Metabolism Studies Essay, Research Paper

Abstract

The purpose in experimenting with computer simulations was to compare oxygen consumption rates in different mammalian subclasses. We compared monotremes, marsupials, and placental mammals at both warm and cold temperatures. The results supported our hypothesis that when temperature increased, metabolic rate decreased. This was also supported using a student’s t-test. We also found that placental mammals had the highest oxygen consumption rates and marsupials had the lowest. We compared oxygen consumption rates in different sized crabs at different temperatures. The results supported our hypothesis that the smaller crab would have a higher rate of consumption. However, in the crabs, as temperature was increased, metabolic rate increased also.

Introduction

The second law of thermodynamics affirms that all living organisms must receive a constant energy input in order to survive (Witz 2000). Almost all bodily activities require energy. It is important to study how animals obtain, process, and dispose of products needed to maintain a positive energy balance. When cellular respiration occurs in the body, heat is produced and given off into the environment by the release of potential energy contained in the chemical bonds of macronutrients. The amount of heat released into the environment and the rate at which chemical reactions occur in the cells are directly related. Two different relationships exist, one that describes the endothermic animal and one that describes the endothermic animal. The rate of heat produced by the endothermic animal while at rest, fasting, and within the thermoneutral zone is dependent upon the basal metabolic rate (BMR). The thermoneutral zone of the endotherm is described as the range of ambient temperatures within which there is a limited change in metabolic rate. The standard metabolic rate is what the rate of heat loss in ectotherms relies upon. The difference between the two rates is the temperature factor. Due to that fact that the temperature of ectotherms has a wider range with ambient temperature than the endotherms, physiologists defined a different measure for the basal level of metabolism.

Although it is possible to measure the animal’s heat lost to the environment by direct calorimetry, it is easier to use indirect calorimetry. An effective way of measuring heat loss is to use the rate of oxygen consumption. Since oxygen is required by most animal cells using biochemical pathways to metabolize macronutrients, and it varies in a predictable way, it is useful in determining metabolic rate. If we can estimate BMR accurately, we can predict the amount of energy needed for important aspects of the animal’s life, such as growth and reproduction.

For comparative purposes in the laboratory, we will be comparing weight-specific metabolic rates. This will allow us to compare the oxygen used by a gram of rat tissue to the oxygen used by a gram of mouse or iguana tissue. We hypothesized that the metabolic rate of the ectotherms, which are the iguanas, will be lower than the metabolic rate of the endotherms, which are the rats and the mice. Computer simulated temperature differences in the environment of both endotherms and ectotherms will also cause a difference in metabolic rate. When exposed to cold temperatures, we hypothesized that the metabolic rate will be greater than when the organism is exposed to high temperatures. The animal requires a greater amount of energy to keep the body warm at low temperatures; therefore, the body must breakdown the macronutrients at a faster rate. Body size also influences metabolic rate. A smaller animal, such as a mouse, should have a greater metabolic rate than a larger animal with the same general morphology, like a rat. This difference in metabolic rate is due to the surface area to volume ratio. A smaller animal has a higher ratio and more surface area exposed to the environment; therefore, it requires more energy to maintain the positive energy balance. Student’s t-tests were used to compare differences in temperature and body size in endotherms and ectotherms, different mammalian subclasses, and in the crab.

Methods

Determining the WMR of endotherms and ectotherms-

In this experiment, we found the average WMRs of a large endotherm, which was a rat, a small endotherm, which was a mouse, and an ectotherm, which was an iguana. The bottom of the metabolism chamber was covered with approximately 50 ml of soda lime, which absorbed any carbon dioxide exhaled by the animal. A thermometer was placed in the chamber for five minutes until the temperature had equalized. Each starving, resting animal was weighed and placed in the chamber. The inside of a calibrated 5-ml plastic manometer tube was wet with tap water, inserted into the hole of a rubber stopper, and then placed into the end of the metabolism chamber. The chamber was sealed by applying a drop of a soap bubble solution to the end of the manometer, and the time it took to move along the manometer was measured. For the mice and rats, we measured the time it took for the bubble to move 5 ml, five times. For the iguanas, who have much slower metabolic rates, we measured the time it took to move 1 ml, one time. Using the volume of air consumed per minute, a series of conversions were applied so that we found the WMR for each animal, correct for size and STP.

Computer Simulations of Metabolic rates-

We compared the metabolic rates of prototherian, metatherian, and eutherian mammals. Metabolic rates were estimated by measuring the oxygen consumption rates of representative species in the mammalian subclasses, and were corrected for body size for comparative purposes. The animals we studied were: Ornithorhyncus-a duck-billed platypus, Echidna-a spiny anteater, Bettongia-a rat kangaroo, Dasyurus-a marsupial “cat”, Trichosurus-a brush-tail possum, Sylvilagus-an eastern cottontail rabbit, Felis- a domestic cat, and Homo sapiens- a human. Student’s t-tests were performed, comparing metabolic rates for: each of the species tested at 5? C and 35? C, monotreme mammals and marsupial mammals, monotreme mammals and placental animals, and marsupial mammals and placental mammals.

We also studied the relationship between metabolic rate and body size using crab oxygen consumption rates. A 5g and a 25g crab were used, and metabolic rates were measured at 23.5? C and 8.5 ?C. Student’s t-tests were used to compare the metabolic rates for: each crab at both temperatures, the small crab at 8.5 ?C with the large crab, and the small crab at 23.5? C with the large crab.

Results

Computer Simulations of Metabolic rates-

We found the average oxygen consumption rate (in g/cm2 x 1000/hr) for the two montremes: Ornithorhyncus was 1.414 at 5 ?C and 0.759 at 35 ?C and Echidna was 1.515 at 5 ?C and 0.889 at 35 ?C. For the marsupials, the average oxygen consumption rate (in g/cm2 x 1000/hr) for: Bettongia was 1.160 at 5 ?C and 0.507 at 35 ?C, Dasyurus was 1.173 at 5 ?C and 0.688 at 35 ?C, Trichosurus was 0.818 at 5 ?C and 0.305 at 35 ?C. In the placental mammals, the average oxygen consumption rate (in g/cm2 x 1000/hr) for: Sylvilagus was 1.746 at 5 ?C and 0.983 at 35 ?C, Felis was 1.874 at 5 ?C and 1.188 at 35 ?C, and Homo sapiens was 1.629 at 5 ?C and 1.718 at 35 ?C. Figure 1 shows the effects of temperature on oxygen consumption rate for monotremes (Ornithorhyncus and Echidna), marsupials (Bettongia, Dasyurus, and Trichosurus), and placental mammals (Sylvilagus, Felis, and Homo sapiens).

Figure 1. The effects of warm and cold temperatures on oxygen consumption rate for montremes, marsupials, and placental mammals.

For each of the species, we compared the average metabolic rates at 5 ?C and 35 ?C. We found that at the two different temperatures, all of the species were statistically significant p\* 0.001, except for in humans, in which p\*0.05. We found that the average metabolic rates of the montreme animals measured at 5 ?C were significantly different from the marsupial mammals at 5 ?C (t=5.02, df=18, p\*0.001). The average metabolic rates of the montreme animals measured at 5 ?C were significantly different from the placental mammals at 5 ?C (t=3.38, df=18, p\*0. 01). Furthermore, we found that the average metabolic rates of the marsupial animals measured at 5 ?C were significantly different from the placental mammals at 5 ?C (t=10.99, df=18, p\*0.001).

The average oxygen consumption rate (in ml O2/g/min) for the 5g crab was 20.45 at 8.5?C and 92.66 at 23.5?C. The average oxygen consumption rate for the 25g crab was 12.50 at 8.5?C and 62.26 at 23.5?C. Figure 2 shows the effects of temperature and body size on oxygen consumption in the crab.

Figure 2. The effects of temperature and body size on oxygen consumption in the crab.

We found that for both crabs, the average weight-specific oxygen consumption rates at the two temperatures were significantly different p\*0.001. At 8.5?C and 23.5 ?C, the average oxygen consumption rates of the 5g crab compared to the 25g crab were significantly different respectively (t=-4.32, df=18, p\*0.001) (t=-20.70, df=18, p\*0.001).

Witz, B. W. 2000. Animal Physiology Laboratory Manual. Nazareth College,

Rochester. 174 pp.