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Weight and Body Temperature in Mammals

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In a recent paper Rodbard (*1*) proposed that the mean normal body temperature of various mammals bears a simple relation to the body weight: specifically, that the temperature is directly proportional to the logarithm of the body weight in animals smaller than 1 kg ($T = C + 1.5 \log W$), and inversely proportional in larger animals ($T = C' - 1.5 \log W$). Values for 30 species were selected from the literature to support this thesis, and these data as figured did indeed show close adherence to the postulated relation.

However, recent studies on body temperatures in smaller mammals, together with a general consideration of values in the literature, have convinced us that this relation is not valid, and that the apparent correlation (*1*) resulted from an inadequate representation of data. Further, even certain of the species there presented would not fit the postulated relation were it not for what appear to be errors of three- to thirtyfold in the average adult weights.

The data presented here are limited to two major sources, since it is not feasible to give a complete listing of mammalian temperatures from the literature and since such further values do not alter the conclusions. The two sources are Wislocki's review article (*2*), which principally relates to the larger mammals (2–2000 kg), and recent unpublished measurements[1] which cover a number of the smaller mammals (1–2000 g). All data available from these two sources are presented, with the exception of values on monotremes, marsupials, edentates, and bats, groups in which a low level and/or a considerable lability of temperature is found. Values for hibernators represent active, nonhibernating animals. Although some of these values represent less reliable or less extensive measurements than others, it was felt of paramount importance to avoid any selective bias that might be involved in eliminating individual species. Values for body weight represent either measurements on the animals in question or estimates of the average adult size taken from more general references (*3–5*).

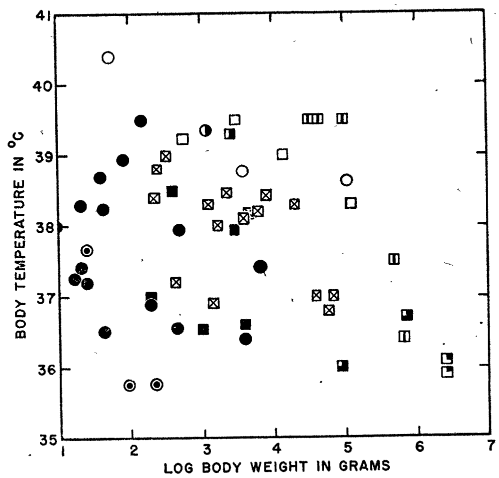

Fig. 1. Body temperature in various mammals as a function of body weight. Open symbols, Carnivores (*Mustela, Vulpes, Callorhinus, Leo*, dog, cat, ferret); point symbols, Insectivores (*Blarina, Scalopus, Erinaceus*); lined symbols, Ungulates (sheep, goat, camel, pig, horse); crossed symbols, Primates (*Perodicticus, Galago, Lemur, Cercebus, Cynopithecus, Cercopithecus, Macacus, Aotus, Leontocebus, Callithrix, Ateles, Cebus, Papio, Pongo, Pan, Homo*); quarter-closed symbols, Proboscidians (*Elephas, Loxodonta*); half-closed symbols, Lagamorphs (*Sylvilagus*); three-quarter-closed symbols, Cetaceans (*Orca, Tursiops*); closed symbols, Rodents (*Microtus, Zapus, Clethrionomys, Perognathus, Reithrodontomys, Peromyscus, Dicrostonyx, Eutamias, Glaucomys, Citellus, Marmota, Tamiasciurus, Erethrizon, Coendou, Cynomys, Cavia*). Squares, after Wislocki (*2*), averages of individual measurements or midpoints of ranges: circles, unpublished data representing an average of 40 measurements/species on 1–30 individuals.

These data are presented in Fig. 1, where body temperatures are plotted as a function of the logarithm of the body weight. The points are distinguished according to source and order of mammal, to show the diversity of representation in the various weight

TABLE 1

Average Body Temperatures in Mammals by Weight Classes

Weight class (g)	Av values for species	Body temp in °C	
		Range	Mean
10^1–10^2	11	35.8–40.4	37.8
10^2–10^3	12	35.8–39.5	37.8
10^3–10^4	17	36.4–39.5	38.0
10^4–10^5	8	36.0–39.5	37.9
10^5–10^6	6	36.4–39.5	37.8
10^6–10^7	2	35.9–36.1	36.0
10 –10^6	56	35.8–40.4	37.8
10^7–10^8	4	36.5–37.5	37.1
1 –10	2	37.8–38.0	37.9

[1] These studies were supported in part by a research grant from the Wisconsin Alumni Research Foundation and by a contract between the University of Wisconsin and the Alaskan Air Command, Arctic Aeromedical Laboratory, Ladd AFB, Fairbanks. We are particularly indebted to Earl H. Herrick for the specimens of *Perognathus* and *Reithrodontomys*.

classes. The mean of the 56 temperature values is 37.8°. The distribution, far from showing any linear correlation, appears to be entirely random, and no trend can be discerned. Ranges and mean values for the body temperature by logarithmic weight classes are summarized in Table 1. In animals ranging from 15 g to 700 kg, the mean class temperatures varied by less than $\pm 0.2°$. The very close agreement of these values is fortuitous for such small groups in view of the variability of the individual species values ($\sigma = 1.23°$; $\sigma_{\bar{x}} = 0.40$), but it illustrates strikingly the independence of weight and body temperature. The next weight class (1000–10,000 kg) is represented by only the two genera of elephants, and although their temperature (36.0°) is lower than the other averages, this can hardly be considered a trend.

Measurements at the extremes of mammal size may be of particular significance in their bearing on this question. In the whale, Zenkovic (*6*) reported an average temperature of 37.6° within 1 hr of death and 37.1° within 2 hr of death in 4 of the larger species (est. adult wt, $5\text{–}10 \times 10^7$ g). Although these values are lower than the general average of 37.9°, they fall within one standard deviation of that value and are actually a degree higher than that for the next smaller animal, the elephant.

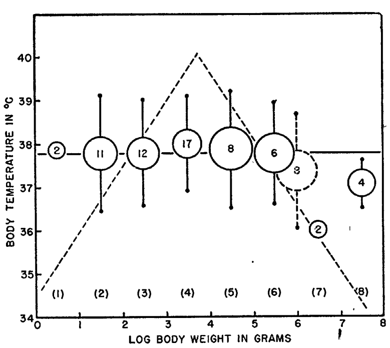

FIG. 2. Mean body temperature by logarithmic weight classes as a function of body weight. Vertical bars show standard deviations of the means; circle radii show standard errors of means; number of species averaged as indicated. The greatest difference, 0.2°, lies between the means of groups 4 and 6 and corresponds to a *t* value of 0.58. Even the difference between group 4 and the pooled values for group 6, plus the low elephant values (broken circle and bars), corresponds to a *t* value of only 1.1, still far below the required level for significance. Rodbard's postulated relations are shown as two broken lines.

At the other end of the size scale, recent measurements on the harvest mouse (*Reithrodontomys*), one of the smallest mice, with a weight of 9 g, have shown a body temperature of 38.0°. The only other information we have found in the literature on animals of less than 10 g is a single measurement of 37.8° on a shrew (*Sorex fumeus*) by Kendeigh (*7*). These values are both within 0.2° of the over-all average for mammals. Fig. 2 summarizes these data, showing the mean temperature values by logarithmic weight classes and their variability, together with Rodbard's postulated relations. It may be noted that in the case of the highest and lowest weight classes the latter relation deviates from the actual values by 3°.

Body temperature may be influenced by many variables: the taxonomic group, the diet, general or seasonal heterothermism, the latitude of origin, activity, the ambient temperature, etc. Indeed, as more data become available, some correlation with weight may be found within selected homogeneous groups.[2] But as a general phenomenon the body temperatures of various species of mammals must be considered to be independent of their weights.

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[2] A suggestion of such a trend within several of the orders, particularly in the carnivores, may be seen in Fig. 1. However, the numbers of species available for comparison in any single order are so few (6–19), and the variability is sufficiently great, that this issue cannot be decided on the basis of the data presented here.

Maintenance of Contraction of Embryonic Chick Hearts *in Vitro*

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By the use of the culture medium given below it has been possible to keep 72-hr chick embryo hearts alive and contracting for over 90 days. They were killed and fixed for study at about this time, so that we do not know as yet how long they will continue to function *in vitro*. The embryonic hearts are cultured, with the medium, on perforated cellophane disks in Carrell flasks. The flasks are tightly stoppered with sterile rubber stoppers. During the long culture period the flasks are *never opened,* and *no change* is made of the culture medium. Such a procedure is unusual in tissue culture.

The behavior of the cultured hearts varies after a few days. Some continue to contract as a unit throughout the entire period. Some show a contraction of the sino-atrial region in a phase different from that of the ventricle-bulbus region. Others finally contract only in the sino-atrial region, with an occasional spasmodic contraction of the ventricle-bulbus region.

In most cases there is practically no cell proliferation in the form of cell outgrowths and migration such as is usual in cultures of pieces of embryonic heart. The cultured hearts show a diminution of total size as the culture period continues.

The culture medium used in these experiments would seem to be of value for maintaining a function-