

# Unit 3: Fur, Feathers, Scales: Insulation

---

## ***Biology in a Box***

A science education outreach program brought to you by a partnership  
between The University of Tennessee and the National Institute for Mathematical and Biological Synthesis



Visit us on the web at <http://biologyinbox.utk.edu>

---

### **Biology in a Box Team**

**Program Director/Author/Lead Editor:** Dr. Susan E. Riechert (University of Tennessee)

**Science Collaborators:** Dr. Thomas C. Jones (East Tennessee State University), Dr. Stan Guffey (University of Tennessee)

**Mathematics Collaborators/Editors:** Dr. Suzanne Lenhart (NIMBioS), Kelly Sturner (NIMBioS), Lu Howard (University of Tennessee)

**Outreach Coordinator:** Dr. Lynn Champion (University of Tennessee)

**Workshop Coordinators:** Kathy DeWein (Austin Peay State University), Gale Stanley (Jacksboro Middle School)

**Production/Assistant Editor:** J.R. Jones (University of Tennessee)

**Previous Contributors:** Sarah Duncan, Communications (formerly with NIMBioS), Rachel Leander, Math Collaborator (formerly with NIMBioS)

*This unit revised September 2012*

---

Copyright 2012 by *Biology in a Box*, and the University of Tennessee. All materials in this unit and on the *Biology in a Box* web server ([BIOLOGYINABOX.UTK.EDU](http://BIOLOGYINABOX.UTK.EDU), [EEB.BIO.UTK.EDU/BIOLOGYINBOX](http://EEB.BIO.UTK.EDU/BIOLOGYINBOX)) may not be reproduced or stored in a retrieval system without prior written permission of the publisher, and in no case for profit.



### **Unit 3: Fur, Feathers, Scales: Insulation Materials List**

- Bag containing body coverings from 18 different animals, labeled 1-18
- Ruler
- Small sealed Petri dishes containing samples of mammal fur all taken from the same surface area (1 each of the following animals from Exercise 1: #1, #3, #4, #6, #7, #10, #13, #14, #15, #16, #18)
- Ice cube tray (prepare ice cubes in advance for Test 2c - fill to 1cm depth & freeze)
- Pail
- Stopwatch
- Dial thermometer
- Large and small zip lock bags
- Control mitt
- 7 Sample mitts (1 each of the following):
  - Aluminum
  - Sawdust
  - Cotton
  - Wool
  - Fur
  - Bubble wrap
  - Leather
- Body covering container samples:
  - Fluffed fur
  - Compressed fur
  - Oiled fur
  - Blubber
- Copper tube
- Exercise 3 container, holding:
  - Polished rock
  - Glass
  - Metal
  - Plexiglas
  - Rubber
  - Fabric
  - Linoleum
  - Wood
  - Dry erase board

# Unit 3: Fur, Feathers, Scales: Insulation

## Table of Contents

<b>Introduction</b> .....	<b>1</b>
<b>Exercise 1: Animal Covering Match</b> ( <i>Grades K and up</i> ).....	<b>4</b>
<i>Mathematics: Grouping like objects</i>	
<b>Exercise 2: Insulation Power</b> .....	<b>5</b>
<i>Mathematics: Measuring length with a ruler, measuring temperature with a thermometer, ranking measurements, forming a hypothesis, recording and plotting data</i>	
<i>Using a centimeter ruler: guidance for younger students</i> .....	5
<i>Calculating the mean (average): guidance for younger students</i> .....	7
Exercise 2a: Fur density and thickness ( <i>Grades 3 &amp; up</i> ).....	7
Exercise 2b: Feel Test .....	10
Exercise 2c: Melt Test.....	11
Exercise 2d: Insulating Mechanisms.....	12
<b>Exercise 3: Keeping Warm</b> ( <i>Grades 4 &amp; up</i> ).....	<b>15</b>
<i>Mathematics: Converting between °C, °F, and K, variables, providing qualitative descriptions of relations described by linear equations, deriving formulas</i>	
The Relationship Between Heat & Temperature .....	16
Thermal Conductivity.....	16
Exercise 3a: Relationship between Conductivity & Insulation.....	17
Exercise 3b: R-values ( <i>Open- ended Exploration</i> ) .....	18
<b>ANSWER SHEETS</b> .....	<b>20</b>
Introduction.....	20
Exercise 1: Animal Guide.....	21
Exercise 2: Insulation Power .....	29
Exercise 3: Keeping Warm.....	31
<b>SUGGESTED READING</b> .....	<b>35</b>
<b>LINKS</b> .....	<b>36</b>

## UNIT 3: FUR, FEATHERS, & SCALES: INSULATION



### Introduction

In this unit, you will examine the coverings of reptiles, birds and mammals, and also learn how some of these coverings protect, or **insulate** their owners from cold and hot temperatures. Animals and even plants generally need to keep their temperatures within a fairly narrow range in order to survive. The chemical reactions that do work in living organisms function best within a narrow range, and physical damage occurs if an individual becomes too hot or too cold. Many organisms have mechanisms to cool themselves down or to warm themselves up, but these processes require energy, and energy is expensive, as it requires the procurement and processing of food. Thus, mammals and birds have developed body coverings that insulate them from the outside, preventing them from gaining or losing too much heat.

Most of the skins in this trunk belong to **mammals**. Mice, cats, bears, kangaroos, dogs and humans are all mammals. Mammals, as well as birds, use energy to produce and maintain a constant internal body temperature. Organisms that maintain body temperatures through internal metabolism (generating body heat through the chemical breakdown of food) are known as **endotherms**. The prefix “endo” means “inside”, and “therm” means “temperature”. Mammals maintain body temperatures between 36 and 38°C or 97 and 101°F, while birds maintain even higher body temperatures (40-42 °C or 104-108° F). **Birds** use feathers to help them keep their bodies warm, while mammals use hair. Most mammals have hair all over their

bodies. We call this fur. On the other hand, **reptiles**, such as lizards or turtles, do not use internal energy to maintain a constant body temperature. Instead, reptiles' body temperatures depend on the temperatures of their environments. Organisms such as reptiles that must absorb heat from their surroundings to maintain body temperatures are known as ectotherms (the prefix “ecto” means “outside”). Reptiles can tolerate a broader temperature range than mammals and birds. However, their coverings do not function as insulators. Instead, their body coverings of scales mostly function to protect them against water loss (dehydration).

You should now easily be able to remember the differences between endotherms and ectotherms by thinking about what each word means, and by how particular organisms obtain/maintain body heat. You should preferentially use these more scientifically correct terms over the often-used terms “warm-blooded” and “cold-blooded”, which can be misleading. For example, the blood of desert reptiles (which most people might call “cold-blooded”) is often much warmer than the blood of the “warm-blooded” animals in the same environment!

The body coverings of mammals, birds, and reptiles are all made of the same material, keratin, a tough protein that does not dissolve in water (is insoluble). Keratin is thus a very versatile protein, in that it can take many forms in animals, such as fur, feathers, scales, horns, and nails and claws, which in turn serve many various functions, including insulation, waterproofing, and defense against predators.

The exercises in this unit are divided into three parts. **Exercise 1. Animal Covering Match**, introduces students to the varieties of fur, feathers, and scales seen in the higher vertebrates: reptiles, birds, and mammals. **Exercise 2. Insulation Power**, provides qualitative and quantitative exploration into the insulation properties of body coverings, and in **Exercise 3. Keeping Warm**, students will explore the principles of heat exchange.

**Q1.** Ultimately, the source of body heat energy in both ectotherms and endotherms is the same. What is this source, and how do ectotherms and endotherms use this energy differently?

## Exercise 1: Animal Covering Match

Look at the skins of the animals included in the trunk.

Examine them carefully and think about how they are similar and how they are different.

Sort the skins into three different groups according to those similarities and differences.

What characteristics did you use to group the skins?

- See if you can match each fur sample to the picture of the animal it has come from.
- Now match the rest of the samples to the pictures of the mammals they have come from.
- Each sample has a number attached to it. You can check your choices when you are finished by checking the numbers in the **Answers Section** at the end of this book **under Exercise 1**.
- Learn more about the animals and the functions of their coverings in **Exercise 1 Answers**, as well.
- Again examine the skins of the animals included in the trunk.

If they have hair, they are from **mammals**. If they have feathers, then they are from **birds**, and if they have rough or scaly skin without hair, they are from **reptiles**. Lizards, crocodiles, turtles, and snakes are all reptiles.

Reptile scales, bird feathers, and mammal hair are all made from the same substance called keratin (pronounced as kara – tin). A reptile's scales help it to save water and thus live on land. A covering of scales prevents **dehydration** (dee hi drey shun), or loss of water in dry air. However, scales do not help to keep the reptile's body warm. Thus turtles, snakes, and lizards live in warm places or else limit their outdoor activities to the warm seasons of the year.

## Exercise 2: Insulation Power

Fur, feathers, and scales are all made of the same material, keratin, yet it is not the material itself that helps to keep mammals and birds warm. After all, the keratinous scales that reptiles have all over their bodies (and that birds have on their legs) provide no insulation, while fur and feathers, which are also made of keratin, do help insulate their owners. Fur and feathers help the animals that wear them maintain healthy body temperatures by trapping still air. The **insulation power** of an animal's covering depends on the amount of still air that the material traps. Two factors determine the amount of air that is trapped in fur and feathers: the thickness of the layer and the density of the individual hairs or feathers (e.g., numbers of hairs/unit of surface area). A thick, dense layer of fur can trap more still air than a thin layer of fur with sparse hairs.

### Using a centimeter ruler: Guidance for younger students

- Place your ruler in front of you. It will look similar to the picture of the ruler below.



- If your ruler has inches marked on one side and centimeters marked on the other side, be sure you are using the centimeter side of your ruler.

The numbering on your ruler indicates lengths in centimeters, and most classroom rulers show numbering from 0 to 30, meaning you can use the ruler to measure a length up to 30 cm.

- Look closely at the numbering and the marks on the centimeter (cm) side of your ruler.

Lines are marked on the ruler to help you determine your measurement and you can see those lines are evenly spaced along the ruler. You will also see that those lines are of different lengths. The longest lines closest to the numbering indicate centimeters, but you will also see lines of shorter lengths between those longer lines. The lines that are only slightly shorter than the centimeter lines indicate the halfway point between centimeters, and the shortest lines indicate millimeters (mm). You can see that the millimeter



lines are very close together! The ruler you are using does not have millimeters numbered because the spaces are too small to write the numbering. The numbers you see on the ruler indicate centimeters. There are 10 millimeters in every centimeter.

- Look at the section of your ruler between the numbers 1 and 2.
- Beginning at the longer line at the number 1, count the number of those very small spaces indicated by the individual lines between number 1 and number 2.

Each one of those tiny spaces you counted has a length of one millimeter. Did you count 10 spaces? There are 10 spaces because the metric system is based on sets of 10. If you count the tiny spaces between any two numbers that are next to each other, you will count 10 tiny spaces.

- Practice measuring things on your desk using the centimeter ruler.
- Work with a partner and measure a textbook, a pencil, and a piece of paper, for example.
- Compare your measurements with your partner and see if you have the same measurements.
- Remember, there are 10 millimeters in every centimeter, and the numbers on the ruler indicate centimeters. If something measures at the “2” centimeter mark on the ruler, that means it measures 20 millimeters, because there are 10 millimeters in every centimeter!
- Now you are going to use your ruler to measure the thickness of the fur samples in millimeters.
- Remember that the smallest spaces on the ruler indicate millimeters. Millimeters are very small, so it will be important to measure as carefully as possible so you get an accurate measurement!

## **Calculating the mean (average): Guidance for younger students**

In these exercises, all of the groups will be ranking the density of fur samples, and each member of a group will also be measuring the thickness of a sample of fur. Since there may be some differences in rankings between groups, or in measurements of fur thickness among individuals in a group, it is more appropriate to calculate the **means**, or **averages**, of these numbers.

We want to end up with just one number to represent the density rank or thickness measurement of a fur sample, but you will have 2-4 ranks or measurements of density or thickness of the sample.

### **To find the average of a fur sample's density or thickness:**

- Add all the fur density ranks or fur thickness measurements together that your group members found, being sure to include all members' measurements.
- Divide the sum of the thickness measurements by the number of people in your group.
- Your quotient is the *mean*, or *average* for your sample.

## **Exercise 2a: Fur density and thickness**

Groups of 2-3 students should each be assigned a sample of fur, so that the density and thickness of fur of each type of mammal represented in the box will be measured.

Your group should observe each of the smaller samples of fur, which have all been obtained from the same surface area ( $19.63 \text{ mm}^2$ ), in the small sealed Petri dishes. Since counting individual hairs would be difficult, even for such a small area of fur, your group should visually rank each fur sample in order from most dense to least dense, assigning a rank of 1 to the most dense fur, and a rank of  $n$  (where  $n$  is the total number of fur samples) to the least dense. It may be helpful to do this via comparing only two samples at a time, deciding which fur is denser, then repeating the procedure until all fur samples are ranked in terms of density. It may also be helpful to place fur samples on a light or dark background for contrast, in order to be able to better see the individual hairs. You should take care to note density in terms

of number of hairs, and attempt to avoid being influenced by differences in *lengths* of the individual hairs. Report these values to your teacher. Each other group will also be ranking the fur samples in terms of density. Since there may be differences in how each group ranked the samples based on density, your teacher may provide you with average values for the density rankings for each fur type to be recorded in the table described later on.

Each member of your group should take a measurement of fur thickness, following the procedure below.

- First place the fur sample on a flat surface.
- Using a centimeter ruler, measure the depth (in mm) of fluff fur when the hair is brushed erect.
- The long guard hairs are used in keeping water out, and should not be counted as part of the insulation value of the fur.

Since each group member has taken these measurements, you should now have two to three values for fur thickness. It will now be necessary to average your values so that you can present one value for thickness of your fur sample to the class. Compute the mean value (average) from the 2-3 measurements your group made of fur thickness. The mean value refers to central tendency. The formula for calculating the mean for fur depth is:

*Mean fur depth* =  $\frac{\sum x}{n}$ , where the symbol sigma ( $\Sigma$ ) refers to a sum,  $x$  represents the individual measurements of fur depth, and  $n$  represents the number of members in your group. In other words, you should add up all of your group's individual measurements ( $x_1 + x_2 + x_3$ ), and divide this total by the number of members in your group. In doing so, you have calculated the mean, or average fur depth for your group's fur sample. For example: If there were three members in your group, and your measurements of fur thickness were 10 mm, 11 mm and 9.5 mm, *Mean fur depth* =  $\frac{10+11+9.5}{3} = \frac{30.5}{3} = 10.1\bar{6}$ , which can be rounded off to one significant digit, or 10.2 mm.

Make note of this mean value, then repeat this procedure to find your group's mean for fur density. Once all groups have obtained estimates of their fur samples' thickness and density, you should report these estimates to the class by filling in these data on a table similar to the one on the following page (but with one row for each fur type), which your teacher should place

on the board. Your teacher may also wish for you to copy down this table on a separate sheet of paper to turn in later.

Fur Type	Density Rank (DR)	Fur Thickness (mm)	Thickness Rank (TR)	Sum Rank (DR + TR)	Overall Rank

- After you have obtained each other groups' values for fur thickness, you should also rank the fur types in terms of thickness, assigning a value of 1 to the thickest fur (representing the best insulation power in terms of thickness), and a value of n (where n is the total number of fur samples) to the fur with the lowest value of thickness.
- You should now calculate the sum ranks for each fur type.
- This is accomplished by adding the rank for fur density to the rank for fur thickness for each mammal species.

The reason that you are doing this is because the thickest fur might not necessarily be the densest, and vice versa, but you are interested in the **overall** insulation power (which depends on both density **and** thickness) of each fur type.

- After obtaining these sum ranks, you can then assign an overall rank (again, from 1 to n, where 1 represents the best insulation power, and n represents the worst).
- The overall rank is simply obtained by ranking the sum ranks from 1 to n, from lowest to highest values.

This ranking can be used as one index of insulation power. Consult the **Animal Guide sheets, under Answers to Exercise 1**, in order to discover the relationship between an animal's environment and the insulation power of its covering.

**Q1.** One might expect that individuals living in the coldest environments would have the thickest fur and thus the greatest ability to trap still air.

What would be a reason for this not being the case? Check **Q1 on the Answer Sheet for Exercise 2.**

The following three experiments (**2b: Feel Test, 2c: Melt Test, and 2d: Insulating Mechanisms**) will help you to further understand the phenomenon of insulation power.

**Materials needed for experiments 2b and 2c:**

*Ice cubes*

*Hot tap water*

Pail

Small and large zip lock bags

**“Feel Test” container**

Stopwatch

Control mitt (double plastic bag)

Treatment mitts (materials trapped between two plastic bags):

cotton, bubble wrap, wool, sawdust, aluminum foil, rabbit fur, leather

**Exercise 2b: Feel Test.** This is a qualitative test that relies on an individual’s judgment and memory using the sense of feel.

- Fill the pail with ice water.
- Insert your hand into the control mitt. **NOTE: You do not have to insert your entire hand fully into the mitt. If there is not sufficient room for larger hands, insert only your fingers (excluding your thumb) as far as they will go without stretching/damaging the mitt!**
- Extend your hand inserted in the mitt into the ice water, taking care not to let water come in through the top of either bag that makes up the mitt.
- Repeat the experiment with the other coverings available.
- Make a ranked list on the blackboard or on a sheet of paper of the coverings from those that kept your hand most warm (1 = best insulation power) to those that did little to protect you from the cold.

**Exercise 2c: Melt Test.** This test relies less on individual judgment, and not at all on memory. While still qualitative because it relies on some judgment, it should provide a more accurate estimate of the relative insulation power of the various materials tested.

***\*\*The day before completing this experiment, fill the ice cube tray to the 1 cm mark indicated and place in freezer.***

- Fill the pail with hot tap water.
- Place an ice cube in the small zip lock bag. Zip this bag shut and insert it into the control mitt.
- Seal the mitt in the large zip lock bag and lay the bag in the hot water.
- Using a stopwatch, check the bag at 5-minute intervals to see how long it takes for the ice cube to melt. (Or, you might instead estimate how much of the ice cube remains after some interval, for example 10 minutes).
- Repeat this experiment for materials that were at the middle, top, and low ends of your insulation rankings from **Experiment 2b: Feel Test.**
- Rank the materials according to their insulation power from the best insulator to the worst.
- Answer the following questions and check your answers under Exercise 2b & 2c

**Q2.** How did your ranks compare between the Feel (**Exercise 2b**) and Melt tests (**Exercise 2c**)? If they differed, which would be the more accurate ranking of materials and why?

**Q3.** What is it about the different materials that made them better or worse insulators?

**Q4.** What is a potential problem with the Melt Test experiment?

**Q5.** Where else in our lives do we see insulation?

### **Exercise 2d: Insulating Mechanisms**

#### Materials

Ice water

Water at room temperature

Pail

Stopwatch (from “Feel Test” container)

#### **“Insulating Mechanisms” container:**

Copper cylinder

Dial thermometer

Zip lock bags

Body covering sample containers

Fat (blubber) sample container

- Run your hand against the fur on the skins. Notice how the fur stands up making the layer of fur thicker. Mammals and birds react to unfavorable temperatures by raising or erecting their fur or feathers.

For the fur samples in the “Insulating Mechanisms” container, you will find:

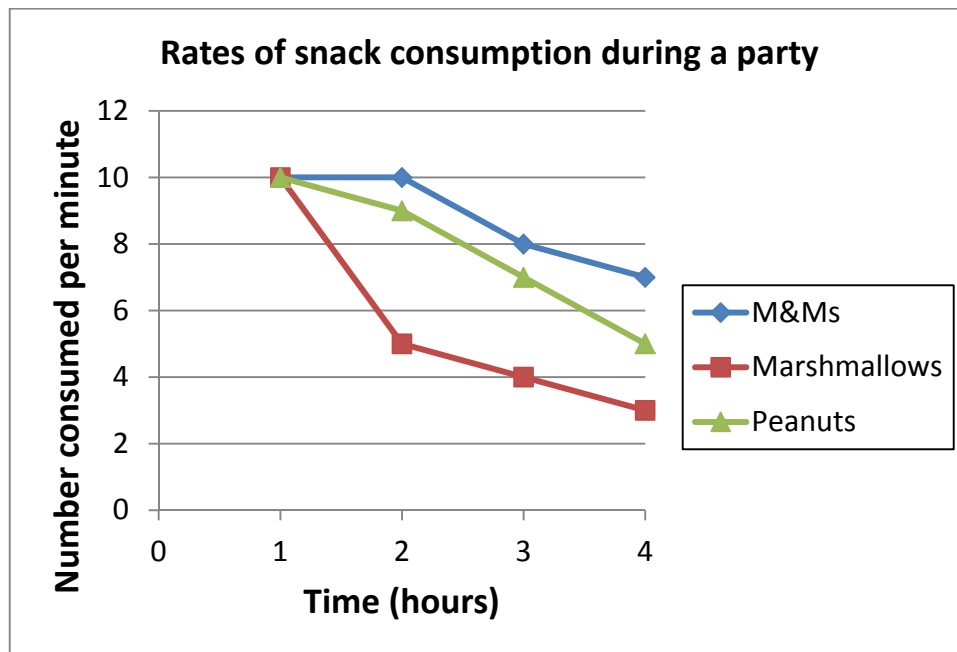
1. Loosely packed fur in a round plastic container that corresponds to erect fur on a mammal
  2. Fur that is more tightly compressed in a container corresponding to non-erect fur
  3. Fur that has been oiled as would happen in an oil spill.
- Fill the copper tube with warm water at human body temperature 37 ° C (Celsius) or 98.6 ° F (Fahrenheit). Insert the thermometer in the top of the tube to insure that you have achieved this temperature.
  - Keeping the thermometer within the copper tube, insert the tube into one of the sample containers: fluffed fur, compressed fur, oiled fur or blubber.

- Insert the cylinder in ice water and measure water temperature within the cylinder at 5 minutes, 10 minutes and 15 minutes. Record your results in a chart.
- Repeat for all three samples of the covering, replacing the water in the copper tube between trials.
- Plot your data for all three fur samples on the same graph. Table 2.1 and Figure 2.1 provide an example of a data chart and plot.

**Table 2.1. Example of data chart**  
**Rates of Snack Consumption during a Party**

Hour	M&Ms consumed per minute	Marshmallows consumed per minute	Peanuts consumed per minute
1	10	10	10
2	10	5	9
3	8	4	7
4	7	3	5

**Fig. 2.1 Example Line Plot: Data from Table 2.1**





- Answer the following questions, based on the temperature data you collected using each of the three fur samples (fluffed, compressed, & oiled).

**Q6.** Which sample provided the best insulation?

**Q7.** Which sample provided the least insulation?

**Q8.** Which samples were most similar, and why is this the case?

**Q9.** Why are oil spills so dangerous to mammals and birds that are exposed to the oil?

**Q10.** Why do humans get ‘goose bumps’ when we feel cold? See **answer sheet for Exercise 2.**

- Examine some of your furs again. Note that some samples have two types of fur present, longer **outer guard hairs** and underlying **fluff**. The guard hairs protect the underlying fluff from getting wet and it is the fluff fur that provides the best insulation.
- Examine a feather. Note that part of the feather is equivalent to fluff fur. In addition to providing lift for flight, the long part of the feather guards the down (fluff) at the base from getting wet. In some water birds, the feathers even hook together to provide greater protection from water.
- Establish a temperature curve for the blubber sample. This too is a good insulator, and mammals that live in the water, particularly in cold regions, utilize blubber (a fat layer) for insulation.
- Answer the following questions:

**Q11.** Why do mammals in cold waters utilize a blubber layer for insulation?

**Q12.** If blubber is such a great insulation, why do not all mammals use it?

### Exercise 3: Keeping Warm

Under **Exercise 2 Insulation Power**, you investigated how feathers, fur, and even blubber help animals to maintain a constant body temperature. In this exercise, you will explore the phenomenon of temperature.

#### **Temperature:**

If you place your hand against your forehead, it feels warm. If you place your hand on your desktop, it feels cool. We can express this fact by saying that the ‘temperature’ of your skin is greater than the temperature of your desk. We can even confirm this fact by measuring the temperature of these two objects with a thermometer. But what *is* temperature exactly?

**The temperature of an object is a measure of how fast the molecules within the object are randomly moving about** and bumping into one another. The surface of your desk may appear to be still, but in fact, the individual molecules that make up its surface are always in motion. The faster an object’s molecules move on average, the greater the object’s temperature.

Temperature in scientific studies is measured in degrees Kelvin (K) or the closely related degrees Celsius (°C). In the United States, we also express temperature in degrees Fahrenheit (°F).

The quantitative relationships among these temperature measures are as follows:

$$K = ^\circ C + 273.15$$

$$^\circ C = K - 273.15,$$

&

$$^\circ F = \frac{9}{5} ^\circ C + 32,$$

where Zero Kelvin (0 K) is the temperature at which an object’s molecules cease to move, also known as **absolute zero**.

- **Using the above relationships, answer the following questions.**

**Q1.** Which temperature is warmer, 0°C or 20°F?

**Q2.** If  $x$  is a real number, then  $x^{\circ}\text{F} > x^{\circ}\text{C}$ . Explain why.

**Q3.** Find the formula to convert  $^{\circ}\text{F}$  to  $^{\circ}\text{C}$ .

**Q4.** Convert  $18^{\circ}\text{C}$  to K.

### **The Relationship Between Heat and Temperature:**

**Heat** is a form of energy sometimes called thermal energy. The amount of heat in an object determines its temperature. The greater the heat contained in the object, the greater the temperature. For example, a gallon of warm water from the Caribbean Sea contains more thermal energy than a gallon of ice cold water from the Baltic Sea.

**Heat always flows from regions of higher temperature to regions of lower temperature.** If we mix a gallon of warm water and a gallon of cold water together in a large bucket, heat will flow out of the warm water and into the cold water. In this way, all of the water in the bucket will eventually have the same temperature.

Heat energy is measured in joules (J), or calories (cal) where  $1 \text{ cal} = 4.18 \text{ J}$ .

### **Thermal Conductivity:**

The last quantity we will consider is **thermal conductivity**, a measure of how easily heat flows through a material. Heat flows very easily through some materials, such as metals and rocks, while other materials, such as air, allow very little heat to flow through them. We can express this fact by saying that metals have greater thermal conductivity than air. If your text book feels cool to the touch, then you know that its temperature is lower than that of your hand. Your fingertips, however, are not sensitive enough to determine the average speed at which the text book's molecules move (i.e. the temperature of the text book). Instead, your fingertips sense the rate at which heat energy flows out of your body and into the book. (Recall that heat flows from higher temperatures to lower temperatures.) This means that an object with very low thermal conductivity could be very hot, perhaps thousands of degrees Celsius, and yet feel comfortable to touch. For example, the conductivity of the **high-temperature reusable surface tile** used to protect the orbiter space shuttle is so low that you can comfortably

hold a tile in your hand only seconds after it is removed from a 2,300°F oven, while it continues to glow red.

The thermal conductivity of an object is usually denoted by  $k$ . Thermal conductivity is measured in Watts per meter Kelvin ( $\frac{W}{mK}$ ), where  $1W = \frac{1J}{sec}$ .

### Exercise 3a: Relationship between Conductivity & Insulation

- Examine the table below, which displays the conductivities of several materials in W/mK.

Material	Conductivity (W/mK)
Water	0.600
Soil	1.500
Rock	4.000
Air	0.025
Blubber	0.140
Deer: 1 hair	0.260
Deer fur	0.091
Copper	401.000

Gates, D.M. and R.B. Schmerl, editors. 1975. Perspectives in Biophysical Ecology. Ecological Studies: Analysis and Synthesis, volume 12. New York: Springer-Verlag, p.53.

- Find the bag labeled Exercise 3 in the trunk. All of the items in the trunk will be at the same temperature. Place your hand on each item to see how cool it feels, and then use this observation to rank the items from most thermally conductive to least thermally conductive.
- Find additional items in your room that have been allowed to equilibrate to room temperature (e.g., a glass of water, a book).
- Use the table provided and Google to check your rankings. You might wish to retest those materials that you first misplaced.
- Answer the following questions.

**Q5.** Which material listed in the table is most conductive, and which is the least conductive?

**Q6.** Which material is the best insulator? Which material is the worst insulator?

**Q7.** What is the relationship between a material's thermal conductivity and its ability to insulate?

**Q8.** Why do snakes move out onto paved roads and lie on them at night?

**Q9.** Which cools you down more on a hot sunny day: sitting in front of a fan or taking a dip in a swimming pool? Why?

**Q10.** Why does deer fur have such low conductivity, when compared to a single deer hair?

**Q11.** Since reptile scales are made of the same material as fur, why is fur a good insulator, while reptile scales are a poor insulator?

### **Exercise 3b: R-values**

#### *Open-ended Exploration*

R-values are used in home and industrial insulation applications. They are based on material conductivity and the laws that govern heat exchange. Animal body coverings follow the same rules.

- As individuals or teams, research the topic of insulation as it relates to R-values outside of class, and learn how they are calculated.
- Apply your knowledge to answering the following questions.

**Q12.** If the temperature outside a home is less than the temperature inside a home, will heat flow into the home or out of the home?

**Q13.** How does the rate at which heat flows through the wall change as the thickness of the wall increases?

**Q14.** If you were to compare the fur of a snowshoe hare in winter to that of a snowshoe hare in the summer, how would you expect these two coats to differ? Which coat would be the thickest? Which coat would be the densest?

**Q15.** If the outside temperature is  $-5^{\circ}\text{C}$  and the internal temperature of a hare is  $99^{\circ}\text{F}$ , does heat flow into or out of the hare's body? What if the hare

is in the desert, and the outside temperature is 40°C? (Be careful with your units!)

**Q16.** What is the heat loss through a 1m square window on a home, if the outside air temperature is 15°C, the inside temperature is 25°C, and the R-value of the window is  $2 \frac{Km^2}{W}$ ? (Be careful with your units!)

## Unit 3: Fur, Feathers, Scales: Insulation ANSWER SHEETS

### Introduction

**Q1. Ultimately, the source of body heat energy in both ectotherms and endotherms is the same. What is this source, and how do ectotherms and endotherms use this energy differently?**

All body heat in both endotherms and ectotherms has the sun as its ultimate source. **Radiation** is the process of energy transfer from the sun via electromagnetic waves. When electromagnetic waves are absorbed by a surface, this causes the molecules in that object to vibrate more quickly, thereby increasing the object's temperature. In this manner, electromagnetic energy is converted to heat energy. Metabolism of food releases heat energy. Plants convert light (electromagnetic energy) into chemical energy, in the form of sugars and stored starches produced in photosynthesis. When an endothermic herbivore eats a plant, the plant material is metabolized (broken down chemically) during digestion. Through this process, the chemical energy in the plant material is converted to other forms of chemical energy that are usable by the animal, and some is converted to fat for energy storage. Some heat energy is released during this process, as well, but is constantly lost to the environment. When a carnivore eats an herbivore, the transfer and conversion of energy from their food is the same as it is in herbivores.

Endotherms regulate and maintain their body temperatures to make up for the heat energy that they lose to the environment by internally modifying their metabolic rates (for example, how quickly they burn fats and sugars). Ectotherms are unable to internally adjust their metabolic rates as are endotherms, as their metabolic rates are dependent on the temperature of their surroundings. However, ectotherms **can** regulate their metabolic rates externally via their behavior, such as by basking, or situating themselves in the sunlight, thus increasing their body temperatures via radiation from the sun, and by **conduction**, or the transfer of heat energy from a warmer surface to their bodies.

## Exercise 1. Answers: Animal Guide

### 1. Mammal: Striped Skunk (*Mephitis mephitis*)



Skunks are in the family Mephitidae, which contains 10 species of skunks in North and South America, as well as two species of stink badgers in southeast Asia. Despite the fact that skunks are members of the mammal order Carnivora, they have a very broad

omnivorous diet. Striped skunks are easily recognized by their characteristic colors and pattern. The fur is black with a white stripe that begins as a triangular shape on the top of the head, forks into two stripes that travel down the sides of the back, and usually merges again near the base of the tail. Another white stripe runs from the base of the snout between the eyes and ends on the forehead. Stripe width and length vary with each individual. Stripes sometimes occur on the tail, but more often the tail is composed of both black and white hairs intermixed. *Mephitis mephitis* is about the size of a domestic cat, with a small head, small ears, short legs, and a long, fluffy tail. Striped skunk fur is not very dense or layered. This reflects the fact that they stay down in burrows during the winter months. Females often remain in their winter dens for the entire duration, but males usually emerge during mild temperature periods to feed.

### 2. Bird: Ring-necked Pheasant (*Phasianus colchicus*)



The ring-necked pheasant is native to Asia, but was introduced to the US for hunting. It is a chicken-like bird with a striking tapered, pointed tail, which may be twenty-one inches long in males. Males are very colorful, with iridescent green-blue or purple heads and necks. Long, iridescent feathers along the sides of the head form a double crest. These “ear feathers” are raised when a male is courting a female. A white collar around the neck gives the species its name.



### 3. Mammal: Rabbit (*Sylvilagus sp.*)



The order Lagomorpha consists of rabbits, hares, and pikas. Once included in the order Rodentia, the differences found in lagomorphs earned them an order of their own. Rabbits differ from rodents in that rabbits have two sets of upper incisors, rather than one. Rabbits also have spongy intertwined bone lining their upper jaws that is believed to aid in heat dispersal when the

animals are running. Rabbits and hares are fast and evasive, and have large hind limbs suited for leaping great distances. Many have large ears that alert them to predator threats. The cottontail rabbit is active throughout the winter, and thus has a thick coat of fur.

### 4. Mammal: Buffalo/American Bison (*Bison bison*)



Buffalo, deer, and goats belong to the Order Artiodactyla, or even-toed mammals. Their family, Bovidae, has 138 species of antelope, cattle, bison, buffalo, goats, and sheep. They are some of the world's largest land animals, and comprise much of the diets of many of the large carnivores of the world. Artiodactyls are sometimes called cloven-hoofed, because their hooves appear to be split into two parts. Actually, these two parts of the hoof are made up of the fused third and fourth toes of each foot. The horns that protrude from the head are

permanent and continue to grow throughout the animal's lifetime. Horns are grown by all adult bovid males and by females of most genera. A horn is composed of a bony core that is covered with a hard sheath of horny material called "keratin". Your fingernails and hair are also made of keratin, as are fur, feathers, and scales. The bison is adapted to withstand cold winters and hot summers. It grows a dark shaggy coat of hairs which is shed each spring and replaced with a shorter and lighter-colored summer coat of hairs.

### 5. Reptile: Rattlesnake (*Crotalus sp.* or *Sistrurus sp.*)



The rattlesnake is an ectotherm, an animal that must absorb heat from its surroundings. Ectotherms often require long periods of basking in the sun to keep warm. It is a member of the viper family (Viperidae), which contains over 220 species of venomous snakes, including more than 30 species of rattlesnakes. Many rattlesnakes

in the genus *Crotalus* are large, and can reach over 2 m in length and 12 cm in diameter. However, the genus *Sistrurus* (3 species of pygmy rattlesnakes) only reaches a maximum of around 80 cm in length. The earliest North American snakes in this family evolved about 5 million years ago. Rattlesnakes are most abundant in dry areas in the desert southwest US, though they are found throughout North and South America, from Canada to Argentina. In the winter, rattlesnakes congregate in dens (sometimes up to as many as 200 snakes!) to keep warm. This snake is covered with scales which help prevent desiccation (drying) and aid the animal in moving. When a snake creeps forward like an earthworm or climbs a tree, the scales on its stomach provide traction.

### 6. Mammal: Black Bear (*Ursus americanus*)



The eight species of bears of the world all belong to the family Ursidae. These large mammals occur in a variety of habitats, ranging from arctic ice floes to tropical rain forests. All species except the polar bear go through a period of deep sleep, known as hibernation, during winter. All bears are in the mammalian order Carnivora. However, nearly all bears are highly omnivorous (eat both plant and animal matter), with the exceptions of the almost

exclusively carnivorous polar bear and the herbivorous panda. Not all black bears have black fur. Some have rusty brown or gray and black coats. Notice that the black bear's fur is not as thick as the fur of mink and weasels that are active all winter. Bears accumulate a lot of fat under their skin during the summer months. This fat helps to keep them warm while they sleep through the winter in a cave or hollow tree.

## 7. Mammal: Coyote (*Canis latrans*)



The family Canidae is comprised of the thirty-three species of wild dogs found throughout the world, as well as domestic dogs, which represent numerous breeds of a single species. They range from small foxes, coyotes, and jackals to large wolves and wild dogs, such as the dingo of Australia. Species may inhabit all habitats, from hot deserts to arctic ice fields. This piece of fur is from a coyote, the most widespread wild canid in North America. Although domestic dogs are more abundant, coyotes are the most widespread **wild** canid in North America. Their success is due in part to the fact that body size, fur color, and constitution are adjusted to the environment in which they live. Desert coyotes are only half the size of their mountain counterparts, and their fur is much lighter in color. Coyote populations at high elevations have fur that is thicker and longer. In the winter, coyotes and other canids produce an undercoat of fluff and retain the outer coat of longer hair (guard hairs). The fluff adds excellent insulation. The fiberglass insulation we put in our walls and ceilings is modeled after canid fluff fur.

## 8. Reptile: American Alligator (*Alligator mississippiensis*)



Alligators are in the family Alligatoridae, in the reptile order Crocodylia. The order Crocodylia contains 23 species of extant (currently living) crocodylians, but only eight species are in the family Alligatoridae (the American and Chinese alligators, and several species of caimans). Adult male alligators typically reach about 13-15 feet in length, although females are usually smaller (around 10 feet). Adult males can weigh up to around 1000 pounds. The armor-plated appearance of crocodylians' backs is due to the presence of bony plates, called osteoderms, beneath the skin. Though these are great for protection, they don't really do much in the way of insulation! With such a large size and no fur or feathers to help them keep warm, these animals must live in warm climates. However, even in their range, winters can sometimes be chilly. During this time, alligators hibernate in burrows



that they excavate with their snouts and tails. Interestingly, however, alligators can survive freezing conditions if they are in water by keeping only their nostrils above the surface. If they get trapped below ice, however, they can survive for over 8 hours, because, being ectotherms, their metabolism is drastically slowed by the icy water.

**9. Bird: Macaw (*Ara sp.*) and/or Peacock (*Pavo cristatus*)**



The brightly colored feathers were collected from macaws, some of the most striking of the parrots. In their rainforest habitat, the bright coloration permits mates to find each other. In addition, these highly social, flock-living birds are very vocal. As a flock flies through the forest canopy early in the

morning, it is very difficult to sleep through the loud squawking. The long feathers are flight feathers and the smaller feathers cover the body. You might also have a section of the 3-foot long tail feather of a male peacock, an oriental bird that displays its fan of tail feathers when courting females. Female peacocks select males that have the most striking displays as mates. The huge, highly colored tail of the male, however, also attracts predators, which could cost the male injury and even death.

**10. Mammal: sheep (*Ovis aries*)**



Sheep are in the order Artiodactyla, also known as even-toed ungulates. The family Bovidae has 138 species of antelope, cattle, bison, buffalo, goats, and sheep. Sheep (and many other even-toed ungulates, like cattle) are called ruminants. These types of animals have a four-chambered stomach. After chewing plant matter and passing it into the first stomach chamber (the rumen), ruminants regurgitate this partially digested “cud” to chew it again.

Though this sounds pretty gross, this is an adaptation for efficiently processing tough grasses and shrubs that would otherwise be quite difficult to digest! Most sheep have a long-haired and matted coat, which reflect their adaptation to cold, wet climates. A soft undercoat called fleece keeps

sheep warm, and has also been used in production of wool garments (that keep us warm when wet or dry, too!) by humans for around 10,000 years!

**11. Bird: Wild Turkey (*Meleagris gallopavo*)**



Turkeys are members of the order Galliformes, and thus are close relatives of the pheasants. Wild turkeys are native to North America. This is the largest bird on the forest floor in the US, and has a lifespan of 10 years. A turkey can be distinguished by its large size and fleshy wattle (‘snood’) that hangs down from its beak. Even though they are somewhat clumsy-looking, wild turkeys are quite capable of flight, and can achieve speeds in excess of 55 mph in short

bursts! Wild turkeys do not migrate from North America to South America for the winter, and rely on their thick coats of feathers, as well as a layer of fat, built up in the fall from eating acorns and hickory nuts, to keep warm.

**12. Bird Foot**



Bird feet are not feathered, but rather covered with scales that are reptilian in nature. Birds can shut off the blood flow to their legs during periods of cold temperatures. Because the scales do not provide insulation against temperature extremes, the birds would lose too much heat through the exposed leg surface if blood were to flow there

during such periods. The foot you have in your box belonged to a turkey, a goose, or a duck. The turkey is the most terrestrial (lives on land) of the three species, and the duck is the most aquatic (lives on water). Can you determine which species you have in your box?

**13. Mammal: Mink (*Mustela vison*)**



The family Mustelidae includes the sixty-five species of weasels, mink, ermine, badgers, skunks, and otters. It also includes the world's smallest carnivore (animal eater) – the American least weasel. Weasels, ermine, minks,

and otters are mainly found in cold environments, and thus have soft, thick fur. They also have an oily outer layer of fur that repels water, because they live near rivers, streams, lakes, coastlines, and marshes. When the ice freezes on a lake or river in the winter, the mink seek open water and may also tunnel in the snow. Thus, in the winter these animals also grow long guard hairs that form a waterproof layer. This additional fur layer helps to keep them warm and dry when swimming in icy waters. Another characteristic of the fur of many weasels is that in the northern part of their range, the animals shed or molt the brown fur and it is replaced with a white coat during the winter.

**14. Mammal: deer (*Odocoileus virginianus*)**



There are 45 species of deer in the family Cervidae, a family in the order Artiodactyla (which also includes sheep, goats, camels, llamas, pigs, giraffes, and other even-toed ungulates). Deer are fast moving, slender-bodied plant feeders who primarily browse on trees, and to a lesser extent, graze on grass. Deer are thus both browsers and grazers. Male deer use their antlers in fights with other males over females. In the

summer, the deer has red-brown fur, which changes to gray-brown during the winter. The throat and underparts of the deer fur are white, with white bands also extending across the muzzle. Deer have fur of medium thickness, and can do well in both hot and cold climates. The characteristic tail of the white-tailed deer is long with white underneath. It is best seen during flight from a potential predator. The white tail is thought to aid in keeping group members together in covered areas, but also serves to attract predators to the rear end of the body, giving it a chance to escape predation.

**15. Mammal: Virginia Opossum (*Didelphis virginiana*)**



The opossum is North America's only marsupial. It is nocturnal, and highly omnivorous, scavenging both plant and animal matter. Opossums have a heavyset body that resembles a large house cat. They have a long head with a pointed snout. Their faces have long whiskers. All opossums have long, furless



tapered tails with a scaly appearance. Females have a fur-lined pouch to carry their young. The color of the opossum varies by the region. Northern populations have thick under fur that is white in color and has black tips. The pale guard hairs give the opossum a gray appearance. Opossums are found in a variety of environments, ranging from relatively arid (dry) to mesic (moderately wet).

**16: Mammal: Kangaroo (*Macropus sp.*)**



Kangaroo means “I don’t understand what you said” in the language of the Australian Aborigines. Apparently an explorer asked a native Australian what the strange beast with the big feet and long tail was, and the Aborigine did not understand what the person was asking. Roos are close relatives of the opossum, as both are marsupials: the young are born at an early stage of development and complete their development within a marsupial pouch. If you were to look at a strand of opossum fur and a strand of kangaroo fur you would see that they are very similar in structure. Note how soft each is. There are 47 species of kangaroo. These are all herbivores (plant-eaters) in that they eat grass, leaves, and roots. Roos swallow their food without chewing it, and later regurgitate a cud and chew it, as do cows. Roos can go for months without drinking water. Their nocturnal habit (active at night) lessens the need for water to cool the animal in the hot Australian environment. Kangaroos are found only in Australia, New Guinea and neighboring islands. Roos also do not need layered fur for warmth. Though the countries in which they live do have snowy areas in the winter, roos tend to stay in the warmer, northern regions of these places, where the winters are relatively mild.

**17. Bird: Canada Goose (*Branta canadensis*)**



The Canada goose is a common North American goose that can be seen on Tennessee waterways, particularly in the fall and winter as flocks move down from summer feeding grounds in the northern US. It makes a loud, honking sound. This plant feeder has gray wing feathers and a lighter gray breast. A predator would have difficulty seeing this bird as it rests on the water. Note that the breast color of many mammals and

aquatic birds is often white, or at least not strongly colored. It costs energy to produce the pigments that give keratin color. The surface of the animal that is not exposed to predators typically lacks pigmentation (color is not selected for).

### **18. Mammal: Goat (Family Bovidae, Subfamily Caprinae)**



Goats belong to the order Artiodactyla (even-toed ungulates), and the family Bovidae. Artiodactyls are sometimes called cloven-hooved animals, because their weight is supported by two main toes on each foot. The subfamily Caprinae contains 35 species of goats, sheep, ibexes, antelopes, and their relatives, including the domestic goat (a single species with over 210 different breeds!). Goats can be found in many climates, including deserts and cool mountainous regions. Domestic goats may be selectively bred for one of several

purposes: dairy use, fiber (fur), goatskin, meat, or as companions. Based on the fur sample you have, from what kind of climate do you think the goat represented by your sample came, or for what purpose do you think it was bred? A goat's hair turns grayer and eventually white as it ages, just as it does in humans. Why does hair turn gray as an individual ages?

---

### **Exercise 2: Insulation Power Answers**

**Q1. One might expect that individuals living in the coldest environments will have the thickest fur and thus the greatest ability to trap still air.**

**What would be a reason for this not being the case?**

Many animals that live in cold environments shed their warm fur coats during the summer months, when not as much insulation is needed. Some of the fur samples may have been collected from animals possessing their summer coats. Also, the thickness and density of an animal's fur may vary on different parts of its body, as different body regions may require more or less insulation. Fur samples may have been collected from different areas of the animals' bodies.



**Q2. How did your ranks compare between the Feel (Exercise 2b) and Melt tests (Exercise 2c)? If they differed, which would be the more accurate ranking of materials and why?**

The ranking based on the degree of ice cube melt would be the least subjective (least influenced by human perceptual bias and memory). Thus the ice melt test would provide the more accurate ranking of material insulation powers.

**Q3. What is it about the different materials that made them better or worse insulators?**

The best insulators should provide for the most room for still air.

**Q4. What is a potential problem with the Melt Test experiment?**

The materials were not all equally thick or dense. It was, for instance, easier to pack in more sawdust in the space provided than wool.

**Q5. Where else in our lives do we see insulation?**

We insulate the floors, walls, and ceilings in our homes. Our jackets, gloves, earmuffs, hats, and boots often have insulation. Sleeping bags and quilts have insulation. Stoves and refrigerators have insulation as well, as do coolers, which we use to keep food and drink cold on camping trips and such. There is a wall of insulation between the engine of a car and the passenger compartment. Remember, insulation can protect from both heat and cold, and in the case of human use, even sound.

**Q6. Which sample provided the best insulation?**

Fluffed fur

**Q7. Which sample provided the least insulation?**

Oiled fur

**Q8. Which samples were most similar, and why is this the case?**

Compressed and wet, because in oiling fur, we are compressing it, which makes it hold less still air.

**Q9. Why are oil spills so dangerous to mammals and birds that are exposed to the oil?**

Oil compresses fur so that it loses its insulation power. As a result, oiled animals have difficulty maintaining body temperature.

**Q10. Why do humans get ‘goose bumps’ when we feel cold?**

Humans have the same hair erecting mechanism that is characteristic of mammals that have fur (fur is merely hair that is more dense than that of humans).

**Q11. Why do mammals in cold waters utilize a blubber layer for insulation?**

The fur of many aquatic mammals does not provide good insulating power, as it is wet much of the time.

**Q12. If blubber is such a great insulation, why do not all mammals use it?**

Blubber or fat is problematic for two reasons. 1) Unlike fur, it cannot be shed during the summer when temperatures are warmer. 2) A fat layer is not dependable, as it is metabolized (broken down) when the body needs energy to do work.

**Exercise 3: Keeping Warm Answers**

**Q1. Which temperature is warmer, 0°C, or 20°F?**

0°C is warmer. Since  $^{\circ}F = \frac{9}{5}x^{\circ}C + 32$ ,  $0^{\circ}C = 32^{\circ}F$ !

**Q2. If  $x$  is a real number, then  $x^{\circ}F > x^{\circ}C$ . Show why.**

$$x^{\circ}F = \frac{9}{5}x^{\circ}C + 32 > x^{\circ}C.$$

**Q3. Find the formula to convert °F to °C.**

$$^{\circ}F = \frac{9}{5}^{\circ}C + 32 \rightarrow$$

$$^{\circ}F - 32 = \frac{9}{5}^{\circ}C \rightarrow$$

$$\frac{5}{9}(^{\circ}F - 32) = ^{\circ}C$$

**Q4. Convert 18°C to K.**

$$18^{\circ}C + 273.15 = 291.15 \text{ K.}$$

**Q5. Which material listed in the table is most conductive, and which is the least conductive?**

Copper is most conductive (with the greatest conductivity value, 401.000). Air is the least conductive (with the lowest conductivity value, 0.025).

**Q6. Which material is the best insulator? Which material is the worst insulator?** Copper is the worst insulation material listed in the table.

Air is the best insulation material listed in the table.

**Q7. What is the relationship between a material's thermal conductivity and its ability to insulate?** They are the inverse of one another: a good insulator is a poor conductor of heat, and vice versa.

**Q8. Why do snakes move out onto paved roads and lie on them at night?** Reptiles are ectothermic, in that they regulate their body temperatures largely by exchanging heat with their surroundings: 'Ecto' means 'outside'. Rocks and roads made of rock material have high conductivities. Exposed to the sun during the day, a paved road takes up heat, and at night will give up this heat to snakes lying on it. This allows snakes to be active longer at night in search of mice and other rodents that are nocturnal (night active). This behavior pattern is a boon to herpetologists who can drive the roads at night to pick up specimens for their research.

**Q9. Which cools you down more on a hot sunny day: sitting in front of a fan or taking a dip in a swimming pool? Why?** A dip in a pool, definitely. This is because the thermal conductivity of water is 24 times better than that of air. It can more quickly absorb our body heat.

**Q10. Why does deer fur have such low conductivity, when compared to a single deer hair?**

Fur and feathers are both good insulators, that is, they have low conductivities. So, it may surprise you to learn that both fur and feathers are made up of thousands of hairs or fibers, each of which is not a good insulator. These individual hairs are poor insulators because they are made of a material called keratin, which has a relatively high conductivity. Fur is a much better insulator than the individual hairs that it is made of because fur traps large amounts of air, which is a great insulator. In fact, the conductivity of air is only about 0.025 W/mK, making it one of the best insulators available.

The amount of air trapped by a cubic centimeter of fur depends on the fur's density, that is, the number of hairs per unit area. Animals that live in cold climates typically have much denser fur than animals that live in warm climates. For example, rabbit fur density is estimated to range from 4,100 hairs per  $\text{cm}^2$  to 11,000 hairs per  $\text{cm}^2$ , while the fur density of most primates is below 1,000 hairs per  $\text{cm}^2$ . In summary, dense fur traps more air, and thus has lower conductivity (and higher insulation power) than sparse fur. The conductivities of several types of fur are listed in the table below.

<b>Animal</b>	<b>Fur Conductivity (W/mK)</b>
Wolf	0.05443
Arctic Wolf	0.04591
Grizzly Bear	0.06059
Polar Bear	0.04396
Rabbit	0.04012

**Q11. Since reptile scales are made of the same material as fur, why is this body covering not a good insulator?** Keratin itself is a good heat conductor, and thus a poor insulator. The keratinous scales of reptiles are flat and fit tightly to the body to prevent desiccation or water loss. They are not designed to trap air, which gives coverings of fur and feathers their great insulation properties.

---

**Q12. If the temperature outside a home is less than the temperature inside a home, which way will heat flow through a window or wall ?**

Heat flows from the inside to the outside.

**Q13. How does the rate at which heat flows through a wall change as the thickness of the material gets larger?**

As the thickness of a material gets larger, the rate at which heat flows through the wall of this material gets smaller.

**Q14. If you were to compare the fur of a snowshoe hare in winter to that of a snowshoe hare in the summer, how would you expect these two coats to differ? Which coat would be the thickest? Which coat would be the densest?**

We would expect the snowshoe hare to shed hair in the summer so that its coat would be less dense in the summer months than in the winter months.

We wouldn't expect the thickness of the fur to change, as fur thickness is determined by the length of the individual hairs.

**Q15. If the outside temperature is  $-5^{\circ}\text{C}$ , and the internal temperature of a hare is  $99^{\circ}\text{F}$ , does heat flow into or out of the hare's body? What if the hare is in the desert and the outside temperature is  $37^{\circ}\text{C}$ ?**

In order to compare the hare's temperature to the outside temperature, we must first convert it to degrees Celsius. Using the formula above we find that

$$\frac{5}{9} (^{\circ}99 - 32) = 37.2^{\circ}\text{C}$$

Then, since heat flows from warmer regions to cooler regions, we see that in both cases, heat flows out of the hare's body.

**Q16. What is the heat loss through a 1m square window on a home, if the outside air temperature is  $15^{\circ}\text{C}$ , the inside temperature is  $25^{\circ}\text{C}$ , and the  $R_{\text{value}}$  of the window is  $2 \frac{\text{Km}^2}{\text{W}}$ ? (Be careful with your units!)**

To find the heat loss per square meter, simply divide the temperature difference by the R value. Since there is a difference in temperature of  $10^{\circ}\text{C}$  (which also is equal to  $10\text{K}$ ), and the R-value of the window is  $= 2 \frac{\text{Km}^2}{\text{W}}$ , energy will be lost at a rate of  $\frac{10 \text{ K}}{2 \frac{\text{Km}^2}{\text{W}}} = 5 \frac{\text{W}}{\text{m}^2}$  through the window. Since the area of the window is equal to 1 square meter, heat is lost through the window at a rate of 5 Watts, or 5 joules per second.

## SUGGESTED READING

### **Grades K-3**

*Fur and Feathers* - Elizabeth Miles

*Feather and Fur! What Makes Cats Purr?: Exploring Your Pet's World* - Boughton Cobb

*Animal Feathers & Fur* - David M. Schwartz and Dwight Kuhn (Illustrator)

*Feathers and Hair* - Ted O'Hare

*All About Heat* - Lisa Trumbauer

*The Magic School Bus in the Arctic: A Book About Heat* - Joanna Cole, Art Ruiz (Illustrator), Bruce Degan (Illustrator)

### **Grades 4-7**

*Animal Skin and Fur* - Jonatha A. Brown, Susan Nations, Debra Voegel

*Why Mammals Have Fur* - Dorothy Hinshaw Patent

*Adaptation* - Alvin Silverstein, Virginia B. Silverstein, Laura Silverstein

*Energy* - Chris Woodford

*Energy* - Alvin Silverstein, Virginia B. Silverstein, Laura Silverstein

### **Grades 7+**

*101 Questions About Skin That Got Under Your Skin...Until Now* - Faith Hickman Brynie

*Energy Projects for Young Scientists* - Richard Craig Adams, Robert Gardner

### **Scientific Journal Articles**

Blouin-Demers, G. and P.J. Weatherhead. 2001. An experimental test of the link between foraging, habitat selection, and thermoregulation in black rat snakes (*Elaphe obsoleta obsoleta*). *Journal of Animal Ecology* 70(6):1006-1013.

Kenagy, G.J. and O.P. Pearson. 2000. Life with fur and without: experimental field energetics and survival of naked meadow voles. *Oecologia* 122:220-224.

M.E. Watanabe. 2005. Generating heat: New twists in the evolution of endothermy. *Bioscience* 55(6):470-475.

## LINKS

### **Chem4Kids.com: Reactions: Thermodynamics**

[http://www.chem4kids.com/files/react\\_thermo.html](http://www.chem4kids.com/files/react_thermo.html)

### **Physics4Kids.com: Thermodynamics & Heat**

[http://www.physics4kids.com/files/thermo\\_intro.html](http://www.physics4kids.com/files/thermo_intro.html)

[http://www.physics4kids.com/files/thermo\\_heat.html](http://www.physics4kids.com/files/thermo_heat.html)

### **Biology4Kids.com: Animal Systems: Integumentary System**

[http://www.biology4kids.com/files/systems\\_integument.html](http://www.biology4kids.com/files/systems_integument.html)

### **Biology4Kids.com: Vertebrates**

[http://www.biology4kids.com/files/vert\\_main.html](http://www.biology4kids.com/files/vert_main.html)

### **Kids' Health: Skin, Hair, and Nails**

[http://kidshealth.org/parent/general/body\\_basics/skin\\_hair\\_nails.html](http://kidshealth.org/parent/general/body_basics/skin_hair_nails.html)

### **Slowing the Flow**

*“Slowing the Flow” is part of the OLogy website for kids from the American Museum of Natural History, and gives kids a great experiment demonstrating the mammalian diving reflex (MDR)*

[http://www.amnh.org/ology/features/stufftodo\\_marine/flow\\_main.php?TB\\_iframe=true&height=580&width=750](http://www.amnh.org/ology/features/stufftodo_marine/flow_main.php?TB_iframe=true&height=580&width=750)

### **Rubber Blubber Gloves**

*“Rubber Blubber Gloves” is another OLogy experiment demonstrating animal insulation from AMNH.*

[http://www.amnh.org/ology/features/stufftodo\\_marine/blubber\\_main.php?TB\\_iframe=true&height=500&width=750](http://www.amnh.org/ology/features/stufftodo_marine/blubber_main.php?TB_iframe=true&height=500&width=750)

### **Infrared Zoo Gallery**

*This is a really cool site that shows infrared thermographs of a wide variety of animals, as well as discusses insulation!*

[http://coolcosmos.ipac.caltech.edu/image\\_galleries/ir\\_zoo/](http://coolcosmos.ipac.caltech.edu/image_galleries/ir_zoo/)

### **BBC News | Science & Environment | Fossil hints at fuzzy dinosaurs**

<http://news.bbc.co.uk/2/hi/science/nature/7950871.stm>

**Temperature & Humidity in Nature**

<http://www.cartage.org.lb/en/themes/Arts/Architec/ArchitecturalStructure/GreenArchitecture/TemperatureHumidity/TemperatureHumidity.htm>

**ColoradoENERGY.org - R-Value Table**

<http://www.coloradoenergy.org/procorner/stuff/r-values.htm>