

## Resting metabolism and thermal conductance in southern Africa's smallest rodent, the Pygmy mouse (*Mus minutoides*)

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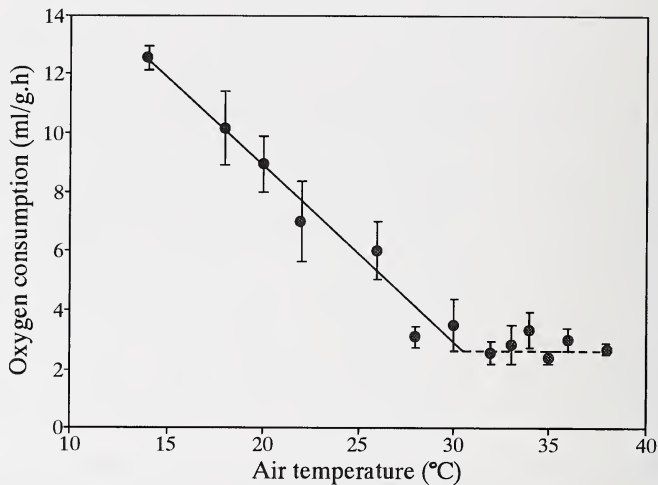
Two parameters frequently determined in ecophysiological studies of mammalian thermoregulation and energetics are basal metabolic rate (BMR; the minimum metabolic rate in an euthermic mammal) and minimum thermal conductance (minimum C; the minimum rate at which heat is exchanged between an euthermic mammal and the environment). Both parameters scale allometrically with body mass across mammal species (e.g. BRADLEY and DEEVERS 1980; HAYSEN and LACY 1985) and deviations from values expected on the basis of body mass are often taken as representing adaptive mechanisms to ecological variables or environmental extremes (e.g. SCHOLANDER et al. 1950; CASEY et al. 1979; HAIM and IZHAKI 1993). The pygmy mouse (*Mus minutoides*) is southern Africa's smallest rodent, is omnivorous, terrestrial, nocturnal, lives singly or in pairs in burrows, under logs and under stones, in both summer and winter rainfall regions and occupies a diversity of habitats of disparate aridity (SKINNER and SMITHERS 1990). Because of its small size, *M. minutoides* is of particular interest in terms of its energetics and thermoregulatory biology.

Eight pygmy mice were trapped at 29°S 30°E in Natal, South Africa in July 1993. Mice were transported to Pretoria (28°15' E 25° 45' S) where they were maintained under natural photoperiod at room temperature (20–23 °C) in individual cages for 6 weeks prior to experimentation. During experimentation oxygen consumption of solitary mice of known body mass was determined at 13 air temperatures of between 14 and 38 °C using an open-flow respirometry system. At each ambient temperature oxygen consumption was measured at one minute intervals over a two hour period in each of four randomly selected mice. Mice were observed frequently during measurement to ensure that they were inactive. Minimum oxygen consumption by a given mouse at a given ambient temperature was taken as the mean of the five lowest consecutive measures within the two hour measurement period. All measures of oxygen consumption were corrected to standard temperature and pressure of dry air. Although body temperatures were not taken, no mouse was found to show signs of hyperthermia (sluggishness, cold body surfaces) on removal from the respirometry system. In contrast at an ambient temperature of 8 °C, mice ( $n = 2$ ) were unable to maintain euthermy for a two hour period and were thus removed from the respirometry system and rewarmed. No attempt was made to observe spontaneous arousal from hypothermy.

Thermoneutrality was defined as the range of temperatures within which oxygen consumption was independent of ambient temperature. Mean oxygen consumption at thermoneutrality was taken to represent basal metabolic rate (BMR). The slope of the linear regression of oxygen consumption on decreasing temperature below thermoneutrality was taken to represent minimum C (McNAB 1980). The lower limit to thermoneutrality (lower

critical), was estimated as the intersect between the regression of oxygen consumption on decreasing ambient temperature below thermoneutrality, and BMR.

Mean oxygen consumption was independent of air temperature between 32 and 38 °C (Fig. 1) and increased linearly with decreasing air temperature at and below 30 °C. There was no evidence for an elevation of metabolism at high air temperatures (up to 38 °C; Fig. 1). Estimates of BMR, minimum C and lower critical temperature are shown in table 1. Mean BMR was slightly higher while minimum C was substantially higher than predicted on the basis of body mass from other rodents and mammals respectively (Tab. 1). The slope of the regression of metabolism on air temperature usually underestimates minimum C as determined by simultaneous measures of metabolism and body temperature (McNAB 1980). This implies that actual minimum C in *M. minutoides* will be even higher than our estimate.



**Fig. 1.** The influence of air temperature on oxygen consumption in resting *Mus minutoides* of mean body mass 8.27 g. Each point represents the mean of 4 individuals randomly selected from a pool of eight. Errors are 1 se. The solid line represents the least squares regression of oxygen consumption on air temperature at and below 30 °C:  $y = 20.8 - 0.597x$ ,  $r^2 = 0.97$ ,  $F_{1,5} = 148.9$ ,  $P < 0.001$ . The dashed line represents basal metabolic rate.

**Table 1.** Thermal parameters of *Mus minutoides*;  $n = 8$  individuals. a – % of basal metabolic rate predicted for an 8.27 g rodent after HAYSEN and LACY (1985). b – % of thermal conductance predicted for an 8.27 g mammal after BRADLEY and DEAVERS (1980). c – Body temperature predicted by extrapolation of the regression of metabolism on air temperature to a metabolism of zero (McNAB 1980).

	Mean $\pm$ sd	% of predicted
Body mass (g)	8.27 $\pm$ 1.82	–
Basal metabolic rate (ml O <sub>2</sub> /g · h)	2.621 $\pm$ 0.636	106 <sup>a</sup>
Minimum thermal conductance (ml O <sub>2</sub> /g · h · °C)	0.597 $\pm$ 0.049	197 <sup>b</sup>
Lower critical temperature (°C)	30.5 $\pm$ 1.1	–
Predicted body temperature (°C) <sup>c</sup>	34.8	–

Small mammals have high mass specific metabolic rates (HAYSEN and LACY 1985), and high mass specific minimum C (BRADLEY and DEEVERS 1980) reflecting their high surface area to volume ratio and low capacity for body insulation. Mammal species from cold climates often show lower minimum C than those from warm climates (SCHOLANDER et al. 1950) while minimum C is often higher in mammals in summer than in winter (CASEY et al. 1979). In at least some winter acclimated mammals minimum C can be increased by exposure to summer conditions. These observations suggest an adaptive basis for residual variation in minimum C once the effect of body mass has been removed (BRADLEY and DEEVERS 1980) although some phylogenetic dependency is apparent (BRADLEY and DEEVERS 1980). The comparatively high minimum C demonstrated by *M. minutoides* in the present study (Tab. 1) implies that when exposed to cold, either energy expenditure in this species will be extremely high or individuals will resort to facultative or obligatory hypothermy (as evidenced by the demonstration of hypothermy in the two individuals exposed to 8°C in the present study). The interspecific equation relating minimum C to body mass in the Muridae does not deviate significantly from that for mammals in general (BRADLEY and DEEVERS 1980) and although minimum C is comparatively high in *Mus booduga* (GOSH et al. 1979; 110% of that predicted for a mammal of the same body mass, BRADLEY and DEEVERS 1980) and *Mus musculus* from the Isle of May in Scotland (JAKOBSEN 1978; 118%) it is comparatively low in a population of *M. musculus* from Marion Island in the sub-Antarctic (P. I. WEBB unpubl. data). There is thus no strong evidence to support a phylogenetic tendency for high minimum C within the genera *Mus*. We therefore suggest either that high minimum C in *M. minutoides* represents an adaptive trait (i.e. *M. minutoides* from the sampled population are either not frequently exposed to low temperatures, and/or are frequently exposed to high temperatures where dry heat loss is advantageous); that there is no adaptive pressure on minimum C in this population (e.g. because individuals are seldom exposed to temperatures at either extreme for prolonged periods); or that minimum C is restrained by some other ecophysio-morphological parameter.

Although in the area in which the *M. minutoides* were trapped mean monthly minimum daily air temperature falls to a yearly minimum of approximately 3–4°C in July, while mean monthly maximum daily air temperature seldom falls below 18°C or rises above 31°C, these are not necessarily the temperatures to which the *M. minutoides* population is exposed. Day time use of burrows or other refugia as well as the timing and location of activity may all contribute towards a moderation of the extremes of temperature experienced. Further study on the behaviour of *M. minutoides* and the microclimate in which it lives is therefore required before the adaptive significance, if any, of high minimum C can be established.

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