Insulation in Marine Mammals

INTRODUCTION

Mammals and birds are *endotherms*—they regulate their internal body temperature using metabolic processes. Most other vertebrates are *ectotherms*—creatures that maintain their body temperature through external sources. Ectotherms are generally better suited to aquatic environments because of the high heat capacity and heat conductivity of water. Water maintains a constant temperature, yet conducts heat quickly when there is a temperature differential between the animal and the water. Ectotherms still face challenges with temperature regulation in cold water, for example most aquatic reptiles are limited to tropical waters and most fish are confined to a narrow temperature range.

Marine mammals have evolved unique adaptations that allow them to overcome the obstacles associated with maintaining a temperature that is often 15–20°C warmer than their surroundings. Whales have a layer of blubber under their skin for insulation. Sea otters have very dense fur that traps air next to the skin, providing insulation. Polar bears have both of these adaptations—dense fur that can trap air next to the skin and a layer of blubber beneath the skin.

In this experiment, you will create insulators that act like fur and blubber using bubble wrap and vegetable shortening, respectively. Bubble wrap is composed of numerous pockets of trapped air, so its thermal properties closely resemble the fur of a polar bear or sea otter. Vegetable shortening has a much lower thermal conductivity than water, so its thermal properties make it analogous to blubber.

OBJECTIVES

In this experiment, you will

* Use the surface temperature sensor to record temperature data.
* Compare the insulating properties of shortening and bubble wrap.
* Relate the data to adaptations in marine and arctic mammals for their survival.

MATERIALS

Chromebook, computer, or mobile device  
Graphical Analysis 4 app  
Go Direct Surface Temperature (GDX-STS) or Surface Temperature Sensor (STS-BTA)\*  
nitrile, latex, or vinyl gloves that fit snugly   
quart-sized bubble wrap bags   
tape   
quart-sized resealable bag   
vegetable shortening   
ice water bath  
warm water bath   
balance (at least 300 g capacity)

\*An interface such as LabQuest is required if using STS-BTA

PROCEDURE

1. Launch Graphical Analysis. Connect the surface temperature sensor to your Chromebook, computer, or mobile device (use an interface if necessary).

2. Set up the data-collection mode.

1. Click or tap Mode to open Data Collection Settings.
2. Set end collection to 120 seconds.
3. Change the data-collection rate to 2 samples/second. Click or tap Done.

3. Tape the surface temperature sensor to the back of a group member’s hand. Place below the middle knuckle for best results.

4. Carefully put a nitrile glove on the subject’s hand, over the sensor. Make sure the sensor stays attached.

5. Place a quart-sized resealable bag over the gloved hand.

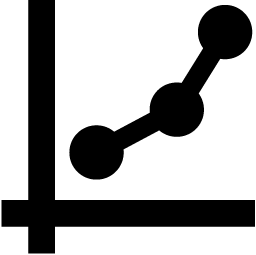
6. Click or tap Collect to start data collection.

7. After 10 seconds, have the subject submerge his or her hand into the ice bath. **Important**: Be careful not to get any water in the bag.

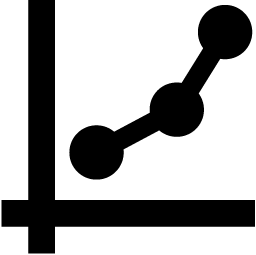
Keep the hand submerged for 90 seconds or until the temperature reaches 15.0°C. Remove earlier if painful.

8. After 90 seconds, have the subject remove his or her hand from the ice water, but keep the bag on. Once data collection stops (120 seconds), the subject can remove the bag.

9. Determine the rate of change for different intervals of time.

1. Select the portion of the graph that represents the initial expose to ice water (approximately 10–30 s).
2. Click or tap Graph Tools, ****, and choose Apply Curve Fit.
3. Select Linear as the curve fit. Click or tap Apply.
4. Record the slope, *m*, as the rate of change in the data table.
5. Dismiss the Curve Fit box.
6. Select the portion of the graph that represents continued exposure to ice water (approximately 30–90 s).
7. Repeat Steps b–e.
8. Select the portion of the graph that represents post-exposure to ice water (approximately 90–120 s).
9. Repeat Steps b–e.

10. Determine the change in temperature.

1. Click or tap Graph Tools, , and choose View Statistics.
2. Subtract the minimum temperature from the maximum temperature to calculate the change in temperature.
3. Record the change in temperature in the data table.
4. Dismiss the Statistics box.

11. Reinforce the edges of a bubble wrap bag with tape to prevent water from leaking in.

12. Have the subject put the gloved hand back into the resealable bag. Then, insert the gloved hand+resealable bag into the bubble wrap bag.

13. Allow the temperature to return to within 2°C of the starting temperature.

14. Repeat Steps 6–10. **Note**: The previous data set is automatically saved.

15. Remove both bags from the subject’s hand.

16. Dry the resealable bag and place the empty bag on a balance. Tare the balance. Add 125 g ± 5 g of shortening to the bag.

17. Seal the bag. Spread the shortening evenly inside the bag by smoothing your hand over the outside of the bag. Leave about 5 cm at the top of the bag clean.

18. Open the bag and place the gloved hand into the bag. From the outside of the bag, evenly spread the shortening over the hand. Make sure to cover the temperature sensor.

19. Repeat Steps 6–10.

20. Warm up the shortening in the bag in a warm water bath until the temperature returns to normal.

21. Place the bubble wrap bag over the bag with shortening and repeat Steps 6–10 to collect your last set of data.

Data TAble

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Insulator | Rate of change 10–30 s  (°C/s) | Rate of change 30–90 s  (°C/s) | Rate of change 90–120 s  (°C/s) | Change in temperature (°C) |
| None |  |  |  |  |
| Bubble wrap |  |  |  |  |
| Shortening |  |  |  |  |
| Shortening and bubble wrap |  |  |  |  |

QUESTIONS

1. Which insulator had the best performance? Why?

2. Why did your control (no insulator) include a bag and a glove? Do either of these have insulating properties?

3. In each trial, what happened to the rate of the temperature change after 20 seconds in ice water? Explain this in terms of energy transfer.

4. Compare the temperature change in each trial after the hand and bag were removed from the ice water bath.

5. Infrared cameras detect heat given off by objects. Polar bears do not show up well on infrared cameras. Explain how this observation relates to the results of this lab.

Extensions

1. Research how evolutionary processes have shaped adaptations in marine mammals, land mammals, and birds that live in extreme climates.

2. Pelagic birds, shorebirds and other birds that spend a significant amount of time in the water often have coated feathers. Research the origins and composition of these coatings, then try coating feathers in different substances and test their insulating properties.

ideas for inquiry

1. Alter the amount of insulation applied to the bag.

2. Test other types of lipids, such as lard.

3. Compare man made insulators such as polyester batting or fiberglass insulation to natural insulators such as wool.