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Metabolic Acclimatization of Bank Voles to Laboratory Conditions

[With 2 Tables & 3 Figs.]

The metabolism (oxygen consumption) was compared in the bank voles, *Clethrionomys glareolus* (S c h r e b e r, 1780) reared in the laboratory for several generations ("laboratory") and in voles captured in the field ("wild"). The general shape of temperature — metabolism curves in the range of +5 to +35°C was similar in laboratory and wild voles and their thermoneutral zone was around 30°C. The metabolism of laboratory voles was usually higher than in wild voles but the difference was statistically significant only in the temperatures 15 and 20°C during the winter and 10 and 20°C during the summer. In laboratory temperatures (15—25°C) the heat production was markedly lower in the laboratory voles, both in the winter and in the summer. The body insulation index in wild voles undergoes drastic seasonal changes, while in the laboratory voles it is quite similar in the winter and in the summer. Consequently, the models of wild rodents bioenergetics can not be based on the laboratory strains of these species.

I. INTRODUCTION

The diurnal models of wild rodent bioenergetics are usually constructed on the basis of the average daily metabolic rate — *ADMR* (G r o d z i ń s k i, 1966; G ę b- c z y ń s k i, 1966; G ó r e c k i, *in litt.*), the resting or the basal metabolic rate — *RMR* or *BMR* (G r o d z i ń s k i, 1961; M c N a b, 1963). For the measurements of the metabolic rate and thermoregulation it is more convenient to use rodents "domesticated" in the laboratory rather than wild animals caught in field. Animals reared in the laboratory for several generations are tamer and are able to tolerate better the conditions of the experiment. Using the laboratory strain it is also easier to select the experimental group with required characteristics, for example with similar body weight, age, physiological state or the same sex.

However, it can be expected that in the laboratory the dependence of metabolic rate on the ambient temperature is somewhat changed. Such changes in the chemical and physical thermoregulation were reported in both *Clethrionomys* and *Microtus* (S m i r i n, 1961; G r o d z i ń s k i, 1962; G ę b c z y ń s k i & O l s z e w- s k i, 1963) and could be explained by the metabolic acclimatization (H a r t, 1964).

The purpose of this investigation was to determine the metabolic acclimatization of bank voles reared for several generations in laboratory conditions. This was done by comparing the oxygen consumption of these laboratory voles with the voles caught in the field.

II. MATERIALS AND METHODS

The material consisted of bank voles, *Clethrionomys glareolus* (S c h r e b e r, 1780) reared in our laboratory — "laboratory voles" and bank voles from the field — "wild voles". Laboratory voles were from the seventh and eighth inbred generations of our strain maintained by brother-sister matings since 1959. These animals were reared in the laboratory at about 20°C temperature (17—21°C), and the length of day fixed to 12 hours (D r o ż d ż, 1964). Wild voles were from the beech forest in the Ojców National Park near Cracow. They were caught during the winter (15 February — 15 March, 1965) and during the summer (1—30 July, 1965) and kept from 3—5 days in the laboratory.

The chemical thermoregulation was determined from the oxygen consumption in the modified respirometer of Kalabukhov — Skvartzov (G r o d z i ń s k i, 1961). In this apparatus the resting metabolic rate (*RMR*) is being measured as the animal is placed in a small cage and its activity is restricted. The oxygen consumption was measured in seven different ambient temperatures, from +5 to +35°C with the interval of 5°C. In both the winter and the summer series the metabolism of laboratory and wild voles was compared using 10 to 22 animals of each kind. Only in the temperature of 35°C which is close to the lethal zone of bank voles, a smaller number of animals was used (Table 1). The total of 349 thirty minute runs were made using 65 animals.

The body weight of laboratory and wild voles was similar in both seasons studied. In the winter the mean weight was 19.5 g for the wild and 21.2 g for the laboratory voles, in the summer the animals were slightly heavier, the mean weight 23.3 and 22.0 g, respectively. The rectal body temperature of voles was measured with the tele-thermistor thermometer before and after each run.

The oxygen consumption was determined in ccm/g/h. From this value the intensity of thermoregulation in cal/g/h/°C and the body insulation were computed according to the formula of H a r t & H é r o u x (1955).

III. RESULTS

1. Oxygen Consumption

In the winter both wild and laboratory voles had the lowest metabolic rate in 30°C and consequently this temperature corresponds to their thermoneutral zone. The absolute increase of oxygen consumption from the thermoneutral zone to +5°C was 4.8670 ccm/g/h in the wild voles and 5.3633 ccm/g/h in the laboratory voles, or 2.28 and 2.48 times, respectively. The curve of chemical thermoregulation in wild voles did not have significant deviations from the straight line (Fig. 1, Table 1). However, the thermoregulation curve of laboratory voles had a characteristic inflection in the temperature 15—20°C, as the oxygen consumption was almost identical over this range. In these two temperatures the oxygen consumption of laboratory and wild voles was significantly different ($P < 0.01$). In all other temperatures the differences between laboratory and wild voles were not significant. In the lower temperature

range (5 and 10°C) the laboratory voles seemed to have a metabolic rate slightly above that of the wild voles (Fig. 1).

In the summer the general shape of thermoregulation curves for both wild and laboratory voles was quite similar to the curves obtained in the winter (Fig. 2, Table 1). The lowest oxygen consumption (thermoneutral zone) was also at the temperature 30°C in the laboratory voles but at 35°C in the wild voles. This temperature is very close to the lethal zone for this species. Consequently, further decrease of the metabolism rate in this temperature can be caused by pathological changes (at 35°C

Table 1.

Metabolic rate of "wild" and "laboratory" bank voles expressed in the oxygen consumption at different ambient temperatures.

Ambient temperature (°C)	Animal number	Oxygen consumption		Animal number	Oxygen consumption	
		ccm O_2/g/h $\pm$ S.D.	Coeff. Var. (%)		ccm O_2/g/h $\pm$ S.D.	Coeff. Var. (%)
Winter:		Wild voles			Laboratory voles	
5	13	8.6560 $\pm$ 0.3161	3.6	10	8.9756 $\pm$ 1.8205	20.3
10	13	7.0777 $\pm$ 0.7316	10.3	10	7.2564 $\pm$ 0.7681	10.5
15	13	6.0773 $\pm$ 0.7243	11.9	10	5.5461 $\pm$ 1.2130	21.8
20	14	4.8329 $\pm$ 0.7570	15.6	10	5.5429 $\pm$ 0.1683	3.1
25	15	4.1970 $\pm$ 0.7607	18.1	10	4.3961 $\pm$ 0.1879	4.2
30	14	3.7890 $\pm$ 0.7215	19.0	8	3.6123 $\pm$ 0.1541	4.2
35	2	4.5319 $\pm$ —	—	4	3.8573 $\pm$ 1.5980	—
Summer:						
5	22	8.5491 $\pm$ 1.1993	14.0	18	8.7438 $\pm$ 1.1313	12.9
10	22	7.1556 $\pm$ 1.0375	14.5	17	7.8196 $\pm$ 0.8016	10.2
15	22	6.4902 $\pm$ 0.8803	13.5	18	6.1649 $\pm$ 1.1135	18.1
20	22	4.9821 $\pm$ 0.5629	11.3	18	5.6774 $\pm$ 0.6422	11.3
25	22	4.1579 $\pm$ 0.5687	13.7	18	4.3766 $\pm$ 0.5385	12.3
30	22	3.5242 $\pm$ 0.6168	17.5	17	3.6143 $\pm$ 0.6746	18.7
35	7	3.4331 $\pm$ 0.6057	17.6	3	3.9306 $\pm$ 0.9306	3.8

nearly half of the animals died during the experiment). The absolute increase of oxygen consumption from 30 to 5°C was 5.0249 ccm/g/h in wild voles and 5.1295 ccm/g/h in laboratory voles — the increase by factor 2.42 and 2.41, respectively. The oxygen consumption in the lowest temperature studied (5°C) in wild voles was slightly higher in the summer than in the winter and in laboratory voles almost identical.

In the summer the shape of both curves was even more similar than in the winter. The difference between wild and laboratory voles was apparent only in 10 and in 20°C. The difference in 10°C was highly

significant while the difference in 20°C was approaching the significance
level (P = 0.065). However, in all temperatures the oxygen consumption
seemed slightly higher in the laboratory voles. The only exception was
the temperature of 15°C when, like in the winter the metabolic rate of
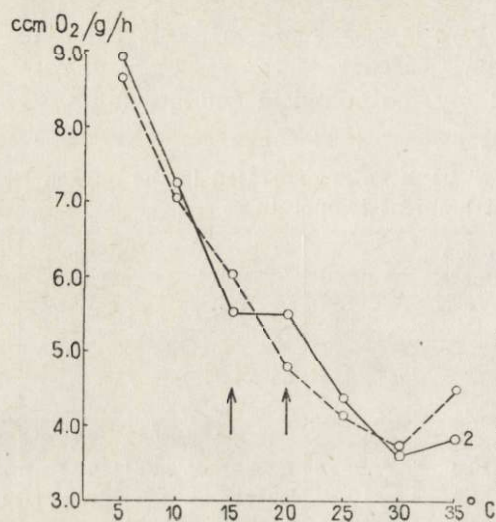wild rodents was slightly above that of laboratory animals (Fig. 1, 2).

Fig. 1. Temperature — metabolism curves
of bank voles in the winter. 1 — wild
voles, 2 — laboratory voles.
Arrows indicate the temperatures in
which the oxygen consumption of wild
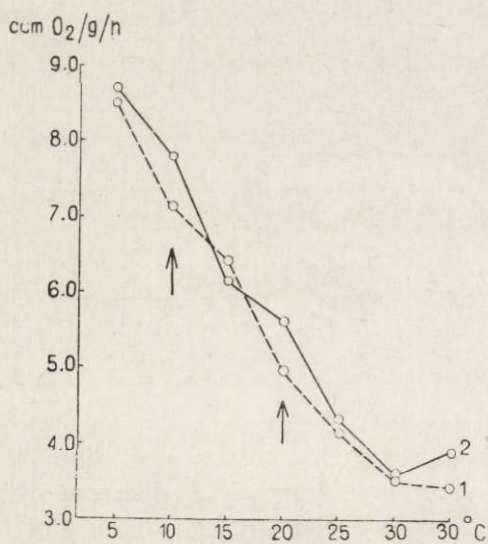and laboratory voles is significantly
different.

Fig. 2. Temperature — metabolism curves
of bank voles in the summer. 1 — wild
voles, 2 — laboratory voles.
For explanation see Fig. 1.

2. Heat Production

The heat production in cal/g/h was computed from the oxygen con-
sumption assuming $RQ = 0.8$, when the caloric equivalent of 1 ccm of
oxygen is 4.8 cal. Considering the value obtained in the thermoneutral

zone (30°C) as 100%, it is possible to express in per cent the increase in heat production with the decrease of ambient temperature. The increase in the winter, when the temperature was lowered from 30 to 5°C was the smalest in wild voles equaling 228.5%. In the summer it was almost equal in the wild and the laboratory animals; 242.6% and 241.9%, respectively. It was still higher in the laboratory voles in the winter when it reached 248.5% (Tab. 2).

Table 2.

Heat production of bank voles in different ambient temperatures.

Ambient temperature (°C)	Heat production in cal/g/h			
	Winter		Summer	
	Wild	Laboratory	Wild	Laboratory
5	41.55	43.08	41.04	41.97
10	33.97	34.83	34.35	37.53
15	29.17	26.62	31.15	29.59
20	23.20	26.61	23.91	27.25
25	20.15	21.10	19.96	21.01
30	18.19	17.34	16.92	17.35

The heat production in cal/g/h/°C differed considerably between temperatures. The zone of 15—25°C to which the laboratory voles were being acclimatized by being reared in room temperature is of special interest. In both seasons the increase in heat production in this zone was much higher in the wild than in the laboratory voles. In the winter it amounted to 0.903 cal/g/h/°C in the wild and only to 0.553 cal/g/h/°C in the laboratory voles; in the summer — 1.119 and 0.858 cal/g/h/°C, respectively. Consequently, the wild voles produced more heat than the laboratory animals; the difference being 0.350 cal/g/h/°C in the winter and 0.261 cal/g/h/°C in the summer (within the range of 15—25°C).

3. Body Insulation

The body insulation index for wild and laboratory voles was calculated from the formula of Hart & Héroux (1955):

$$Ii = \frac{\text{Body temperature} - \text{Ambient temperature}}{\text{Oxygen consumption}}$$

In the ambient temperature of 5—35°C the body temperature of the voles did not exhibit significant directional changes and all the measurements were between 36.2 and 38.5°C. Consequently, the mean temperature of 50 animals (37.23°C) was used for the calculations.

The seasonal differences in body insulation of voles are much larger than the differences between wild and laboratory animals. The differences in insulation between the winter and the summer were considerably larger in the wild voles (Fig. 3). In all temperatures the body insulation of wild voles was better in the winter than in the summer. This was specially true about the temperatures from 5 to 20°C when the insulation index was on the average 12% higher in the winter animals. In laboratory
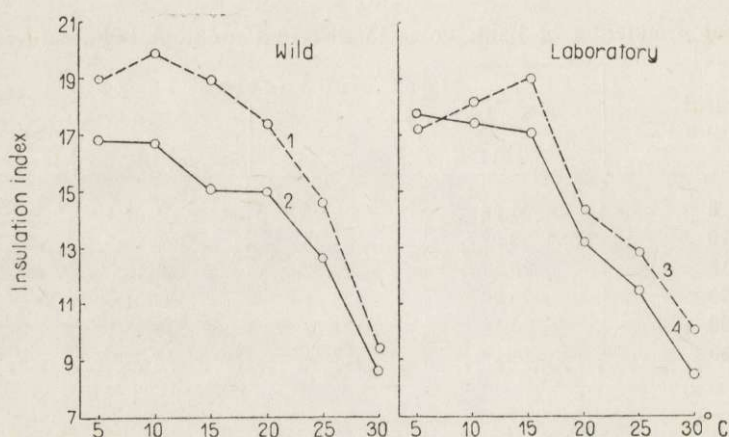
Fig. 3. Body insulation index in wild and laboratory voles in temperature from +5° to +35°C.
1, 3 — winter; 2, 4 — summer.

voles the seasonal changes of insulation were very small and resulted in slightly higher insulation index in winter animals between 15 and 30°C. In lower temperatures (10 and 5°C) the body insulation of laboratory voles was insufficient in both winter and summer (Fig. 3).

IV. DISCUSSION

The metabolic rate of wild bank voles reported in this work is in accordance with the data on voles caught in the field (B a s h e n i n a, 1958; S u n - Ż u - J u n, 1959; J á n s k ý, 1959; G r o d z i ń s k i, 1961). The shape of temperature-metabolism curves and the location of thermo-neutral zone around the temperature of 30°C confirms the data of B a s h e n i n a (1958) and S m i r i n (1961). However, the data of different investigators on the seasonal changes of the metabolism of wild voles are contradictory. According to S u n - Ż u - J u n (l.c.) the oxygen consumption of voles between 10 and 30°C was markedly higher in the winter than in the summer. However, V o l č a n e c k a j a (1954) reported

that in the winter the oxygen consumption may be even lower than in the summer, as in the winter the physical thermoregulation increases. In this work it was demonstrated that the metabolism rate of wild voles is very similar in the winter and in the summer (there were no significant differences in any temperature studied). However, over the whole range from 5 to 20°C it appeared to be slightly lower during the winter (Fig. 1, 2, Tab. 1). This slight decrease of the metabolic rate in the winter could be explained by the increased insulation of the bank vole fur in this season (Gębczyński & Olszewski, 1963). These investigators did not find analogous seasonal changes of the fur of laboratory voles. In our laboratory voles there were only minimal seasonal changes in both the chemical thermoregulation and the body insulation.

It is difficult to estimate when the "domestication" changes of metabolic rate occured in the studied strain of laboratory animals. In the bank vole the first signs of such metabolic acclimatization were found already after several weeks stay in the laboratory (Smirin, 1961). Hart (1964) reported that in the wild and laboratory rats after six weeks of acclimatization to cold (6°C) there were some structural and physiological metabolic modifications. Consequently, it appears that in the wild rodents the first changes in the heat production take place already after very short stay in laboratory conditions. Permanent changes in the body insulation appear more slowly and probably require long adaptation to the laboratory temperature.

In the laboratory voles the acclimatization of metabolic rate and thermoregulation took place predominantly in the narrow zone between 15 and 25°C. Although the changes in this zone are rather slight, it seems that using laboratory voles for constructing the models of bioenergetics is inadvisable. These models are usually constructed on the basis of the *ADMR* measured at 20°C with the corrections for thermoregulation (Grodziński, 1966; Gębczyński, 1966; Górecki, *in litt.*). The bioenergetic models computed from *RMR* or *BMR* (Grodziński, 1961; McNab, 1963) also depend heavily on the corrections for thermoregulation. At 20°C the oxygen consumption of laboratory rodents is higher than in wild rodents with the difference of 14.6% in the winter and 13.9% in the summer. It seems relevant that in the natural habitat the temperature in the nest of bank voles is 17—19°C being very close to the temperature discussed above (Daniel, 1964). Considering the differences in the thermoregulation in lower temperatures it is possible to estimate that the models of bioenergetics based in laboratory voles would have an error of 15—20%. Consequently, for the bioenergetic studies wild animals from the field should be used. They should be kept in the laboratory only for a very short period (2—5 days) which is

necessary for the psychological adaptation to the captivity. However, in more difficult or long term bioenergetic studies it is often necessary and quite justified to use laboratory voles.

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AKLIMATYZACJA METABOLIZMU NORNICY RUDEJ DO WARUNKÓW LABORATORYJNYCH

Streszczenie

Porównywano metabolizm (zużycie tlenu) u nornic rudych, *Clethrionomys glareolus* (S c h r e b e r) hodowanych w laboratorium od kilku pokoleń („laboratoryjne") i nornic z terenu („dzikie"). Ogólny kształt krzywych termoregulacji w zakresie od +5 do +35°C jest dość podobny u nornic laboratoryjnych i dzikich, a ich strefa termoneutralna leży wokół 30°C. (Fig. 1., 2., Tab. 1.). Metabolizm nornic laboratoryjnych jest zwykle wyższy od metabolizmu nornic dzikich, jednak statystycznie różni się tylko w temperaturze 15 i 20°C w zimie, oraz w temperaturach 10 i 20°C w lecie. W strefie temperatur laboratoryjnych (15—25°C) produkcja ciepła zarówno w zimie, jak i w lecie, jest wyraźnie niższa u nornic laboratoryjnych (Tab. 2). Indeks izolacyjności ciała u nornic dzikich podlega ostrym zmianom sezonowym, podczas gdy u nornic laboratoryjnych jest dość zbliżony w zimie i w lecie (Fig. 3.). „Domestykacyjne" zmiany metabolizmu nornic laboratoryjnych obejmują więc zarówno zmiany w termoregulacji chemicznej, jak też znaczne ograniczenie termoregulacji fizycznej. Konstruując modele bioenergetyki dzikich gryzoni powinno się używać zwierząt z terenu, a nie szczepów tych zwierząt hodowanych w laboratorium.