Heating and Cooling Rates of *Terrapene ornata* and *Chrysemys picta* in Water

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Introduction

The body temperature of an ectotherm is commonly thought of as being entirely dependent upon the prevailing ambient temperature. However, behavioral and physiological thermoregulation in some ectotherms allows them to maintain internal heat levels at, or about, their euristic temperatures (Bartholomew and Tucker, 1963; Boyer, 1965; Weathers and White, 1971; Lucey, 1974; Goin, 1978; Smith, 1979).

A common method for investigating this phenomenon is by heating and cooling the animal in a constant temperature water bath. Turtles are, perhaps, the easiest and most practical group with which to work, and a number of investigators have determined rates of heating and cooling for various testudinid species: Hutton et al. (1960), Weathers and White (1971), Spray and May (1972), and Smith et al. (1981). However, little has been done to compare the temperature change rates of turtles from contrasting environments.

The purpose of this investigation is to compare the heating and cooling rates of a terrestrial turtle, *Terrapene ornata* (Agassiz), and *Chrysemys picta* (Schneider), an aquatic.

Materials and Methods

Three ornate Box turtles (*T. ornata*) were collected from Moniteau County, Missouri, and transported to laboratory facilities at the University of Wisconsin–Stevens Point. Three specimens of the Midland Painted turtle, *C. picta*, were collected in Portage County, Wisconsin.

The animals were maintained for a number of weeks prior to the experimentation. They were fed on earthworms enriched with cod-liver oil several times each week, and acclimated to 25°C. Each turtle was returned to its housing at this temperature after each trial throughout the duration of the investigation. A minimum of 24 hours separated testing trials for each turtle.

Two constant-temperature agitating water-baths (Model MR-3220A-1, Blue M Electric Company) were used for heating and cooling trials. Their water temperatures were maintained, respectively, at 40°C and 10°C, ± 0.5°C.
Fig. 1. Arrangement of turtle in water-bath used in heating and cooling of the animal.

A thermistor probe was inserted into the cloaca and secured with adhesive tape. The turtle was then firmly restrained on a wooden platform by heavy elastic bands. At the start of a trial, both turtle and board were submerged in the water-bath and held in place with rubber restrainers. An adjustable wire mesh platform in the bath positioned the animal so that its access to air was possible, while the carapace remained completely submerged (Figure 1).

The body temperature was monitored by a Model 47 YSI telemeter at one-minute intervals until the end-point temperature was reached. The end-point was determined to be within 1 degree C of the water-bath temperature, i.e., at 39°C, or at 11°C, respectively.

Turtle weights were measured with an Ohaus 2610 g Dial-o-gram animal balance.

Results

Both Terrapene ornata and Chrysemys picta individuals heated faster than they cooled during the 36 individual trials. The end-

Table 1. End-point time/weight relationship data for heating and cooling of Terrapene ornata and Chrysemys picta. All times given are the means of three trials.

<table>
<thead>
<tr>
<th>Turtle</th>
<th>Terrapene ornata</th>
<th>Chrysemys picta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Heating Time (min)</td>
<td>23.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Cooling Time (min)</td>
<td>33.6</td>
<td>36.0</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>215.5</td>
<td>220.5</td>
</tr>
</tbody>
</table>
point time/weight relationship data for the heating and cooling of both species are summarized in Table 1 and illustrated in histograms (Figures 2 and 3). The end-point times shown are the means of three trials. The length of time required for a turtle to reach end-point temperature increased with an increase of animal weight within each species. This was true of both heating and cooling times.

Figure 4 is a histogram of the mean end-point time/weight relationships which compares the two species for heating and cooling rates. Here it is shown that Chrysemys picta, with a greater mean
weight ($\bar{x} = 434.6$ grams) than *Terrapene ornata* ($\bar{x} = 267.1$ grams), exhibited significantly shorter ($p < 0.01$) end-point time intervals for both heating ($t = 3.71$, df = 16) and cooling ($t = 6.64$, df = 16).

**Discussion**

It has been previously shown that dead turtles will heat and cool at equal rates (Smith et al., 1981). However, the live specimens of *Terrapene* and *Chrysemys* exhibited faster heating than cooling rates.
Fig. 4. Comparative end-point time/weight relationship for Terropene ornata and Chrysemys picta. All values (except weights) are the averages of the means of three trials.

It can be deduced that some physiological phenomenon accounts for this, as the animals were securely restrained and thus prevented from any sort of behavioral thermoregulation. This is of course in accordance with the findings of other investigators: Weathers and White (1971), Crawshaw et al. (1980) and Smith, Robertson and Adams (1981). Bartholomew and Lasiewski (1965) also reported this phenomenon in their classic work on the marine iguanid Amblyynchus cristatus.
It appears that the mechanism providing for differential rates of heating and cooling lies in an alteration of conductivity regulated by the circulatory system, and a temperature-dependent heart rate. It has been shown that the cutaneous and carapace bloodflows are diminished during cooling and increased during heating (Weathers and White, 1971; Smith et al., 1981). Assuming that the blood acts as a vehicle for heat distribution, a lesser flow through the tissues most in contact with a cold medium would serve to retard cooling of the animal, and this reaction would prolong the period of time during which the turtle remains active. That the heart rate decreases while cooling, and increases during warming, has been shown by Akers and Damm (1963), Belthea (1972) and Pough (1976). In fact, Riedesel et al. (1971) claim that a direct linear correlation exists between cloacal temperature and heart rate (1971)

In sum, when a turtle is subjected to cooling environmental conditions, a decrease of superficial blood flow, and, perhaps, the slower heart rate, may account for decreased heat conduction to the environment and permit the turtle to remain active for a longer time. And conversely, when warming environmental conditions result in increased cutaneous and carapace bloodflow through vasodilation, and increased cardiac output distributes heat rapidly, the turtle is thereby able to reach its ecratic temperature in a shorter period of time.

In this investigation, the finding that heavier turtles of a species required a longer period of time to reach heating and cooling endpoints is consistent with the results of Weathers and White (1971) and Smith, Robertson and Adams (1981), who reported that heating and cooling rates were inversely proportional to body weight. This can be explained by the simple physical principle that a smaller surface-to-volume ratio implies a longer passage of time for heat distribution.

Weight, however, is not the only factor influencing the heating and cooling rates of turtles, for our Chrysemys picta, with a 38.5% greater mean weight than the Terrapene ornata samples, heated (12.3%) and cooled (14.5%) the faster. Speculation at least suggests that anatomical morphology has a considerable influence on heating and cooling rates, and may override mass as an effective factor.

Of the two turtle species, C. picta has the flatter shape and greater surface-to-volume ratio, and has more exposed skin and flesh. T. ornata is more convex dorsally, nearing the spherical, with a minimum of unprotected skin. It would seem that the greater surface area and larger expanse of flesh in C. picta would tend to increase thermal conduction and thus accelerate heating and cooling rates. And in agreement with this principle, a recent investigation (Smith et al., 1981) found the Soft-shelled turtle, Trionyx spinifer, to exhibit a similar trend. It is highly compressed dorso-ventrally.
Ecologically speaking, the slower rates of heating and cooling stemming from the dome shape of Terrapene ornata may have other benefits for this species. Slower heating coincides with slower loss of moisture, and this is a significant consideration in a xeric environment where the control of evaporative water loss can be vital. The dome-shaped carapace and reduced flesh (with more slender legs) also provide greater ease of mobility over rough terrain, as well as effective protection from predators.

The basking and diving habits of the Painted turtle result in frequent and rapid fluctuations of body temperature. The dorso-ventrally compressed morphology permits rapid warming (when basking) after a cool dive. But the same anatomical features are also counter-productive in that the rate of cooling is also accelerated once the animal returns to cool water. In a compensation for this, C. picta has a lower ecoretic temperature (Pough, 1976) and is able to function in lower levels of heat than T. ornata. Moisture loss is not a potential problem for the aquatic Chrysemys, and its streamlined form allows for more ease of mobility through a viscous medium, as well as providing a lower profile to predators.

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