Canimals

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Purpose Investigate the rate of heat loss of animals using can models and investigate how the heat-loss rate is related to

- the size of the animal; and/or
- the animals fur and fat; and/or
- the environmental conditions: outside temperature, wind.

Introduction

Maintaining a normal body temperature is very important for animals. It has a large impact on animals' habitats, their behaviour patterns and food intake. In this lab, we look at heat loss due to radiation from the skin. To model small warm-blooded animals, we use metal cans filled with warm water ("canimals"); the cans are different sizes, have different surface covers, and are placed in different environmental conditions. The water temperature is recorded at uniform time intervals and a cooling curve is plotted.

Theory

In this lab, we look at heat loss due to radiation from the skin. If a warm body of mass m_{body} is placed in a cool environment, it will lose energy to the environment in the form of heat ΔQ, which is related to a temperature change ΔT :

$$\Delta Q = m_{body} c \Delta T \tag{1}$$

Here c is the specific heat capacity of the body, which is similar to the specific heat capacity of water for animals, therefore,

$$\Delta Q = m_{body} c_{water} \Delta T \tag{2}$$

For the heat loss, ΔQ and ΔT are in fact both negative, but we will neglect the negative sign here to focus on the magnitudes of the changes in these two terms.

We will be using metal cans filled with warm water to model animals, thus we call this lab "canimals". As the canimal is made of both the metal can and water, we need to find the equivalent body mass, $m_{body,}$ of equation (2).

The actual heat loss will be

$$\Delta Q = (m_{can} c_{can} + m_{water} c_{water}) \Delta T \tag{3}$$

Therefore,

$$m_{body} = \frac{m_{can} c_{can} + m_{water} c_{water}}{c_{water}} \tag{4}$$

where m_{can} is the mass of the empty can, m_{water} is the mass of the water inside the can, c_{can} is the specific heat capacity of the can (use c_{can} = 0.452 J/gC°), and c_{water} is the specific heat capacity of water (4.186 J/gC°). We ignore the masses of fur or fat.

Without any heat input, the temperature of the body will drop with time, creating a curve that we call "the cooling curve". The slope of the cooling curve is the cooling rate $\frac{\Delta T}{\Delta t}$. It depends on many factors for a real animal such as the difference between the temperatures of the body to the outside, the size and the skin structure of the animal, the presence of fur, and conditions like shelter, wind, rain etc.

The rate of heat loss is given by

$$R = \frac{\Delta Q}{\Delta t} = (m_{can} c_{can} + m_{water} c_{water}) \frac{\Delta T}{\Delta t} = m_{body} c_{water} \frac{\Delta T}{\Delta t} \tag{5}$$

Normally the cooling curve is not a straight line, but if the temperature drop is small, the curve will be approximately linear and the slope of the graph will give an estimate of $\Delta T/\Delta t$ at that average temperature. Therefore, we can calculate R, the rate of heat loss.

Apparatus set of canimals with lids and bases, thermometer, stopwatch, fan, "fat", "fur".

Data

Note: In this lab, the results of the entire class are pooled. Each desk measures one canimal, makes one $\Delta T/\Delta t$ graph, and calculates the rate of heat loss R. But you will use the entire class's data to write your "Conclusion" and "Discussion".

Describe your setup of the experiment:

- Record your "canimal" number, its mass (without lid), outer diameter, and height. Remember to record uncertainties for each measurement.
- State whether you are using "fat", "fur", "wind" or "ice", and briefly describe what they are and where you put them.
- Record the room temperature. If ice is part of the environment, also measure the temperature between the canimal and the ice package.

Set up the temperature measurement: Put the lid and the base of the canimal on. Put the thermometer to an appropriate height with a rubber band so that you can read the temperature from 30°C and above. Put on the fur or fat if required. If you will be using a fan, place the fan so that it is blowing straight toward the canimal. The air path must be unobstructed, both behind and in front of the fan.

Fill the canimal with warm water (Around 40-42 °C), leaving room for the lid. Measure and record the water temperature once every minute to find a "cooling curve". You should start somewhat higher than 40°C and keep recording until you have 15 data points below 40°C. Gently stir the water a few times after each reading with the thermometer, but make sure you do not touch the can with your hand. Again, remember to record uncertainties for time and temperature.

On a rough graph, plot each temperature you record after each minute to observe your cooling curve in real-time to check for any issues.

Measure the mass of the can full of water. Subtract the mass of the can to find the mass of the water. Calculate the equivalent body mass, m_{body}, of the canimal. Ignore the masses of fur or fat.

Record the following data in the collective-data table, including uncertainties where appropriate (Each desk fills one row):

Can #	Conditions (Fur/fat/wind,etc.)	Mass of empty can (g)	Mass of can + water (g)	Mass of water (g)	Equivalent body mass, m_{body} (g)	Diameter *D* (cm)	Height *H* (cm)

Calculations

Plot the cooling curve (i.e. the graph of temperature versus time) starting from 40°C for 15 minutes. Assuming it is linear (see Note below), find the slope of the graph (you can hand-graph, use LoggerPro, or Excel). This slope will be referred to as "the cooling rate of the canimal at body temperature." Express the cooling rate in °C/min.

Note: this slope can be different if the experiment was performed at a significantly different temperature because the cooling curve is in fact a *curve*. For our small range in temperature, we assume that the slope changes slowly enough that we can take it as a constant.

Calculate A, the area of the black radiating surface of the canimal. Find the area to mass ratio, A/m_{body}.

Add the following calculated results into the collective-data table. For calculated results, always record at least 5 significant digits. Ignore uncertainties in calculated results for now.

Can #	Black area, A (m^2)	A/m_{body} ratio (m^2/kg)	Cooling rate, $\Delta T/\Delta t$ (C/min)	Heat loss rate, R (W)

Report

By now, you have a lot of experience writing lab reports so you know that your report should be a complete, logical and understandable article for a general reader (not the marker!). Keep the readers in mind when you write!

For example, your title should not be "Canimals". It is an interesting word, but it is made up, and people will not know what it means. Something like "Investigating Heat Loss in Animals using Can Models" is much more descriptive. You are the author and have the privilege of titling your own article!

For "Data" include data from your desk, including the data used to generate the cooling curve. Remember to include uncertainties on all data.

For "Calculations", show how you arrived at all the numbers you entered into the collective-data sheet. Include a copy of your cooling curve graph and show your slope calculations. Introduce and insert the collective-data sheet.

For "Uncertainty Analysis" calculate δR, the uncertainty in R. Recall equation (5):

$$R = \frac{\Delta Q}{\Delta t} = m_{body} c_{water} \frac{\Delta T}{\Delta t}$$

Here the relative uncertainties in m_{body} and c_{water} are negligible compared to the relative uncertainty in $\Delta T/\Delta t$, which comes from the uncertainty from the slope of your cooling curve graph.

For "Conclusion/Discussion" sections, choose one or both from the topics below. The topic(s) you choose should be consistent with the title and the purpose of your report. Do not limit your discussion to the suggestions below – introduce your own thoughts.

Topic 1: Size of animals.

Pick three or more “bare canimals” that are very different in size and compare the cooling rate and the rate of heat loss *R.* For each canimal you pick, assume that the canimal’s diet consists solely of Planters™ dry-roasted peanuts (listed on the jar as 790 kJ per 30 g serving). What fraction (%) of its body mass would it have to consume each day in order to maintain its body temperature? From these results, explain why there exists a lower limit to the size of warm-blooded animals. What shape should a resting animal take in cold weather? In hot weather? Why?

Topic 2: The effect of fat/fur

How effective is dry fur in reducing the heat-loss rate in still air? In the wind? Hint: Compare *R* of a furry canimal with that of a bare canimal. How effective is wet fur in reducing the heat loss rate in still air? In the wind? What does the above say about the severity of heat loss by accidental drenching in cold windy weather? What does it say about the effectiveness of sweating as a heat removal mechanism in warm weather? Compare the heat loss rates of canimals with and without fat. What does this suggest about the necessity of the blubber layer beneath the skin of sea mammals? What is the difference between fur and fat?

Please note that your “Conclusion/Discussion” should appear like a small essay, rather than a series of answers to questions from the lab manual. If you are using a subset of collective data for a specific comparison, make a smaller table showing only the data used.