The insulation bag: learning thermoregulation through a “hands-in” activity

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Submitted 4 October 2011; accepted in final form 13 November 2011

The extensive diversity of habitats to which animals have adapted necessitated the evolution of a number of different anatomic and behavioral mechanisms to tolerate the extremes in ambient temperatures to which these animals are exposed. Among these anatomic solutions to the seemingly compromising effects of extreme cold are the development of thick, subcutaneous blubber deposition, modified feathers, and extraordinary hair density (1). Huddling, hibernation, and burrowing are some examples of behavioral adaptations that help animals properly thermoregulate to maintain core body temperature (1). Understanding the contribution of thermoregulation to the maintenance of homeostasis can be effectively taught by a hands-on activity demonstrating the insulative properties of materials intended to emulate what animals have evolved (3). This activity compares the capacity of fat, feathers, and air to insulate the body from a cold environment. Conceptually, the activity addresses the following content objectives:

1. Animals that live in extreme environments have evolved adaptations to tolerate such environments, including extreme cold.
2. One of these adaptations is insulation, which effectively retains heat, even in cold air or water.
3. Both fat and air (feathers and fur) can serve as insulators. For example, seals and polar bears have developed a thick layer of fat, which reduces their heat loss. Other animals, such as birds and terrestrial and aquatic mammals, have developed an undercoat of fine feathers or hair, which traps air and reduces heat loss.
4. The human body does not have these adaptations, but people use protective clothing to serve the same purpose based on the same principles.

This activity is easily scalable and adaptable for high-flowthrough participation, such as at science festivals, at science fair events with exhibition tables/booths, or during classroom visits. This activity was developed and adapted for the American Physiological Society (APS) exhibition booth at the 2010 United States of America Science and Engineering Festival in Washington, DC. Approximately 2,500 participants (children and adults) experienced this along with a separate activity on cardiovascular function during the 2-day festival (2).

The activity uses common household materials, which facilitates its integration into classrooms at any grade level (Table 1).

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Gallon freezer-strength zipper-lock bags for mitts (can use quart size as long as hands can fit easily without stretching or tearing the bag)</td>
<td>6</td>
</tr>
<tr>
<td>Sandwich-size or 1-quart freezer-strength zipper-lock bags for “fat” layers</td>
<td>4</td>
</tr>
<tr>
<td>Vegetable shortening (to simulate fat)</td>
<td>8 cups (2 liters)</td>
</tr>
<tr>
<td>Roll of duct tape</td>
<td>1</td>
</tr>
<tr>
<td>19-Liter bucket/pail with handle (5 gallons)</td>
<td>1</td>
</tr>
<tr>
<td>Ice and cold water mixture</td>
<td>2.5 gallons (9.5 liters)</td>
</tr>
<tr>
<td>Large binder clips (to secure the “hand mitts”)</td>
<td>6</td>
</tr>
<tr>
<td>Towels (to keep the work area dry)</td>
<td>2</td>
</tr>
</tbody>
</table>

The zipper-lock bags are used to produce double-layered mitts that contain an insulating layer of bubble wrap (simulating feathers), vegetable shortening (simulating fat), or nothing (control). These three types of mitts are then placed in a bucket containing ice-cold water to simulate a cold environment. Participants then place their hands in the mitts to test the temperature difference among the three conditions, describing and commenting on the experience.

Preparing the “hand mitts.” In each of three experimental conditions (no insulation, simulated feathers, and simulated fat), a double-bag system is used. One zipper-lock bag is turned inside out and placed within a regular zipper-lock bag so that the zip strips are matched with each other to provide a seal (Fig. 1). After the zipper lock is closed, duct tape is used to secure the seal. In the case of the control condition (no insulation), this basic setup is all that is required.

For the mitt that simulates feathers, bubble wrap is rolled around the inner (inverted) zipper-lock bag twice to create a double layer of insulation and secured with tape. The inner bag is then inserted into the outer bag and sealed with the zipper lock and duct tape, similar to the control bag. The bubble wrap should fill the space between the inner and outer zipper-lock bags.

For the mitt that simulates fat, each of four sandwich-sized zipper-lock bags with is filled ~2 cups of vegetable shortening. Any excess air is then pushed out, and each bag is sealed with the zipper lock. Duct tape is used to secure the seal. Each bag of fat is flattened out to create a thin layer. Like the bubble wrap, these four “fat” bags are placed around the inner zipper-lock bag so that it provides a layer of insulation between the inner and outer...
zipper-lock bags. After the mitt has been assembled, the outer and inner bags are sealed using both the zipper lock and duct tape. Note that if you plan to use the “fat” mitt for >1 h in the cold water, you should make additional fat simulation mitts to rotate them in and out of the ice water (see below).

Preparing the experimental setup. Fill a 5-gallon bucket 1/3 full of ice and add water to half fill the bucket. Arrange the three mitts around the inside rim of the bucket and secure each bag to the bucket rim with binder clips. Label the clips “No Insulation,” “Feathers,” and “Fat,” respectively. Use clips to

Fig. 1. Making and using the test “mitts” for simulating insulation by feathers. A: invert a zipper-lock bag inside out for the inner bag. B: insert the bubble wrap in between the inner and outer bags. C: seal the zipper-lock strip lock with bubble wrap in the space between the two bags. (Not shown: seal the top edges with duct tape. For the “fat” mitts, use four bags with a layer of vegetable shortening instead of bubble wrap.) D: secure the model mitts to the sides and clamp them together in the middle in a bucket half filled with ice water. Students reach into a combination of mitts to compare and contrast the insulation provided by the simulated fat or feathers or no insulation. E: use the poster to provide visual cues for learning content. The prompting question and images of polar bears and birds engage participants and encourage active participation.
secure the mitts together in the middle of the bucket (Fig. 1D). Adjust the water level so that ~2/3 of the length of each mitt is immersed. Note that the fat mitts must be replaced after ~1 h as the fat becomes cold and no longer provides adequate insulation from the cold water. The ice in the water must be replenished as well if it is used over several hours. Pour off some of the water and refresh the bucket with additional ice. Do not allow the water level to become too high or it will leak into the mitts by the participants. Print out the “How do I keep warm?” poster and post it near the activity table (Fig. 1E).

Activity. The authors used this activity as part of a science festival booth and found that participants of all ages were quickly engaged and explored the three mitts. Young children were eager to put their hands in the mitts and observe how the effects of each mitt differed. Images of polar bears and birds provided visual cues for the students to compare and contrast the adaptations of these respective animals. The question prompt (“How do I keep warm?”) encouraged children to consider the ways that animals (i.e., geese, polar bears, sea otters, and penguins) maintain their temperature in cold weather. The instructors asked children whether humans could swim in icy waters or stand in cold winds. This led to discussions of how humans are not adapted for these climates but create their own insulation using clothing including coats, hats, masks, and gloves.

Participants were curious and eager to experience the mitts that simulated types of insulation and, subsequently, made comparisons in feeling the different materials for insulation. The discussions explored and described how animals that live in extreme environments have evolved structural adaptations to tolerate extreme ambient temperatures (both hot and cold). The discussions included highlights on adaptations to the environment as well as relevance to human physiology, thermoregulatory control, and maintenance of homeostasis. Participants interacted with the hands-on activity for ~5 min, either individually or in small groups, with three experimental setups (three buckets, each with a set of three testing mitts) on one table. Because the concept of thermoregulation could be discussed at various levels, instructors found it easy to adapt their discussions and questions to the age of the participants.

Summary. This hands-on activity was prepared with relative ease, quickly engaged participants of a wide range of ages, and captured their interest in addressing the poster question on thermoregulation. The experimental setups allowed participants to easily compare and contrast the insulatory capacity of each simulation. With this experiential context, discussions that were relevant to the core concepts of thermoregulation, homeostasis, and adaptation were easily facilitated by the instructor.

The easy setup and simple materials make this hands-on activity a good exercise for the K–12 classroom, especially one with limited laboratory resources. However, this activity could also be used as a demonstration in the college classroom to spark discussion and critical thinking about conductive heat loss or Fourier’s law of heat transfer. Alternatively, this activity could be used with slight modifications as a laboratory exercise to teach the fundamentals of heat loss. By placing a thermometer inside the bag to measure the change in skin surface temperature over time, students could monitor heat loss and calculate the rate. Students could also investigate the importance of insulation thickness by varying the amount of fat in the bag. Additionally, they could examine the role of the temperature gradient in heat loss by varying water temperature. Students could also explore the link between a habitat and insulation by wetting the insulatory materials and then comparing the rate of heat loss between wet and dry insulators. Finally, students could compare thermoconductivity values of different biological insulators (fat, wool, etc.) to predict the rate of heat loss and then compare it with experimental values using these materials.

ACKNOWLEDGMENTS

This activity was adapted and developed for the 2010 United States of America Science and Engineering Festival by the authors and other American Physiological Society members and staff, including Miranda Byse, TanYa Gwathmey, Mesia Moore Steed, and Clintoria Richards Williams.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS


REFERENCES