Construction and Use of a Direct Calorimeter to Estimate Energy Expenditure in Hibernators

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Metabolic rates have traditionally been estimated through indirect calorimetry (gas exchange or respirometry) due to its ease and availability. Oxygen consumption neglects the contributions of anaerobic metabolism, while direct calorimetry is more difficult. As a result, most studies utilize indirect calorimetry wherein oxygen consumption and/or carbon dioxide production are measured. One limitation to this approach is that anaerobic metabolism is ignored.

Model Organism - Golden-Mantled Ground Squirrels (Spermophilus lateralis)

- The ambient temperature in their metabolic chamber was ~4° C
- Body temperatures are ~1° C above ambient temperature, with records as low as ~2° C being recorded. Body temperatures rapidly increase to about 36° C in just a few hours when hibernators spontaneously arouse from torpor
- Oxygen consumption during hibernation may be as low 1/100 of active rates. Little is known of anaerobic metabolism during hibernation.

Hypothesis
We hypothesize that anaerobic metabolism would make a significant contribution to overall metabolism in torpid small rodent hibernators.

Calibration
Complete transfer of heat from one substance to another is not instantaneous. An electrical resistor is placed in the animal chamber to generate a constant amount of heat in watts. The amount of heat absorbed by the mineral oil per unit time is related to the voltage. The proportionally constant or time constant of heat flow in the system is determined by the materials present in the animal chamber, the properties of the mineral oil, and the rate at which the mineral oil is pumped.

Two time constants are used to interpret the data from the calorimeter. The first is related to the time for the mineral oil to reach dynamic equilibrium, where heat can no longer be added or lost from the mineral oil. The second is related to the amount of time it takes for the mineral oil to make one complete cycle through the copper tubing.

The rate of change of the voltage is used to calculate the wattage at every second. A hyperbolic curve is produced comparing voltage to time when a constant amount of heat is generated within the animal chamber. The voltage reaches thermal equilibrium is directly proportional to the wattage used.

Conclusions
We successfully constructed a direct heat calorimeter that is sensitive enough to detect the heat production from a torpid squirrel.

Our preliminary results suggest heat production in squirrels undergoing an alarm arousal is greater than for squirrels spontaneously arousing from torpor (n = 2 squirrels).

Respirometry shows much more modest differences between alarm and natural arousals

These data are consistent with an important role for anaerobic metabolism during hibernation.