Bergman's Rule – the science of losing heat
Experiment

Animals have many adaptations to survive winter. A 19th century German biologist named, Carl Bergmann, made an interesting observation. He noticed that many animal species tend to be larger in their northern, colder ranges than individuals of the same species in their southern, warmer ranges. This concept is known as Bergmann's Rule. For example, deer that live in the Yukon are bigger and heftier, than those found closer to the equator, which tend to be smaller and leaner. This size difference affects an animal's ability to regulate its temperature. Large animals can trap heat more easily which is an advantage when you live in colder climates, while smaller animals have an ability to radiate heat away over a larger surface area, an adaptation that is better suited to warmer climates.
This lesson provides two options to explore the science behind this adaptation.

Instructions – Option 1: The Benefit of Being Big

This activity is a simple way to demonstrate that larger animals have an advantage to survive winter by simply being big. You will need a cold day with temperatures below freezing to implement this option.

Materials:

- ☐ 3 plastic bottles of different sizes with secure lids
- ☐ Marker
- ☐ Science Journal

1. Have students gather three clean plastic containers with secure lids from home. Ensure containers are significantly different in size (e.g. an old medicine canister, 1- litre pop bottle and a 2-litre juice container).

2. Fill each container with tap water, leaving a small space at the top. Water should be approximately the same temperature.

3. Have your students label their containers with a local animal name that represents the size of their containers. For example, they may think of them as:
    - Small container – Red Squirrel
    - Medium container – Coyote
    - Large container – Moose

4. Go outside with your students and have them find a place to put their containers. Containers should be in approximately the same place and exposed to the same amount of shade or sunlight.

5. Leave the containers for a long period of time (1 to 2 hours). You may want to consider the shelter building extension activity as an option to build upon the science of losing heat while the containers are exposed to the cold temperature.

6. After 1-2 hours of time has elapsed, have students find their containers and explore the liquid state of each container's contents. Have students summarize their observations in their science journal. The following questions, can help guide their thinking:

    - Did any of your containers form ice crystals or freeze completely?
    - Which container had the most ice crystals? Which had the least?
    - Did the size of container affect the amount of ice crystals formed?
    - If your container was an actual animal, which one is able to cope more easily with colder temperatures? Explain your reasoning.
    - Why do you think an animal's size is an adaptation to winter?

Discussion

Large animals are adapted to withstand colder temperatures by simply being big! Endothermic animals, often referred to as warm-blooded animals, need to generate heat to maintain a constant internal temperature to survive. Larger animals have the ability to generate more heat, as well as, the ability to trap this heat more effectively in their bodies due to their bigger size. Another way to express this idea is that animals that are bigger radiate, or lose heat more slowly, than animals that are smaller.

Instructions – Option 2: Surface to Volume Ratio – the science behind Bergman's Rule

In this activity option, students will explore the surface to volume ratio of various sized containers and explore how this ratio can influence heat loss.

Materials:

☐ 3 square plastic containers of different sizes with lids

☐ Plastic cup ☐ Hot tap water

☐ Thermometer ☐ Journal

1. Have students bring in three clean square or rectangular plastic containers with lids.

2. Have students create the following table in their science journal.

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Start time: _____ End time: _____ Time Lapsed: _____	Initial Temperature °C	Volume (cm3) V = L x W x H	Surface Area (cm2) Area = L x W Surface Area is the total area for all 6 sides of your container.	Surface Area (SA) to Volume Ratio Ratio = SA / V	End Temperature °C
Container #1					
Container #2					
Container #3					

3. Calculate the Volume for each container and document this in your science journal.

Volume = length x width x height

4. Calculate and record the surface area for all three containers.
   Area = length x width. Total Surface Area (SA) for each container is the Area for all 6 sides added together.

5. Determine the Surface Area to Volume Ratio for each container and record this number.

6. Run a tap of water until it has a consistent hot temperature.

7. Fill your plastic cup and each of your three food containers with hot water. Place lids on all your containers.

8. Put your thermometer in the cup to take the initial temperature of your hot water. Record what this temperature is.

9. Go outside to find a place to put your three containers. Place them in approximately the same location where they are exposed to the same amount of shade or sunlight.

10. After 30 minutes, remove the lids and take the temperature of the water in all three containers. Record your information under End Temperature in your science journal.

11. Reflect on the following questions in your science journal:
    - Which container cooled more quickly? Why do you think this happened?
    - How does surface area change in relation to volume?
    - Based on your observations, what influences an animal's ability to retain heat more, surface area or volume? Explain your reasoning.
    - What is more responsible for radiating heat away from an animal's body? Surface Area or Volume? How do you know that?
    - How might climate affect the size of animals?

Discussion

Thermoregulation, the ability for an endothermic animal to maintain its core temperature, is critical to survival. Bergman's rule states that animals of the same species tend to be larger in the northern, colder areas of their range, while those in the southern, warmer parts are smaller. The surface area to volume ratio is one adaptation many animals have adopted to deal with colder (or warmer) temperatures. Animals with a higher surface area to volume ratio loose heat more quickly relative to its volume compared to those with a lower surface area to volume ratio. In other words, the larger the animal, the smaller the surface area to volume ratio and the less relative area to lose heat. In this experiment, the smaller container will have a higher surface to area to volume ratio. As a result, it should record a lower temperature than the larger containers after 30 minutes. Consider having your students taking the temperature every 5 minutes and graphing their results. Examples showing surface area to volume ratio, as well as temperature to time of a 500 ml, 1000 ml and 2000 ml container are shown below.

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