EXPLORATIONS

Activity 18

Body Cooling Rate of Animals

Objectives

- To model the cooling rate of different sizes of animals
- To determine the effect of skin surface area on the cooling rate of animals

Materials

- TI-73
- Unit-to-unit cable
- CBL 2™
- Temperature sensor
- Large beaker or container
- Two surgical gloves
- Water (ice water and room temperature)
- Data Collection and Analysis pages (p. 170 - 173)

In this activity you will

- Make two models to simulate the cooling rate of different skin surface areas.
- Use the CBL 2™ with a temperature sensor to measure the cooling rate of the models.
- Compare the cooling rates of the models to determine the effect of skin surface area on the results.

Problem

How does the skin surface area affect a body's cooling rate?

Introduction

An animal's skin surface is the site of a large amount of heat transfer between the animal's body and the environment. If the temperature of the environment is warmer than the animal's body, heat is transferred into the body through the skin surface. If the temperature of the environment is cooler than the animal's body, heat is transferred out of the body through the animal's skin surface. This is especially the case with *ectothermic* (cold-blooded) animals. Many *endothermic* (warm-blooded) animals have adaptations to conserve body temperature, such as fur, feathers, circulatory patterns, and perspiration. However, the skin of endotherms still serves as a site of heat exchange.

Animal body types also reflect this phenomenon. Smaller animals have a larger skin surface area to body volume ratio while large animals have a smaller skin surface area to body volume ratio.

Hypothesis

Before testing, complete the **Hypothesis** section on the **Data Collection and Analysis** page to predict how the amount of skin surface area affects the cooling rate. Then complete the **Experimental Design** section on the **Data Collection and Analysis** page.

Procedure: Collecting the Data

1. Fill the beaker with ice and water.
2. Tie off the fingers of one of the gloves. (Tying the fingers in a knot will do the trick.)
3. Plug the temperature sensor into Channel 1 (**CH 1**) on the CBL 2™.
4. Start the DATAMATE program.
5. The Main Screen is displayed. If **CH 1:TEMP(C)** is displayed at the top of the screen, go to step 10. If **CH 1:TEMP(C)** is not displayed, go to step 6.
6. Select **1:SETUP**.
7. Select **CH1**. Select **1:TEMPERATURE**.
8. If you are using the TI stainless steel temperature sensor, select **4:STAINLESS TEMP(C)**. If you are using a different temperature sensor, select the appropriate item from the menu.

   Note: *The flexible TI temperature sensor is the same as the stainless steel.*
9. Select **1:OK** to return to the Main Screen.
10. Select **1:SETUP**. Select **MODE**, and then select **2:TIME GRAPH**.
11. The **TIME GRAPH SETTINGS** are displayed. If the screen shows **TIME INTERVAL: 30**, **NUMBER OF SAMPLES: 20**, and **EXPERIMENT LENGTH: 600**, go to step 14. If the settings are not correct, go to step 12.
12. Select **2:CHANGE TIME SETTINGS**. For **ENTER TIME BETWEEN SAMPLES IN SECONDS**, enter **30**. For **ENTER NUMBER OF SAMPLES**, enter **20**. The **TIME GRAPH SETTINGS** screen reappears, showing the new settings.
13. Select **1:OK** twice to return to the Main Screen.
14. Fill the glove that has the fingers tied with 200 ml of hot water.
15. Insert the temperature sensor into the water inside the glove.
16. Holding the end of the glove closed, put the glove into the beaker of ice and water.
17. When you are ready to begin, select **2:START**. The CBL 2 beeps twice and displays a graph with the temperature in °C in the upper right corner.
18. Continue to hold the glove in the beaker of ice and water. The CBL 2 beeps twice when it has finished collecting the data.

19. The graph is displayed showing the data that was collected. Use ▸ and ◂ to move to each data point. On the **Data Collection and Analysis** page, record the temperature for each 30-second interval in the table and sketch the graph.
20. Press ENTER to return to the Main Screen and select **5:TOOLS**. Select **1:STORE LATEST RUN** and select **1:OK** to return to the Main Screen.
21. Repeat steps 14 through 20, refilling the beaker with ice and water and using the glove that does not have the fingers tied.
22. To exit from the DATAMATE program, press ENTER to return to the Main Screen. Select **6QUIT** and press ENTER.
23. To display the lists showing the results of the second trial, press LIST. The times are stored in **L1**. The temperatures are stored in **L2**.

Graphing the Data

1. From the Main Screen, select **4:GRAPH**.
2. After the graph displays, press ENTER to return to the Graph menu.
3. Select **4:MORE**.
4. Select **6: L2 AND L3 VS L1.**

Data Analysis

After testing, use the table and graphs on the **Data Collection and Analysis** page to answer the questions about your results.

Extension

- Calculate your own skin surface area to volume ratio.
  - To find the approximate skin surface area of the human body, there are three different methods:
    - ◊ Three-fifths times your height squared.
    - ◊ 100 times the surface area of your hand print.
    - ◊ Twice your height times the circumference of your thigh.
  - To find your approximate volume, multiply your body weight in kg by .9.

  Compare your surface area to another student with similar body volume. Suggest an explanation for the differences in surface area of your two bodies.
- Make models using rubber gloves and warm water to represent a baby and an adult with different skin surface area to volume ratios. Use the CBL 2™ and temperature sensor to measure the cooling rates.

Data Collection and Analysis

Name ______________________________

Date ______________________________

Activity 18: Body Cooling Rate of Animals

Problem

How does the skin surface area affect a body's cooling rate?

Hypothesis

An animal with less skin surface area will cool off __________________________ than an animal with more skin surface area.

Experimental Design

1. Independent Variable: ______________________________

2. Treatments: ______________________________

3. Dependent Variable: ______________________________

4. Number of Trials: ______________________________

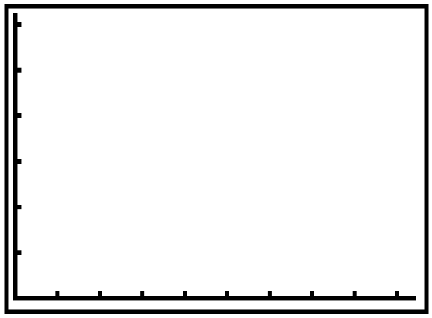
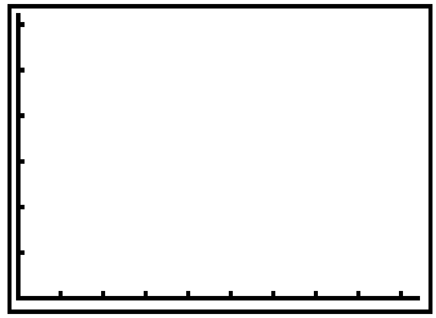
5. Constants: ______________________________

Data Collection

1. After collecting the data for each glove, use the displayed graph to record the temperatures in the table below.

Time (min. : sec)	Temperature (°C) of Glove with Fingers Tied	Temperature (°C) of Glove without Fingers Tied
0		
30		
1 : 30		
2 : 00		
2 : 30		
3 : 00		
3 : 30		
4 : 00		
4 : 30		
5 : 00		
5 : 30		
6 : 00		
6 : 30		
7 : 00		
7 : 30		
8 : 00		
8 : 30		
9 : 00		
9 : 30		
10 : 00		

2. Draw and label the graphs of your data below or print them on the computer and attach them to this page.

Data Analysis

1. What do the slopes of the graphs represent?

2. What do the differences in the two slopes indicate about the cooling rates of the two gloves?

3. Explain why the graphs of the two gloves differ.

4. What does the *y*-intercept represent?

5. Refer to the table and compare the temperatures of the two gloves at the same time intervals. Which glove changed temperature more quickly? List some data points from both gloves to support your answer.

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Conclusion

1. An animal with less skin surface area will cool off ____________________ than an animal with more skin surface area.

2. Compare the surface area of both gloves. Does the surface area of the glove seem to affect the rate of temperature change?

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3. How does this phenomenon affect animals in extremely cold or hot environments? Why don't whales, seals, and penguins have long legs and necks?

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Teacher Notes

Activity 18

Body Cooling Rate of Animals

Objectives

- To model the cooling rate of different sizes of animals
- To determine the effect of skin surface area on the cooling rate of animals

NSES Standards

- Science as Inquiry: Abilities necessary to do scientific inquiry
- Science as Inquiry: Understanding about scientific inquiry
- Life Science: Populations and ecosystems
- Life Science: Diversity and adaptations of organisms
- Science and Technology: Understanding about science and technology
- History and Nature of Science: Nature of science

Preparation

- To help students understand surface to body area ratios for different animals, use a fixed number of 1 cm cubes to build animals with different body plans and calculate the surface area.

  Example: Using 48 cm cubes, construct one animal with no appendages (4x3x4 cm) and calculate the volume (48 cm^3) and surface area (80 cm^2). Then build an animal with 4 legs and a head (4x3x3 body, 4 legs 2 blocks tall, and a head 2x1x2). Again calculate the volume (48 cm^3) and surface area (106 cm^2).

Management

- Assign these student jobs for this lab:
  - Materials/setup person (sets up samples, sensor)
  - Tech person (operates CBL 2™ and TI-73)
  - Data recorder (reads temperature readings from the TI-73 at each collection interval)
  - Runner (brings CBL 2 and TI-73 to the computer to print graphs with TI-GRAPH LINK™ or TI™ Connect and brings **Data Collection and Analysis** pages to the teacher)

- Clear covered plastic shoeboxes will hold a CBL 2™, pH sensor, cups, rinsing bottle, and other equipment neatly at each station. If students are sharing one pH sensor, representatives from each lab group should bring test beverages in the cups to the sensor. Mounting the sensor on a ring stand is an option.
- Students can record temperature readings in their lab journals as they are displayed on the TI-73. This keeps them engaged throughout the data collection period and if they lose the data/graph later, they can still write up their lab reports. Students can also access the data in the TI-73 lists after data collection. You can send the lists to all students' calculators using [APPS] **1:Link**:

  a. Press [APPS].

  b. Press [ENTER] to select **1:Link.**

  c. Select **4:List** and press [ENTER].

  d. Press [▼] to move the ▶ beside the list you wish to send. Press [ENTER].

  e. Repeat step **d** for each list you wish to send.

  f. Set the receiving unit by pressing [APPS] [ENTER] [▶] to select **RECEIVE**. Press [ENTER]. **Waiting…** displays on the TI-73 screen.

  g. On the sending unit, press [▶] to select **TRANSMIT** and press [ENTER].

  For more permanent storage of data, use TI-GRAPH LINK™ or TI™ Connect to save the lists in a computer folder. However, students may inadvertently lose their data or overwrite it in the next trial, so recording data in journals is a good option.

- Students can assess each other using a teamwork rubric after the lab. Provide a checklist of positive and negative behaviors. Copy these on quarter sheets of paper.
- If there is only one class cooling beaker, have students from each lab group take turns with their gloves.
- You can enter data from each lab group into a class computer spreadsheet or manually record it on an overhead transparency. Have one student from each group responsible for recording the data during the period. This will provide repeated trials for the experiment if time does not allow each lab group to perform it more than once. Students then can average the repeated trials to get a more accurate set of data.

Assessment

- Students can print line graphs using TI-GRAPH LINK or TI Connect and label the horizontal axis time and the vertical axis temperature. Students can also paste their graphs into a word processing document and write summaries.
- Students may form conclusions about the effect of body design on cooling rates based on their data.

Selected Answers

Experimental Design

1. Independent Variable: *rubber gloves with and without fingers*
2. Treatments: *fingers, no fingers*
3. Dependent Variable: *rate of temperature change*
4. Number of Trials: ——
5. Constants: *type of glove, amount of water, starting temperature of water, exposure to wind*

Data Analysis

1. What do the slopes of the graphs represent?

   The slope of the graph represents the rate of change of temperature.

2. What do the differences in the two slopes indicate about the cooling rates of the two gloves?

   The steeper slope of the glove without fingers indicates that the rate of cooling is faster than in the glove without fingers which has a less steep slope.

3. Explain why the graphs of the two gloves differ.

   The glove without fingers has less surface area per body volume so it cools more slowly. The glove with fingers has more surface area per body volume so it cools more quickly.

4. What does the *y*-intercept represent?

   The y-intercept is the initial temperature of the water in the gloves.

5. Refer to the table and compare the temperatures of the two gloves at the same time intervals. Which glove changed temperature more quickly? List some data points from both gloves to support your answer.

   The glove with fingers cooled more quickly.

Conclusion

1. Compare the surface area of both gloves. Does the surface area of the glove seem to affect the rate of temperature change?

   The greater the surface area of the glove the more quickly the water inside cools.

2. How does this phenomenon affect animals in extremely cold or hot environments? Why don't whales, seals, and penguins have long legs and necks?

   Animals such as whales, seals, and penguins live in cold environments. Their shortened appendages decrease their skin surface area and assist in decreasing body heat loss.