

Thermotelemetric study on the hibernation of a common hamster, *Cricetus cricetus* (Linnaeus, 1758), under natural circumstances

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Abstract

By means of radio-thermotelemetry a study was made of the thermoregulatory patterns during hibernation of a common hamster, *Cricetus cricetus* (L., 1758) under natural conditions.

In the euthermic state, body temperature (T_b) fluctuated between 36.4 and 38.6°C with T_b higher than 37.0°C probably indicating activity. The hamster went into deep hibernation 23 times. The entrance into hibernation lasted 20–60 hours, the state of deep hibernation 17–110 hours and the subsequent arousal 3.5–6.5 hours. Both the duration of arousal and of a bout of hibernation seemed to be negatively correlated with T_b . The euthermic interbout state lasted 4–25 hours. The minimum T_b during deep hibernation ranged between 10.0 and 2.6°C. Sixteen bouts of hibernation could be observed completely with their respective intervals from entrance to arousal. In 11 bouts arousal followed after a drop of the ambient temperature (T_a), in four bouts after a rise of T_a and in one bout at a constant T_a .

Résumé

Une étude des phénomènes de thermorégulation pendant l'hibernation d'un hamster commun, *Cricetus cricetus* (L., 1758) dans des conditions naturelles, a été effectuée au moyen de la radio-thermotélémetrie.

A l'état euthermique, la température du corps (T_b) a varié de 36,4 à 38,6°C, une T_b supérieure à 37°C indiquant probablement l'existence d'activité. Le hamster est tombé en hibernation profonde 23 fois. L'entrée en hibernation dure 20–60 heures, l'état d'hibernation profonde 17–110 heures, le réveil subséquent 3,5–6,5 heures. Durée du réveil et durée d'une période d'hibernation semblent être négativement corrélées à la T_b . La phase euthermique entre deux périodes d'hibernation dure 4–25 heures. La T_b minimum pendant l'hibernation profonde, varie de 10 à 2,6°C. Seize périodes d'hibernation ont pu être observées, avec les intervalles respectifs, depuis l'entrée en hibernation

jusqu'au réveil. Dans le cas de 11 périodes d'hibernation, le réveil a fait suite à une baisse de la température ambiante (T_a), dans le cas de quatre périodes il s'est produit après une hausse de la T_a , et dans un seul cas il s'est produit à une T_a démeurée constante.

Introduction

Since the experiments of Horvath (1881) the knowledge of rodent hibernation has considerably increased. Especially during the last decade intensive research has led to a better understanding of the neuro-endocrine regulation of this process.

Studies on rodent hibernation have been performed on a limited number of species, in particular the golden hamster (*Mesocricetus auratus* Waterhouse), a variety of dormice (Gliridae) and ground squirrels (*Citellus* spec.). As interspecific differences exist (Lyman & O'Brien, 1974; Pivorun, 1976; Twente et al., 1977; Lyman et al., 1982) a general view on the physiology and regulation of rodent hibernation is impossible. Almost all investigations, mentioned in the literature, are carried out under controlled laboratory conditions.

This investigation was undertaken in order to characterize the hibernation of the species *Cricetus cricetus* (Linnaeus, 1758), the common hamster, under natural conditions. Emphasis was laid on quantifying various thermoregulatory patterns. Data on this subject are very scanty and almost confined to the arousal process (Eisentraut, 1928; Raths & Külzer, 1976). Quantitative data concern-

ing the course of body temperature (T_b) during the entrance into hibernation or during the deep hibernation state (abdominal T_b below 10.0°C) are practically unavailable.

By means of radiotelemetry coupled to intracorporal temperature measurement the course of T_b during hibernation could be followed in the natural habitat of the animal. By applying this technique disturbance of the hamster in the field is sharply reduced and prolonged studies can be conducted.

Materials and methods

The experimental animal was caught on 14 October 1984 in the municipality of Stein, in the south of the Dutch province of Limburg, in a small-scale agricultural area. The burrow was situated in a ryefield. The animal was a subadult male weighing 276 g.

In the Biomedical Centre of the State University of Limburg, a temperature sensitive transmitter (weight 3.9 g: 1.4% of body mass) was surgically implanted in the abdominal cavity, following the procedure of Lenders et al. (1986). By means of the transmitter T_b could be measured accurately to 0.1°C . For technical details on the modified transmitter type used see Olders et al. (1986).

After a post-operation observation period of 10 days the animal was returned to its burrow. During the period of 26 October to 7 April T_b was followed radiotelemetrically. Due to the fact that the transmitter had a small range (about 60 m, hamster above ground), the hamster was not tracked at night during the pre-hibernation phase. In this way disturbance of the natural behavior was prevented.

Measurements of T_b carried out during the pre-hibernation phase and the euthermic period between two bouts of hibernation were done at 15 minute intervals. Entrance into hibernation was followed by measuring T_b at 15, 30, 60, 120 or 240 minute intervals (depending on the rate T_b dropped). During the beginning of the deep hibernation state measurements were done every eight hours. This frequency was increased as the expected end of this state approached. Nevertheless the be-

ginning of arousal was missed in some cases. Observations during this process were made every minute.

The ground temperature at nest depth was taken as an approximation of the ambient temperature (T_a) of the hamster. T_a was measured with temperature probes at eight different depths between 5 and 65 cm at a distance of approximately 4 m from the nest. During the entire hibernation period ground temperatures were determined each day at 07.00 h and 14.00 h. The temperature could be measured with an accuracy of 0.1°C . After the final bout of hibernation the burrow was opened in order to determine the exact nest depth.

Results

In the pre-hibernation phase T_b fluctuated between 36.4 and 38.6°C . During the daytime this value varied between 36.4 and 37.0°C . At leaving the burrow and returning to it T_b was between 37.0 and 38.6°C . Such a relatively high T_b also appeared once or twice at night in the burrow, lasting 0.8–1.2 hours. Such periods were followed by periods in which T_b fluctuated between 36.4 and 37.0°C . These lasted 0.75–5 hours.

Between 16 November 1984 and 3 April 1985 the hamster went into deep hibernation 23 times. During this period the burrow was not left. The course of T_b was nearly the same for every bout of hibernation (Fig. 1). At a certain point of time T_b gradually fell down to a minimum level ($T_{\min.}$). Within the 23 bouts $T_{\min.}$ ranged from 2.6 to 10.0°C . Subsequent to reaching $T_{\min.}$ there was a period of deep hibernation lasting between 17 and 110 hours. Arousal took a relatively short time: 3.5–6.5 hours. Seven arousals could be followed from the start. For $T_{\min.}$ between 9.0 and 6.4°C arousal lasted 3.5–4.5 hours, for $T_{\min.}$ between 3.6 and 2.9°C the duration was 6.0–6.5 hours. In Fig. 2 this relation is shown. In the same figure it can also be noted that at a certain temperature, varying between 10 and 13°C , the rising rate of T_b increased. The total duration of a bout ranged between 40.5 and 176.5 hours. The euthermic state between two bouts lasted 4–25 hours. In this period

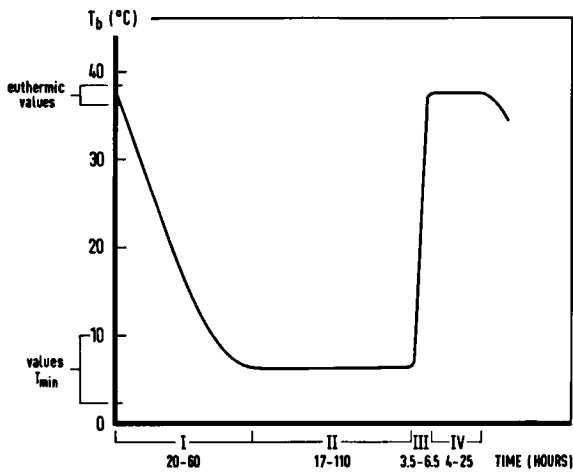


Fig. 1. General course of T_b during hibernation. The range of values for $T_{min.}$ and $T_{b,euthermic}$ is given as well as the range of duration of each part of the hibernation process (I–IV) ($n = 23$ bouts, 22 euthermic interbout periods). I = Entrance into hibernation; II = Deep hibernation state; III = Arousal from hibernation (see also Fig. 2); IV = Euthermic period between 2 bouts.

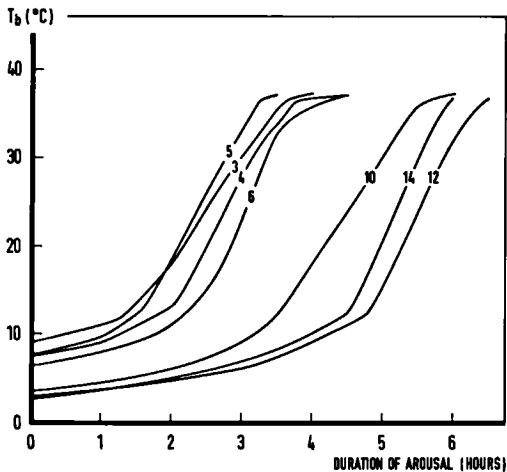


Fig. 2. The course of abdominal T_b during the seven arousals from deep hibernation that could be followed entirely (bouts 3–6, 10, 12, 14).

T_b fluctuated between the same values as in the pre-hibernation phase. At the start and the end of the hibernation period the bouts lasted shorter than in the middle (Fig. 3). In the same figure the $T_{min.}$ of every bout (except bout 7, 8 and 9) is given.

The ground temperature at a depth of 55 cm, the depth of the nest, was assumed to be the best measure for the temperature directly surrounding the

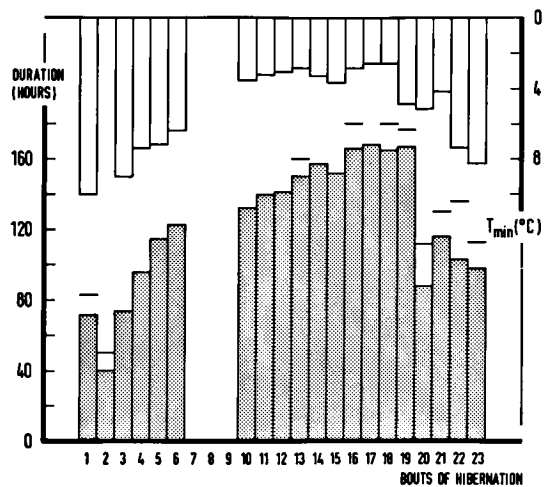


Fig. 3. Duration of 23 bouts of hibernation in relation to the $T_{min.}$ of every bout. The duration of the bouts 7, 8, and 9 could not be determined; the duration of the bouts 1, 2, 13, 16 and 18–23 could not exactly be established. Here, the possible value ranges between a minimum and maximum limit, shown by means of a dash.

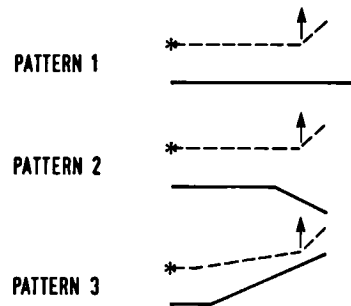


Fig. 4. Three observed patterns in the relation between T_b (dotted line) and T_a (straight line). * indicates the moment $T_{min.}$ is reached, † the moment of arousal.

hamster (T_a). During the hibernation period T_a dropped gradually from about 10.0 to 1.2°C (around bout 18) and rose after this to 7.5°C at the end of bout 23. T_a fluctuated almost daily (0.0–1.8°C) and was never constant for longer than five days.

The relation between T_b and T_a is shown in Fig. 4. T_b is given from the moment that $T_{min.}$ was reached (indicated by *). At this moment $T_{min.}$ was minimally 0.0 and maximally 1.8°C higher than T_a with a lowest $T_{min.}$ of 2.6°C. In 16 bouts the relation $T_b - T_a$ could exactly be determined. In this re-

lation three patterns could be distinguished. After $T_{\min.}$ is reached T_b remains constant with a constant T_a (Fig. 4, pattern 1), in one bout followed by arousal. With a falling T_a , T_b also remains constant, in 11 of the 16 bouts followed by arousal (Fig. 4, pattern 2). A greater or smaller rise in T_b was noticed when T_a increased. In four bouts this resulted in arousal (Fig. 4, pattern 3). Three times within a bout a drop in T_b was observed (data not shown) after a falling of T_a . This is in contradistinction to pattern 2 shown in Fig. 4.

Discussion

The T_b -values measured in the pre-hibernation phase are normal for the common hamster. They vary between the minimum (35.0°C) and maximum (39.5°C) values (average around 37–38°C) mentioned in literature (Raths, 1963; Malan & Hildwein, 1969; Weiner & Gorecki, 1975; Gorecki, 1977). According to Gorecki (1977) and Visinescu (1968) there is a circadian rhythm in the daily T_b -fluctuations. The highest values are reached respectively in the afternoon and at night. In this study such a rhythm was not established. The relatively high T_b measured in the pre-hibernation phase and the euthermic state between two bouts probably indicate activity of the hamster. A difference in T_b between the active (37.0–38.6°C) and the resting/sleeping state (36.4–37.0°C) was also found by Twente & Twente (1965) in the golden-mantled ground squirrel, *Citellus lateralis*.

The duration of arousal proved to be dependent on $T_{\min.}$: a lower $T_{\min.}$ lengthened this process. Such a correlation could not be established for the entrance into hibernation. The shorter duration of arousal observed by Eisentraut (1928) and Raths (1976), 2.0–4.0 hours, could perhaps be due on one hand to different experimental conditions (e.g., laboratory experiments, higher $T_{\min.}$) and on the other hand to different means of determining T_b . Raths (1957, 1961, 1963), for example, measured the cheekpouch temperature as opposed to the abdominal temperature measured in this study. During arousal the cheekpouch temperature rises more quickly than the abdominal temperature (Lyman,

1948; Lyman & Chatfield, 1950). The course of the rise in T_b during arousal (Fig. 2) is typical for many rodent species. Eisentraut (1928) and Raths (1957) already observed this when studying *Cricetus cricetus*. It is generally accepted that the sudden rise in abdominal bodywarming at a particular T_b is due to the cessation of a vasoconstriction in the anterior part of the body (Lyman et al., 1982).

Pengelley & Fisher (1961), Twente et al. (1977) and Pivorun (1976) mention the presence of a negative correlation between T_a and the duration of a bout of hibernation. As T_b is approximately the same as T_a this negative correlation should also be valid for T_b . This investigation seems to indicate there is indeed such a correlation (Fig. 3).

It is very difficult to measure a relevant T_a of the hamster during hibernation. The measurements may not disturb the animal. Further, the T_a measured must not be influenced by the hamster itself and at the same time it has to give a good indication of the energy flow between the hamster and its environment. Our T_a -determination at a distance of 4 m from nest site and at nest depth comes up to these requirements the best.

This study shows that when in a certain bout $T_{\min.}$ is reached and T_a drops (Fig. 4, pattern 2), T_b remains constant and is often followed by arousal. These results are compatible with those found in particular by Heller and co-workers in their studies of the golden-mantled ground squirrel, *Citellus lateralis* (Heller & Hammel, 1972; Heller & Collier, 1974; Heller, 1979). Particular brain-areas appear to be involved in the control of hibernation. The pre-optic anterior hypothalamic area plays a major role in the regulation of T_b . In this brain-area the set-point (T_{set}) threshold for temperature regulation is situated. Usually T_b is slightly above T_{set} . A decrease in T_b ($= T_{\min.}$ during deep hibernation) due to a decrease in T_a can result in the thermosensitive hypothalamus reaching a temperature which is lower than T_{set} . This results in heat producing processes that restore T_b to a value above T_{set} . The stimulated heat production not only keeps T_b constant with decreasing T_a but also often results in arousal. In three cases a drop in T_a was followed by a drop in T_b (in contrast to what has been said before). This fall in T_b followed after

a number of T_a -rises in which T_b also rose. The fall in body temperature is probably the result of the fact that T_b was well above T_{set} . Body temperature returned to the previous value of T_{min} . The joint rise of T_b and T_a (Fig. 4, pattern 3) is probably the result of a relatively slow release of warmth.

The results of this study are based on the data of one subadult male. They show clear trends in certain thermoregulatory patterns (Figs 2–4). Although intra-specific differences might occur, probably these trends are also present in adult males and (sub)adult females. It would be very interesting to study this, however such an investigation is very time-consuming. The method employed in this study has proved to be ideal for prolonged research under natural conditions but at the same time it is very labor-intensive. Automatization of the observations in the field would be a suitable solution. We are at work on the realization of such a system.

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