowane prawdopodobnie dopływem do populacji ryjówek osobników młodocianych z drugiego miotu. W warunkach wzmożonej termoregulacji zimą w krwi ryjówek

zaznacza się charakterystyczna hemokoncentracja, która prowadzi do wzrostu sumarycznej powierzchni erytrocytów jako miejsca wymiany gazowej. U przezimków najkorzystniejsze warunki wymiany gazowej są wiosną, w okresie mobilizacji organizmu do rozrodu.

Neomys anomalus, charakteryzujący się niższym poziomem Hb i mniejszą liczbą *RBC* niż *Neomys fodiens*, wydaje się być gatunkiem słabiej przystosowanym do ziemno-wodnego trybu życia.

Stosunkowo wysoki poziom metabolizmu i duża aktywność ryjówek znajdują odbicie w wysokich wartościach Hb, a także w występowaniu, zwłaszcza w rodzaju *Sorex*, ogromnej liczby drobnych erytrocytów. Liczba ta jest kilkakrotnie wyższa, niż odpowiednie wartości charakteryzujące inne gatunki ssaków. Umożliwia to ryjówkom wydatne zwiększenie powierzchni wymiany gazowej.

Przyczyną odrębności morfologicznej tkanki krwiotwórczej ryjówek, występującej począwszy od 5—6 tygodnia ich samodzielnego życia (Perkowska, 1963), może być przeciążenie tej tkanki, spowodowane niezwykle intensywną produkcją erytrocytów.

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