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Body Temperature in Five Species of Shrews

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Gębczyński M. 1977: Body temperature in five species of shrews. Acta theriol., 22, 35: 521—530 [With 3 Tables & 2 Figs.].

Body temperatures (T_B) were measured in five species of insectivorous mammals, *Sorex minutus*, *Sorex caecutiens*, *Sorex araneus*, *Neomys anomalus* and *Neomys fodiens*. Mean T_B of shrews ranged from 37.3 to 39.1°C varying with species but more so with the age of animals and season when measurements were made. Daily T_B rhythm in *S. araneus* and *S. minutus* showed amplitudes of 0.6°C. Low ambient temperature (5°C) changed the T_B of shrews from −1.1°C to +0.5°C and at 30°C a rise of T_B from 0.1°C to 1.3°C was observed. High pre-measurement activity results in an increase of T_B up to 2°C above the normal level. Starvation affects T_B in shrews but reversible hypothermy was not observed.

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INTRODUCTION

Of 278 mammalian species for which the T_B was listed by Altman & Dittmer (1968) only seven belong to the *Insectivora*. This may reflect the scant interest by physiologists for this Order of mammals. Yet this group is important in comparative physiology due to the many species (374), their adaptability to various environments, and the extremely small size of some shrews. Initial body temperatures for two species of shrews were given by Kendeigh (1945). Nevertheless his hypothesis concerning a relatively low T_B in *Blarina brevicauda* was not confirmed by the greater amount of data obtained by Doremus (1965) and Neal & Lustic (1973). The studies of Vogel (1974) unexpectedly indicate that the smallest mammal, *Suncus etruscus*, undergoes reversible hypothermy. Although T_B for this species is not known, T_B for *Suncus murinus*, a related but much larger form, is within the normal range for mammals (Hasler & Nalbandov, 1974). However, Bashenina's (1965) suggestion of reversible hypothermy in *Sorex minutus* (subfamily *Soricinae vs Crocidurinae* for *Suncus*) could not be confirmed by measurements of oxygen consumption (Gębczyński, 1971). Range of T_B in *Sorex cinereus* is relatively wide (36—41°C) depending on pre-measurement activity (Morrison, Ryser & Dawe, 1959) although torpor was not observed.

In more detailed studies on shrews belonging to the genus *Sorex* their specific biology should be considered. Individuals born in a given year are sexually inactive though completely independent from their parents. They achieve sexual maturity after overwintering. Young adults differ from overwintered old adults in many morphological and physiological features (for extensive review see Pucek, 1970). Therefore the aim of this study was not only to document T_B in several species of European *Insectivora* but also to analyze whether this parameter depends on age and season. Moreover, observations were made of the influence of different ambient temperatures, activity and starvation on the stability of T_B in shrews. This made it possible to determine whether reversible hypothermy occurs in soricine shrews, as it does in crocidurine shrews.

MATERIALS AND METHODS

A total of 239 insectivores belonging to five species (Table 1) were trapped in different seasons of the year in Białowieża National Park in Northeastern Poland. Live-traps were checked every 2 or 3 hours, usually at night except

Table 1

Individual insectivores tested by season. Adults were born the previous year and overwintered. Juveniles were born the year they were measured. Body weigths (g) are given in brackets.

Species	Spring		Summer		Autumn	Winter
	Ad.	Juv.	Ad.	Juv.	Juv.	Juv.
Common shrew (*Sorex araneus*)	18 (10.4)	18 (7.2)	13 (10.3)	27 (7.1)	8 (6.7)	21 (5.6)
Masked shrew (*Sorex caecutiens*)	5 (5.8)	—	—	—	4 (4.1)	—
Lesser shrew (*Sorex minutus*)	3 (3.7)	3 (2.7)	6 (4.3)	15 (2.7)	31 (2.8)	14 (2.5)
Water shrew (*Neomys fodiens*)	13 (14.8)	—	7 (15.7)	25 (11.1)	—	3 (12.8)
Mediterranean water shrew (*Neomys anomalus*)	3 (10.0)	—	2 (10.3)	—	—	—

during extreme weather conditions when they were checked only in the evening and morning. Trapped animals were maintained in the laboratory in separate cages containing moss litter. Animals were fed minced meat, *Tenebrio* larvae and water *ad libitum*.

Intial T_B measurements were usually made an hour after transporting the animals into the laboratory. Successive determinations were made daily. No significant differences in T_B were noted between the first and subsequent measurements. Temperature was measured *per rectum* by an electric thermometer (Electro-laboratiet, Denmark) accurate to 0.1°C using a flexible probe (F6) with a diameter of 0.9 mm inserted 15 mm in *Sorex minutus* and up to 30 mm in *Neomys fodiens*, and other shrew species.

RESULTS

1. Body Temperature under Normal Conditions

Sorex araneus. T_B in the common shrew is variable and dependent on the season and age of the animal. Comparison of T_B in young adults from several successive seasons shows that the mean value increases from spring to autumn yet the differences between spring [1] and summer-autumn are not statistically significant. It is only the drop observed in winter that is important in comparison with autumn ($P<0.02$, Student's t test; Table 2).

Old adults were caught only in spring and summer. Mean T_B in both seasons is nearly the same (Table 2) but T_B in both spring and summer animals is significantly lower ($P<0.01$) compared with young animals in the same season. T_B values at variance with the mean were noted in three shrews, all juvenile *Sorex araneus*, which lived several hours after the initial determination:

1. Winter, T_B 34.4°C at 7:30 am, 36.9°C at 2:00 pm.
2. Summer, T_B 34.5°C at 8:00 am, 37.8°C at 10:00 am.
3. Summer, T_B 34.9°C at 8:00 am, 38.4°C at 11:00 am.

Since T_B drops of this magnitude have never been observed in this laboratory I assume that these low temperatures resulted from some unknown effects of trapping.

Sorex caecutiens. Relatively few (9) of these shrews were caught. Yet both old adults from spring and young adults from autumn experienced consistently elevated T_B in comparison with that of other species of *Sorex* (Table 2).

Sorex minutus. In this species, as in *Sorex araneus*, T_B of young adults is highest in autumn ($P<0.02$). Also T_B of old adults in spring and summer is lower than for young adults though the difference ($P<0.01$) is significant only in summer (Table 2). In only one *Sorex*

[1] In 1975, when measurement occurred, young of the year were first trapped 28 May, nearly a month earlier than usual. Thus it was possible to compare young adults with overwintered (old) adults during the same season.

Table 2

Rectal temperatures of 5 species of European shrews by age and season of capture. n = number of measurements. Mean values omit the very low temperatures of 3 *S. araneus* and 1 *S. minutus* discussed in the text.

Species	Measurement	Spring		Summer		Autumn	Winter
		Ad.	Juv.	Ad.	Juv.	Juv.	Juv.
Sorex araneus	Mean ± S.D.	37.3 ± 0.8	38.0 ± 0.8	37.4 ± 0.9	38.3 ± 0.8	38.6 ± 0.6	38.1 ± 0.8
	min—max	35.2—38.8	36.1—39.1	35.9—38.8	36.3—39.9	37.0—40.4	36.3—39.8
	n	23	25	16	114	22	41
Sorex caecutiens	Mean ± S.D.	38.3 ± 1.0	—	—	—	39.1 ± 0.6	—
	min—max	37.4—40.0	—	—	—	37.8—40.2	—
	n	12	—	—	—	17	—
Sorex minutus	Mean ± S.D.	37.7 ± 0.5	38.3 ± 0.8	37.4 ± 0.9	38.2 ± 0.5	38.6 ± 0.6	38.2 ± 0.8
	min—max	37.2—38.7	37.2—39.4	36.2—38.4	36.8—39.0	37.0—39.8	37.0—39.6
	n	8	10	19	38	143	18
Neomys fodiens	Mean ± S.D.	38.4 ± 0.7	—	38.3 ± 0.6	38.7 ± 0.7	—	38.4 ± 0.6
	min—max	37.4—39.6	—	37.7—39.6	37.6—40.0	—	38.2—39.2
	n	41	—	16	48	—	9
Neomys anomalus	Mean ± S.D.	38.9 ± 0.6	—	38.1 ± 0.5	—	—	—
	min—max	37.8—39.8	—	37.5—39.2	—	—	—
	n	10	—	6	—	—	—

minutus trapped in autumn was T_B 35.2°C; after three hours in the laboratory it rose to 37.4°C. Similar low, reversible T_B was not observed in the other species shrews.

Neomys fodiens. The water shrew does not display significant seasonal fluctuations in T_B. Also there are no significant differences between young adults and old adults (Table 2) though in summer T_B for old adults is slightly lower than in shrews born that year.

Neomys anomalus. Individuals of this species were trapped only in spring and summer. The mean T_B in both seasons is high, and for old adults from spring it is even higher than for young adults (Table 2).

2. Daily T_B Rhythm

For *S. araneus* and *S. minutus* T_B measurements were made every three hours, day and night. Fluctuation were minimal. Maximum T_B

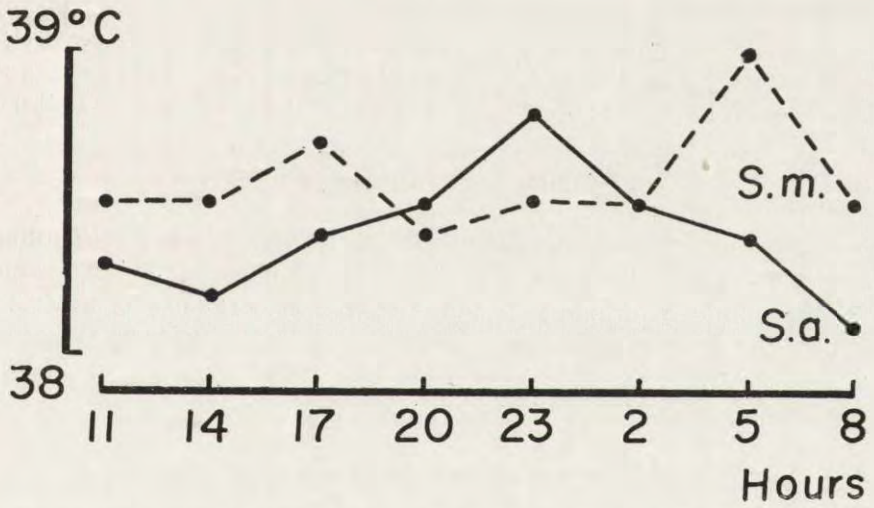

Fig. Daily T_B rhythm in the common shrew, *Sorex araneus* (S.a.), and the lesser shrew, *Sorex minutus* (S.m.).

S.m.	S.D.	.4	.3	.3	.4	.5	.4	.5	.5
	n	12	10	10	10	12	6	6	9
S.a.	S.D.	.6	.4	.5	.3	.5	.2	.4	.5
	n	16	16	15	15	15	7	9	16

of 38.8°C for the common shrew occurred at 11 pm and decreased to 38.2°C between 8 am and 2 pm. Lesser shrews' mean daily differential is also 0.6°C but the rhythm of this variation differs from that of the other species since it is maximal between 5 pm and 5 am (Fig. 1).

3. Influence of Ambient Temperature on T_B

Shrews were kept for three hours with access to food at ambient temperatures of approximately 5°C or 30°C. Body temperatures were measured immediately before and after this period. At 5°C T_B falls, but not in all cases. *N. fodiens* from spring and *S. areneus* from winter show a rise in T_B, about 0.1°C and 0.5°C, respectively (Table 3). Conversely, all shrews tested at 30°C experienced elevated mean T_B. This rise is quite remarkable, amounting from 0.5°C to 1.3°C except for *N. fodiens* in the spring (0.1°C) (Table 3).

Table 3

Influence of ambient temperature on T_B in five species of shrews caught in different seasons. n=number of measurements; −=drop of T_B; +=rise of T_B.

Species	Season,	age	n	at 5 C	n	at 30 C
Sorex araneus	summer,	juv.	3	−1.1 (37.2)	6	+0.7 (39.0 ± 0.3)
	winter,	juv.	4	+0.5 (38.6 ± 0.2)	3	+1.3 (39.4)
Sorex caecutiens	autumn,	juv.	2	−0.1 (39.0)	4	+1.2 (40.3 ± 0.2)
Sorex minutus	summer,	juv.	3	−0.3 (37.9)	3	+0.7 (38.9)
	autumn,	juv.	18	−0.7 (37.9 ± 0.6)	13	+0.5 (39.1 ± 0.5)
Neomys fodiens	spring,	ad.	6	+0.1 (38.5 ± 0.4)	6	+0.1 (38.5 ± 0.8)
Neomys anomalus	spring,	ad.	4	−0.8 (38.1 ± 0.5)	3	+0.7 (39.6)

4. Influence of Activity on T_B

S. araneus and *S. minutus* forced to run in a cage for 5 to 7 minutes prior to T_B determinations responded with elevated T_B. The mean T_B of 7 juvenile *S. araneus* in summer was 39.6°C (39.0°C to 40.3°C). That of 4 juvenile *S. minutus* was 40.0°C (39.7°C to 40.6°C) in autumn. Thus average T_B elevations were respectively 1.3°C and 2.0°C compared with seasonal means.

5. Starvation and T_B

Sorex araneus deprived of food were initially hyperactive, resulting in elevated T_B. After this, they experienced either stationary or depressed T_B (Fig. 2A). In *S. caecutiens* a slight drop in T_B was observed during the first 5 hours after food deprivation. After 7 hours T_B dropped considerably, body movements decreased, and the animals refused offered food.

Starvation of 18 *S. minutus* for 2 hours did not alter their mean T_B. However, two adult *S. minutus* observed in the spring had elevated T_B following intense activity. Subsequently both died nearly simultane-

ously. These two shrews may be considered exceptional since others observed in autumn endured 7 hours of starvation. Then their T_B increased slightly for 5 hours after food removal then plateaued (Fig. 2B).

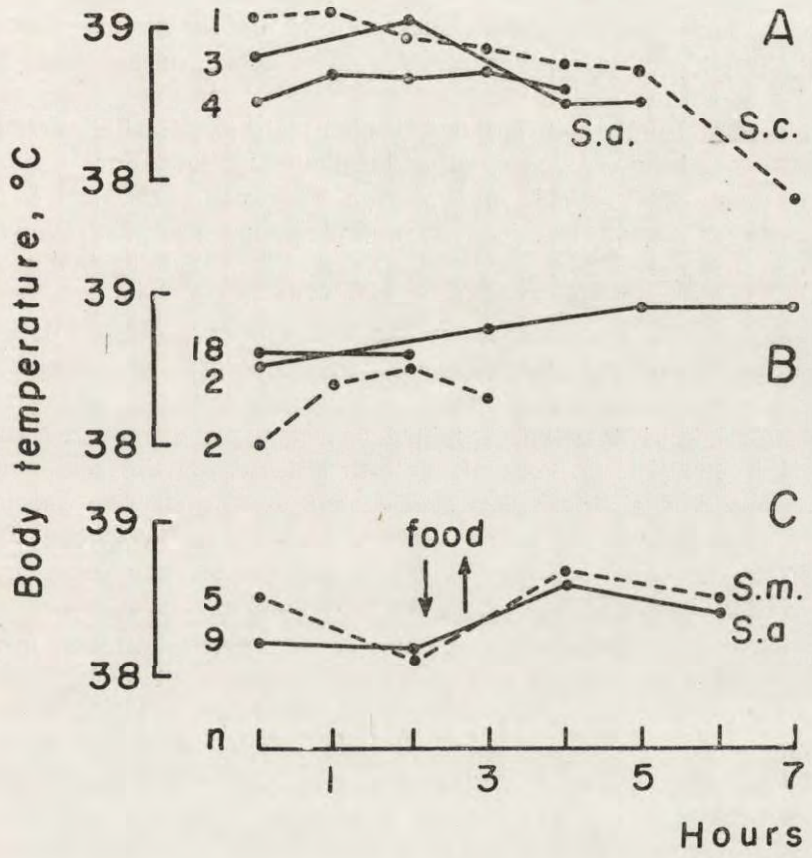

Fig. 2. Influence of starvation on T_B in three species of shrews.
A. *Sorex caecutiens* (S.c.), autumn; *Sorex araneus* (S.a), spring (n=3 juv., 4 ad.). B. *Sorex minutus* (S.m.); continuous line = autumn, broken line = spring. C. *Sorex minutus* and *Sorex araneus*. After 2 hours without food, food was offered for 30 minutes and then removed.

Two series of measurements were made on starved *S. araneus* and *S. minutus*. During this time they were offered food for 30 minutes only. The first 2 hours without food did not cause T_B change of *S. araneus* but in *S. minutus*, T_B dropped. Food consumption was followed by T_B rises in both species, after which their temperature again fell (Fig. 2C).

DISCUSSION

Body temperature, a fundamental parameter in bioenergetics, is relatively easy to determine but data exist for about 7% of the mammalian species and these data are often not in agreement. Morrison & Ryser (1952) demonstrated that T_B in mammals is apparently independent of body weight. Nevertheless, T_B is unquestionably connected with the metabolic level characteristic of a given species (McNab, 1966). Since shrews are characterized by high heat production rate it may be assumed that their T_B is correspondingly great. This assumption has, however, been only partially documented. Both *Sorex cinereus* (Morrison *et al.*, 1959) and *Blarina brevicauda* (Neal & Lustick, 1973) occupy positions in the upper part of the known T_B range for mammals. The present data demonstrate that T_B in European shrews are correspondingly high. Differences among the five species studied are small, although in spring and summer, old, adult *Sorex araneus* and *S. minutus* have lower T_B in comparison with three other species. The lower T_B of old adults compared with that of young adults of the same species may be explained by metabolic differences (Gębczyński, 1965). It is more difficult to account for the seasonal differences observed in these two species but T_B for all five species of shrews, regardless of age and season, is generally between 37.3°C and 39.1°C. T_B in 14 of the 19 age-season groups studies is in the range of 38.0°C to 38.7°C.

The effect of experimental starvation on T_B is not uniform, initially resulting in both a rise of and a drop in T_B, as well as lack of any change. In *Sorex minutus*, starvation for three hours resulted in nearly simultaneous death of two animals, yet two others lived 7 hours without nourishment. This ability to withstand starvation is doubtlessly affected by many physical and physiologic parameters (*e.g.*, coprophagy: see Loxton *et al.*, 1975) but no reversible hypothermy was caused by starvation in the laboratory. It must be stressed that shrews can withstand ambient temperature drops to 5°C but respond by a slight decrease as well as a slight rise in T_B. However, elevated T_B, often significantly, invariably occurred at 30°C. Other shrews react to high ambient temperature similarly (Morrison *et al.*, 1973).

It can generally be concluded that shrews are characterized by an ability to maintain temperature constancy within a wide range of ambient temperature. They are also able to survive temporary food deprivation and, though T_B may fluctuate, reversible hypothermy in the *Soricinae* is not indicated by the present data. Differences of T_B among the species of shrews studied are relatively small.

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TEMPERATURA CIAŁA U PIĘCIU GATUNKÓW RYJÓWEK

Streszczenie

Zmierzono temperaturę ciała u pięciu gatunków drobnych ssaków owadożernych: *Sorex minutus, S. caecutiens, S. araneus, Neomys anomalus, N. fodiens;* łowionych w różnych porach roku (Tabela 1). Średnia wartość temperatury ciała waha się

od 37,3 do 39,1°C — zależnie od gatunku a przede wszystkim od wieku zwierzęcia i sezonu jego złowienia (Tabela 2). Dobowy rytm ciepłoty ciała u *S. areneus* i *S. minutus* wykazuje amplitudę około 0,6°C (Ryc. 1). Niska temperatura otoczenia (5°C) zmienia temperaturę ciała ryjówek od −1,1 do +0,5°C a przy 30°C obserwuje się wzrost od 0,1 do 1,3°C (Tabela 3). Duża ruchliwość przed pomiarem, może podnieść temperaturę ciała nawet do 2°C powyżej wartości normalnej. Głodzenie ma pewien wpływ na badany wskaźnik (Ryc. 2), ale nie stwierdzono by wywoływało ono odwracalną hipotermię.