

Body Temperature of the Herbivorous Bonaire Island Whiptail Lizard (*Cnemidophorus murinus*)

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Body Temperature of the Herbivorous Bonaire Island Whiptail Lizard (*Cnemidophorus murinus*)

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The whiptail lizards (*Cnemidophorus* and *Ameiva*: Teiidae) are typically widely foraging insectivorous animals. In contrast, populations on dry Caribbean islands may consume mostly plant material, perhaps because insects are depauperate on these islands (Jan-

zen, 1973; Schall and Ressel, 1991; Dearing and Schall, 1992). The energetic and physiological consequences of this shift in diet have not been explored, but such information could cast light on the evolution of herbivory in lizards. The diverse array of zoophagous and herbivorous *Cnemidophorus* species makes these lizards an ideal model to examine the physiological, behavioral, and anatomical differences necessary to allow feeding on arthropods vs. plant material (Dearing, 1993). Here we present data on the body temperature of one of the herbivorous whiptail species, *Cnemidophorus murinus* from Bonaire, Netherlands Antilles. To our knowledge, substantial data on body temperature of a herbivorous *Cnemidophorus* have not been presented for comparison with the abundant data available for insectivorous *Cnemidophorus*.

Janzen (1973), in noting that insular populations of *Ameiva* often shift to a plant diet, proposed that herbivorous lizards must "maintain the internal compost heap at a high temperature in order to process foliage fast enough to get the energy needed." Marken Lichtenbelt (1992) showed with *Iguana iguana* that plant dry-matter digestibility did not increase with higher body temperatures, but passage time decreased at the higher temperatures. Thus, for this large herbivorous lizard, higher body temperature should facilitate efficient processing of plant foods. Janzen's hypothesis and Marken Lichtenbelt's experimental results suggest that herbivorous whiptail lizards should increase their body temperature after feeding and should reach higher temperatures than experienced by congeneric insectivorous species. We therefore sought to determine if *C. murinus* has a higher body temperature than insectivorous *Cnemidophorus*, and if their body temperature is highest after feeding.

Cnemidophorus murinus is primarily herbivorous. Approximately 75-80% of food materials consist of leaves, flowers, and fruit of a large variety of plant species; most lizards collected had only plant material in their stomachs (Dearing and Schall, 1992). We collected 30 *C. murinus* every 10 d during an entire year. These specimens were used in a diet study (Dearing and Schall, 1992) and an examination of reproductive biology (Dearing and Schall, 1994) and all lizards were collected under permission of the appropriate island authorities. Regular estimates were made of density of the sampled populations and no reduction in numbers of this very abundant lizard was observed (Dearing and Schall, 1992). Lizards were shot with a .22 cal air gun, and cloacal temperature taken within ten seconds with a Schultheis rapid reading thermometer using standard precautions. All animals were collected between 1000 and 1200 h, approximately 4 to 6 h after sunrise. Recorded also were date of collection, gender, snout-vent length (SVL), body mass, reproductive condition of females (reproductive = oviductal eggs or yolking ovarian follicles > 3 mm diameter), and volume of food in the stomach (methods in Dearing and Schall, 1992, 1994). Lizards were collected at three sites (Dearing and Schall, 1992); comparisons among sites revealed no differences for any of the variables (Kruskal-Wallis tests, $P > 0.05$), so data were pooled.

Fig. 1 shows the distribution of all body temperatures taken from *C. murinus*. Females had slightly higher body temperatures than males ($\bar{x} = 38.7$ C, SD = 1.8, N = 488 for females; $\bar{x} = 38.3$ C, SD = 1.8, N

= 582 for males; $t = 3.67$, $P < 0.05$). Similar small differences between mean body temperature of males and females have been occasionally reported for other *Cnemidophorus* species (Schall, 1977). Although the difference reported here is statistically significant, we doubt that there is any real biological phenomenon needing explanation. Nonetheless, subsequent analyses were conducted for each gender independently. There was no effect of reproductive condition (females only) or SVL on body temperature (Mann-Whitney test and Spearman correlations, $P > 0.05$). Mean temperature on Bonaire varies little over the year, but rainfall is strongly seasonal and influences diet and fat storage (Dearing and Schall, 1992, 1994). Body temperature, however, did not vary with rainfall each month (rainfall data from Dearing and Schall [1994]; Spearman correlations, $P > 0.05$).

The above results show that data need to be partitioned only by animal gender for analysis of body temperature vs. stomach volume. There was no correlation between stomach volume and body temperature, nor for relative stomach mass (stomach volume/body mass, assuming 1 ml stomach contents equals approximately 1 g) (Spearman correlations, $P > 0.05$). We have no data on the activities of each lizard prior to its being collected. Therefore, it is possible that some of the lizards had recently emerged from cool burrows and had not yet begun normal feeding and thermoregulation. Therefore, we redid all analyses for animals most likely to be active or basking ($>37^\circ\text{C}$; 37° is approximately 1 SD below the mean for both males and females). Stomach volume was weakly negatively correlated with body temperature for both males and females (Spearman correlations, $r_s = -0.10$, $P = 0.037$, $N = 404$ for females, and $r_s = -0.22$, $P < 0.001$, $N = 464$ for males). We also divided the data into three groups for each gender: body temperature >1 SD above mean, body temperature within 1 SD of mean, and body temperature <1 SD of mean. Stomach volume distributions did not differ among these three groups for females (Kruskal-Wallis test, $P > 0.05$), but did differ for males (K-W test, $P = 0.01$). For males, the high body temperature group had the smallest volume of food in the stomach ($\bar{x} = 0.57$ ml, vs. 0.89 for the mid temperature group, and 0.81 for the low temperature group).

Mean body temperature of *C. murinus* was compared with data for 12 species of insectivorous *Cnemidophorus* from the mainland of North, Central, and South America (Schall, 1976, 1977; Bowker, 1993). All 12 had mean temperatures higher than *C. murinus* (ranging from 0.2–2.8 C). Data were available to conduct statistical comparisons for six of these; in all cases the lower temperature of *C. murinus* was significantly different from the other species (t-tests corrected for differing variances when appropriate, $P < 0.05$).

Janzen's hypothesis proposed that herbivorous lizards, including whiptail species that have switched to a plant diet, must maintain a high body temperature to digest foods. The body temperature of *C. murinus* is not higher than its insectivorous congeners, and appears to be slightly lower than many other species of *Cnemidophorus*. This does not necessarily contradict Janzen's hypothesis because *Cnemidophorus* typically maintain higher body temperatures than most other lizards (Schall, 1976, 1977; Bowker, 1993)

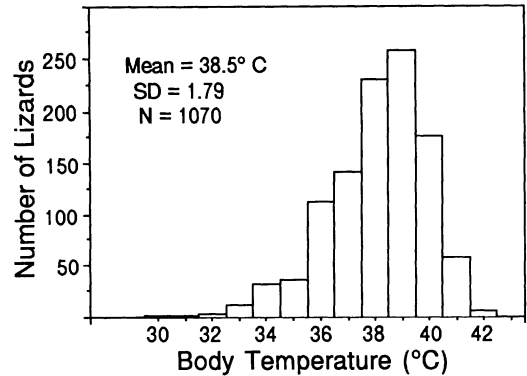


FIG. 1. Body temperature distribution for Bonaire island whiptail lizards, *Cnemidophorus murinus*.

and may thus be preadapted to a plant diet when insects are scarce. Perhaps *C. murinus* and other herbivorous whiptails have conservative modal body temperatures, not subject to much change even with a major shift in diet (Schall, 1977). Instead, these lizards may thermoregulate to a typically high *Cnemidophorus* body temperature for a longer period each day. Comparisons of time budgets for insectivorous and herbivorous *Cnemidophorus* would resolve this question.

We were surprised that *C. murinus* did not raise its body temperature after feeding; in fact, the data suggest that lizards with full stomachs may lower their body temperature slightly. Some insectivorous *Cnemidophorus* are known to increase body temperature after feeding (Schall, 1977) and Marken Lichtenbelt (1992) found that higher body temperature increases the efficiency of digestion of plant material for a specialist herbivore. Plant materials, though, vary substantially in their physical and nutritive properties (fruits vs. leaves, for example). Marken Lichtenbelt's data suggest there may be different optimal temperatures for digestion of different types of plant foods, so a uniform increase in selected body temperature as lizards fill their stomachs may not be expected. The diet of *C. murinus* at our three study sites differed substantially; at one site, for example, small berries were the most important food, whereas at another site leaves were much more common (Dearing and Schall, 1992). Despite these differences, body temperature distributions did not differ among the sites.

In summary, our results hint that the herbivorous Bonaire *Cnemidophorus* may have a slightly lower temperature than many insect-eating congeners and may lower its body temperature after feeding on plant materials of all kinds. These unexpected results suggest an alternative hypothesis. Earlier we proposed that *C. murinus* may ferment plant foods in its intestine (Dearing and Schall, 1992). These lizards may be selecting a temperature that is optimal for their alimentary tract microbes, a temperature slightly lower than normal for active insectivorous *Cnemidophorus*.

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Tumors of the Iliac of Modern and Tertiary Australian Frogs

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To judge from the review of anuran pathology by Reichenbach-Klinke and Elkan (1965), frogs exhibit a low incidence of bone tumors. More specifically, tumors of the ilia of Australian frogs, recognized initially by localized expansion of the iliac shaft, seem to be a rare occurrence. Examination of at least 3000 ilia of modern and fossil specimens by one of us (MJT)

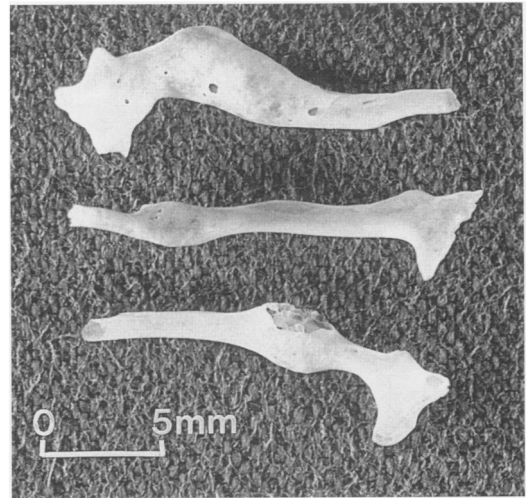


FIG. 1. Three iliac bones containing tumor masses of varying sizes.

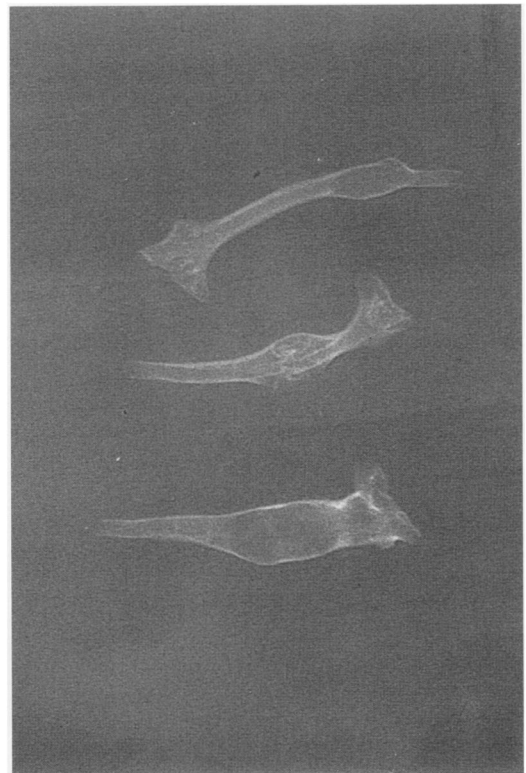


FIG. 2. Radiographs of the three bones shown in Fig. 1. Expansive intramedullary tumors are present. These are radiolucent with focal calcification. The overlying cortex is thinned.