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**Oxygen Consumption and Behaviour of the Golden Hamster
at Different Ambient Temperatures**

[With 2 Tables & 1 Fig.]

In golden hamster (*Mesocricetus auratus*, Waterhouse, 1839) measurements were taken of the oxygen consumption rate, body temperature, and respiratory movements — within a 15 to 40°C range of ambient temperature. Observations were made of the different behavioural patterns associated with resistance to the thermal pressure of the environment. Metabolic rate in animals starved for 24 hrs is lowest at an ambient temperature of 24—35°C, amounting to about 60 kcal/kg^{0.75} day. Body temperature is rather unstable, showing fluctuations from 36 to 41°C — these changes being governed by the ambient temperature and by activity of the animals. The number of respiratory movements is likewise closely dependent on the ambient temperature, the lowest number occurring at 30°C (28 resp./min.). Evidently, the comparatively low metabolic rate, the ability to endure notable fluctuations in body temperature as well as the varied manifestations of behavioural patterns, represent forms of adaptation of this species to conditions of an arid and hot climate.

1. INTRODUCTION

Small homeotherms have a less favourable body surface—volume ratio than large ones. In effect, the possibility of maintaining a stable body temperature is much inferior. Under conditions of physiological heat, hence in a temperature higher than the neutral zone, heat penetrates the body whose small mass accounts for the rapid rise in temperature. Defence means against hyperthermia, panting and/or sweating, are of little avail owing to the small quantity of water which can be evaporated by these animals without hazard of dehydration (Schmidt-Nielsen, 1964). For this very reason small homeothermal animals avoid high temperatures of the environment by way of finding out niches with more favourable thermal conditions. Some species have a wider range of body temperature fluctuations. The golden hamster represents a species in which has been found an astonishing capacity to survive a rised body

temperature. For example, under the earlier experiments of increasing the temperature of the surroundings, from 15 to 40°C throughout a period of 90 min, temperature of the brain rose from 36.5 to 41.5°C. Subsequent bringing down of the ambient temperature to 15° involved a return to the initial body temperature within 30 min; the behaviour remained unchanged (Tęgowska & Narębski, 1973). Some other species of small mammals display similar, though not so spectacular, changes in body temperature under analogous thermal effects of the environment. And so, ground squirrel, *Spermophilus beecheyi* (Richardson, 1829), has a body temperature range of 38—41°C (Baudinette, 1972); in rat, *Rattus rattus* (Linnaeus, 1758), the temperature ranges between 38 and 40°C; while in *Rattus villosissimus* — between 36 and 40°C (Collins & Bradshaw, 1973).

Golden hamster, *Mesocricetus auratus* (Waterhouse, 1839) is a rodent of the *Cricetinae* family; south-eastern Europe and Asia Minor, with arid and hot summers, are the countries of origin of this species. For many years now, golden hamster has served as a laboratory animal, and yet its reason measurements were taken of the oxygen consumption rate, the respiratory rhythm, body temperature and changes in behaviour of this species, as evoked by the changing ambient temperatures.

2. MATERIAL AND METHODS

Experiments were conducted on 20 hamsters of both sexes, with an average body weight of about 120 g. The animals were kept in separate cages. Food supplied *ad libitum* consisted mainly of oats, bread, carrots and milk. The rhythm of illumination was 10L/14D. Ambient temperature of the breeding conditions remained at the level of 20±2°C.

Oxygen consumption rate was measured on animals kept singly, in chambers 14.4 l in volume; use was made of a closed circuit respirometer (Gębczyński, 1963). The preliminary period lasted from 5 to 30 min, while the measurement proper required one hour. Results were considered against the standard temperature and pressure. Heat production was calculated on the assumption that the calorific equivalent of oxygen is 4.8 kcal/l. Just before the performance of measurements and immediately after, rectal body temperature was taken with an accuracy up to 0.1°C, at a depth of 4.5 cm. In use was the Ellab electric thermometer and RM-4 probe. In view of the tameness of the animals which did not resist being picked up by hand, the performance was a speedy affair.

At ambient temperatures (T_A) ranging from 15 to 40°C and a gradient of every 5°C, two series of experiments were performed. The first series took place between 8 a.m. and 3 p.m., and was conducted with animals starved for 24 hrs. During the experimental period animals were far being active, mostly spending time sleeping. The second series of experiments was carried out on the same animals, between 5 p.m. and 9 p.m., the time when hamsters are usually very lively. Individual animal of this group were feed before and during the experiments. During the taking of measurements the hamsters often took food, „washed” themselves or ran about their cages.

Under the first series it was possible to examine the respiratory rhythm by means of direct observation and on application of a stopper. On the other hand, such measurements were impossible to take on moving animals. Under both experimental series, observations were made of the animal behaviour throughout the measuring period, and notes were taken of category and duration of the individual form of activity, of the assumed posture, of any other behavioural manifestations.

3. RESULTS AND DISCUSSION

3.1. Metabolic Rate

Lowest metabolic rate has been found in the inactive and starved hamsters, at an ambient temperature (T_A) of 30°C (Table 1). Yet both at T_A of 25° and 35°C, oxygen consumption is but slightly higher than at 30°C, the difference remaining statistically insignificant. The minimum metabolic rate of 0.85 cc O₂/g hr should be regarded as the standard (Fig. 1). The basal metabolic rate (BMR) converted into the metabolic body size is lower almost by 20% than the interspecies value calculated by

Table 1

Metabolic rate in the golden hamster as dependent on the ambient temperature and on the experimental conditions.

Ambient temp °C	n	Body wt., g	ml O ₂ /g hr ± S. D.	kcal/animal hr	kcal kg ^{0.75} day
Inactive, after 24 hrs of starvation					
15	20	117.6	1.57 ± 0.4	0.886	105.81
20	18	123.3	1.03 ± 0.5	0.610	70.34
25	20	124.1	0.88 ± 0.2	0.524	60.19
30	20	119.0	0.85 ± 0.2	0.486	57.40
35	20	119.5	0.87 ± 0.2	0.499	58.70
40	13	112.0	1.26 ± 0.3	0.677	83.79
Active, unstarved					
15	18	115.5	1.57 ± 0.4	0.870	104.97
20	18	123.3	1.27 ± 0.3	0.741	85.45
25	16	118.0	1.28 ± 0.2	0.725	86.13
30	13	127.3	0.96 ± 0.2	0.587	66.09

Kleiber (1961); it amounts barely to 57.4 kcal/kg^{0.75} day. In the common hamster, *Cricetus cricetus* (Linnaeus, 1758), a species with a body weight three times as high, the corresponding value amounts to 55.1 (Górecki & Wołek, 1975). However, both findings represent the lowermost border value in rodents (Poczopko, 1971). In immature golden hamsters the basal metabolism goes beyond the predicted value (Hissa, 1968); yet this may result from the fact that measurements were taken at T_A 23°, hence below the thermoneutral zone.

As judging by the results of measurements of oxygen consumption, the thermoneutral zone lies between 25 and 35°C. Yet a measurement of the body temperature and of respiratory movements reveals it to be nar-

rower, to lay between 25 and 30°C. Consequently, the neutral zone is somewhat above the temperature of preference of the species (Gumma & South, 1970), and which works out at 26°C.

At a T_A lower than 25°C oxygen consumption rapidly increases, reaching 1.57 cc/g hr at 15°C, thus being by 85% higher than at 30°C. Evidently, hamsters possess a notable ability to rise the metabolic rate under temperatures below the neutral zone. In a similar way there has been noticed a significant rise in the oxygen consumption rate of animals kept at a T_A of 40°C. Nevertheless, this is a range coming close to the lethal temperature — part of the animals died on being measured.

Oxygen consumption of hamsters examined in the second series of experiments, *i.e.*, of animals which were active and unstarved, followed a different pattern. In this group there also takes place a decline in the oxygen consumption rate at 30°C; it remains, however, on a higher level than in the first group in spite of the difference remaining at the level of significance ($0.1 > P > 0.05$; *t* Student's test). On the other hand, at T_A 15°C, there is no difference between the two groups whatsoever. It is justifiable to draw the conclusion that the effects of this ambient temperature are sufficiently great to preclude the additional influence of activity or of the state of hunger appeasement. On comparing the findings referring to the two groups, greatest differences are discovered at 20 and 25°C, under which hamsters of the second group have an oxygen consumption higher respectively by 23.3 and 45.4%.

3.2. Rectal Body Temperature

Body temperature (T_B) of the golden hamster is comparatively low and should be assigned to the lowest zone of temperatures in rodents (Hart, 1971). It is characterized by a comparatively substantial lability, already the pre-experimental measurement fluctuating between 36.5 and 37.9°C, largely in dependence on the condition, active or inactive, of the animals. Body temperature depends, moreover, on still other factors, *e.g.*, on the number of animals per cage: the diurnal rhythm of the temperature was clearly pronounced when the hamsters were caged together in a group. When isolated, both the rhythm was damped and the T_B level reduced (Möller & Bojsen, 1974). At a 20 to 30°C range of T_A the T_B of the first group is $36.4 \pm 0.7^\circ\text{C}$. In this experimental group the rapid intensification of metabolic processes at 15°C brings about an increase in the T_B by about 1°C. However, the T_B goes up still more at a T_A of 35° and 40°C, reaching 41.5° (Fig. 1). It should here be pointed out that the increase in T_B under measurements of the metabolism at 35°C was not accompanied by any rise in oxygen consumption.

The considerable lability in T_B of the golden hamster is further proved

by results of measurements of this index in unstarved and active animals. In this case, T_B is clearly higher than in the group of inactive animals, after 24 hrs of starvation. Exclusively at T_A of 15° is it similar in both groups, while in the other cases it is much higher in active, test animals, owing to their greater heat production involving a T_B rise. These observations are borne out by Jansky's findings (1959) in the matter of oxygen consumption by hamsters enjoying movement. Yet the rapid increase in T_B values under higher ambient temperatures is mainly due to the warmth of the surroundings — as proved by the present investigations. In a state of hyperthermia hamsters are very little active and so there is no endogenous production of additional heat. In young hamsters, which are still devoid of fully-developed thermoregulatory mechanisms, the effect of T_A on the T_B is comparatively limited (Kohout & Petrsek, 1957).

Table 2

Fluctuation range of body temperature and behavioural patterns in hamster — as governed by the ambient temperature.

Ambient temp. $^\circ\text{C}$	Body temp., $^\circ\text{C}$, Min. — Max.	n	Behaviour
15	35.8—38.3	17	Excessive activity or crouching.
20	35.2—37.0	20	No symptoms of thermal discomfort ¹ .
25	35.2—37.2	17	No symptoms of thermal discomfort.
30	35.4—37.8	20	Slight symptoms of thermal discomfort, resting beyond the nest, changing position.
35	37.5—39.8	19	Resting beyond the nest, often changing position, testicles descended.
40	40.0—42.4	8	Resting beyond the nest, attempts of escape, swelling of the testicles.

¹ «Thermal discomfort» stands for the effect of temperatures felt as excessively cool or immoderately hot, by the test animals; these temperatures evoke characteristic changes in the animal behaviour.

Under exposure to a high T_A , hamsters do not display any symptoms of thermal discomfort so long as their T_B does not go beyond 38°C (Tęgowska & Narębski, 1973). The present study bears out these observations (Table 2), in that under neutral, or even under lowered T_A , the hamster T_B may reach 38°C — largely in dependence on the behaviour of the animals.

3.3. Respiratory Rate

A notable negative correlation has been discovered between this index and the ambient temperature (Fig. 1). At T_A 30° it was lowest, 28 resp./min. Already at 25 and 20° it was higher by about 32% and respectively 43%. At 15° the index was twice its lowest value. And yet, a still greater breath activation can be noticed at temperatures 35 and 40°C , the respiratory rate being then three times that at 30°C . Above this threshold there

come into play symptoms of cardiopulmonary insufficiency. Breathing becomes rapid, the respiratory rate amounting to an amplitude of 90 to 120/min. The breathing is shallow, more or less three times a minute interrupted by a deeper respiration; this level of the respiration rate was the warning signal to stop experimenting. If the testing was carried on,

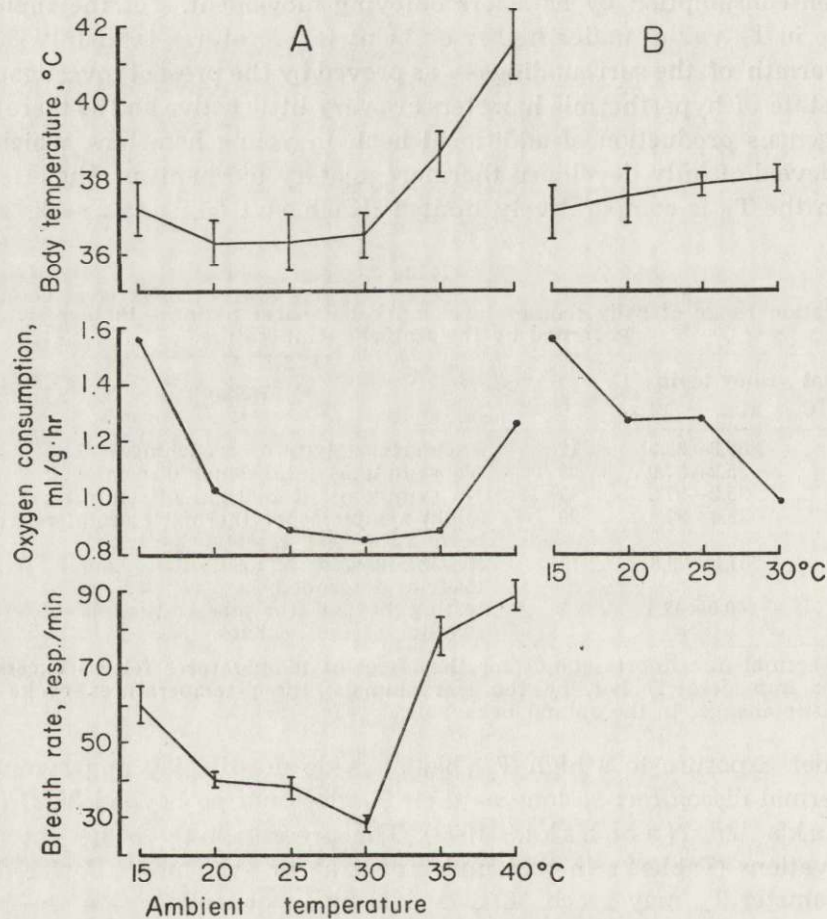


Fig. 1. Body temperature, respiratory movements and oxygen consumption in golden hamster, under different temperature.

A — animals examined during a period of inactivity, after 24 hrs of starvation. Measurements were carried out between 8 a.m. and 3 p.m. B — animals examined between 5 p.m. and 9 p.m., during a period of activity, under regular feeding.

animals inevitably succumbed to death within a time interval of 30 min. to 3 days after the testing period. Death was preceded by ataxia. Unsuccessful attempts to save the animals' life by cooling down the body pro-

duced hypothermy of 33 to 34°C. These results are indicative of the fact that death was due to breakdown of the central nervous system. Never has there been noticed, under hyperthermy, any rapid shallow breathing in which the animal profits of the mechanical resonance of the respiratory organ (Crawford, 1962). For this reason, there is no panting in hamster.

3.4. Observations on the Behaviour

On warm, springtime days and in summer, there can be noticed in hamsters descendance of the testicles into the scrotum. At lower ambient temperatures, or else during other seasons of the year, the testicles are concealed. Therefore during observations of the behaviour, notes were made on the position of the testicles.

Behaviour of the animals, their activity and postures assumed, proved directly dependent on the ambient temperature. And so, at T_A of 15°C, hamsters are active all the time — they run about the cage, spending but brief instants crouching in the nest (Table 2). The testicles are concealed. At T_A of 20 and 25°C, there occur no symptoms of thermal discomfort; the animals spend their time curled up in the nest, on approaching 25°C not always being curled, lying on their side instead. In both cases the male testicles are concealed in the body cavity. At higher ambient temperatures of 30°C, hamsters keep out of their nests, lying down, often on their backs. In males, the testicles begin to appear. Still another posture is assumed by the animals at T_A of 35°C — they spend their time beyond nests, resting on their abdomens, frequently changing their position. Testicles descend into the scrotum and become clearly visible. At T_A of 40°C, behaviour is similar as at 35°C, with the only difference of some restlessness manifest in a more frequent change of posture; sometimes the animals appear to search for an exit of the cage. Testicles are distinctly visible and quasi swollen.

Observations made under this study reveal distinct forms of behavioural thermoregulation mainly involving adjustment of movements, assuming of appropriate postures and profiting by the nest as best possible. The position of the testicles, too, as governed by the ambient temperature, is obviously associated with the maintaining of an adequate temperature these organs. This way, the spermatozoa are protected against hyperthermy with its noxious effects.

The basal metabolic rate in golden hamster is somewhat lower than the interspecies value worked out by Kleiber (1961). Likewise in the common hamster metabolic rate is low, though exactly similar to that in golden hamster (Górecki & Wołek, 1975). Be that as it may, changes in the metabolic rate brought about by fluctuations in T_A follow

a very typical pattern in both species of the hamsters, similar to that observed in other animals (Gębczyńska & Gębczyński, 1965; Taylor & Sale, 1969; Baudinette, 1972; Collins & Bradshaw, 1973). Body temperature of golden hamster is not very stable, be it even in the neutral zone; it depends mainly on the behaviour of these rodents. Under hyperthermy, body temperature of golden hamster soon rises to 42.5°C, then animal dies; resistance of these animals to overheating is negligible. At a temperature of physiological coolness, T_B of inactive animals drops to 35.2°C; intensive movements may rise it to somewhat above 38°C. Tolerance to so great a range of body temperature fluctuations seems to be an adaptive trait, a response of hamsters to impressive changes in the ambient temperature. This tolerance does not seem to be associated with the hibernating ability, as according to findings of other authors (Kayser, 1961; Satinoff, 1970), a decline in body temperature is not a passive response to coolness, and hibernation starts at a regular body temperature of the animals. And so, hamsters put up a defence against the thermal action of the environment by chemical thermoregulation and also by behavioural thermoregulation. Hamsters are characterized by a capacity to survive body temperature fluctuations no smaller than by 5°C.

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ZUŻYCIE TLENU I BEHAVIOR CHOMIKA ZŁOCISTEGO ZALEŻNIE OD TEMPERATURY ŚRODOWISKA

Streszczenie

U chomika złocistego (*Mesocricetus auratus* Waterhouse, 1839) zmierzono tempo zużycia tlenu, temperaturę ciała i ruchy oddechowe w zakresie temperatury środowiska od 15 do 40°C. Obserwowano także różne formy behavioru związane z przeciwstawianiem się termicznemu działaniu otoczenia. Tempo metabolizmu u zwierząt głodzonych przez 24 godziny jest najniższe przy 25—35°C i wynosi około 60 kcal/kg^{0.75} na dzień (Tabela 1). Temperatura ciała jest mało stabilna i może się wahać od 36 do 41°C, zależnie od temperatury otoczenia i aktywności zwierząt (Tabela 2). Ilość ruchów oddechowych jest też ściśle uzależniona od temperatury środowiska i jest najniższa przy 30°C, gdyż wynosi zaledwie 28 oddechów na minutę (Ryc. 1).

Zatem względnie niski poziom metabolizmu, zdolność znoszenia dużych wahań temperatury ciała i różne przejawy behavioru są formami przystosowania się tego gatunku do życia w warunkach klimatu suchego i gorącego.