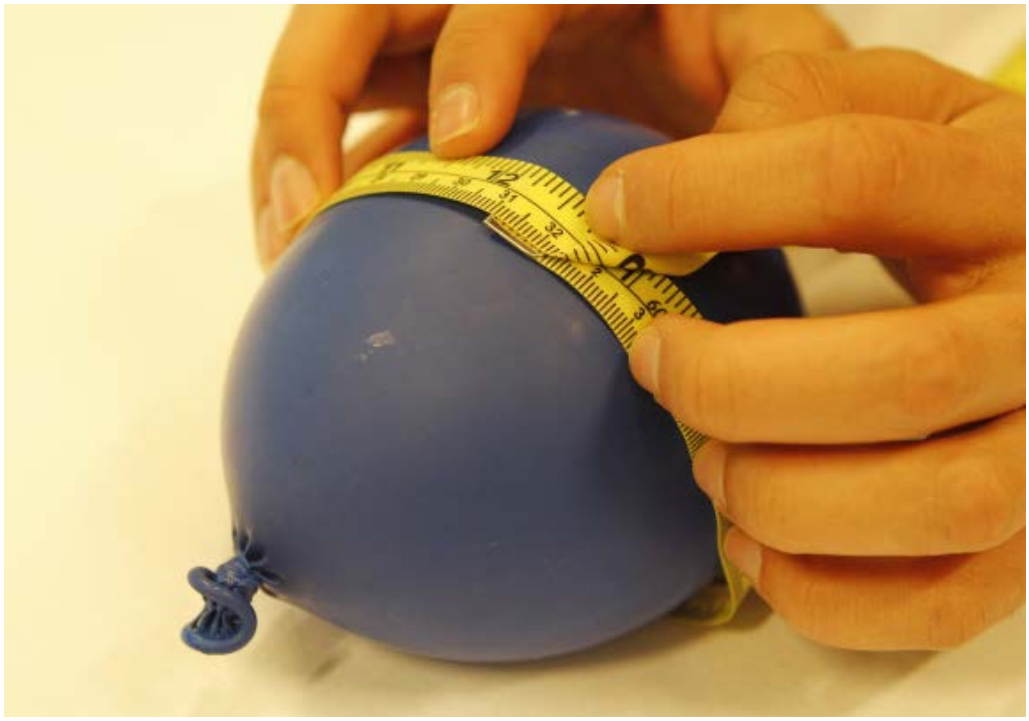
BERGMANN'S RULE ACTIVITY GUIDE

How does size affect temperature regulation?



FOR EDUCATOR

APPLICATIONS IN:

LIFE SCIENCES – Thermal Regulation/Adaptations/Structure and Function
PHYSICAL SCIENCES – Surface Area to Volume Ratios/Radiation and Insulation of Thermal Energy
MATHEMATICS – Surface Area vs. Volume/Topology

NGSS* ALIGNMENT:	Elementary School	Middle School	High School
PS1.A Structure and Properties of Matter	X		
PS3.A Definitions of Energy		X	
PS3.B Conservation of Energy and Energy Transfer	X	X	X
LS1.A Structure and Function	X		
LS4.C Adaptation	X	X	X

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BERGMANN'S RULE - Introduction for Educators

FOR EDUCATOR

OVERVIEW

An interesting phenomenon is seen with deer species across the Western Hemisphere. Those in the Northern regions tend to be bigger and heftier. Those closer to the equator, tend to be smaller and leaner. This is related to thermoregulation for deer. Larger volumes can trap heat more easily while heat is radiated away across larger surface areas. Larger deer have a lower surface area-to-volume ratio and can better trap the heat they need in cooler climates. The smaller deer, have a larger ratio and are more able to radiate heat away to remain cool. Bergmann's rule is quite apparent in deer, but is also seen in other animals.

LEARNING GOALS

- Be able to describe the relationship between surface area and volume
- Be able to explain how this relates to thermoregulation
- Be able to state Bergmann's rule

HOW TO USE

The materials are segmented specifically for you to use just what you need. You can have students simply explore ideas or follow a more quantitative approach. You can do everything either as a **demo** or **experiment**. We have provided pre-made **"concept overview," "record sheets", "questions to think about"** to use if you wish.

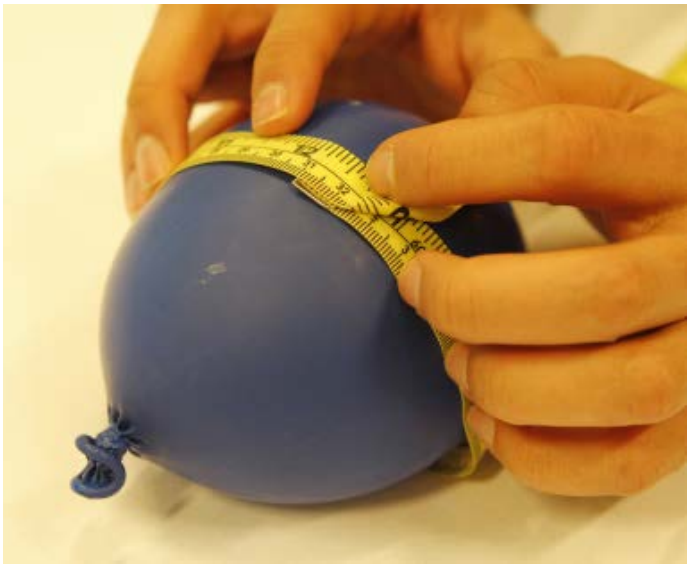
TIPS

- You may need to explain the difference between surface area and volume.
- Have your students put the balloons in cups (not Styrofoam!) to keep them stable and separated so they do not insulate each other.
- A possible useful variation is to give all students one balloon each and then combine everyone's data into one big table.

CALCULATING SURFACE AREA AND VOLUME

To calculate volume and surface area calculations, we approximate that the water balloons as spheres. You will need to take some measurements and calculate the surface area and volume.

FINDING CIRCUMFERENCE:



Once the balloon is filled with water, tie it off so water does not squirt out. Then take a measuring tape and wrap it around the widest part of the balloon. This is the circumference. If you do not have a measuring tape, take a piece of string or strip of paper and wrap it around the balloon and measure the length of the string that goes around the balloon

FINDING VOLUME AND SURFACE AREA FROM CIRCUMFERENCE:

For volume, you can pre-measure the volume of water in your using a beaker or measuring cup. However, you may find it difficult to fill up a balloon in this way and wish to calculate the volume instead. You can solve for the radius from the circumference and use what you calculated to find both volume and surface area:

Solve for R from Circumference:

$$Circumference\ (C) = 2\pi R$$
$$R = \frac{C}{2\pi}$$

Use what you found for R in Volume Formula:

$$Volume(V) = \frac{4}{3}\pi R^3$$

Use what you found for R in Surface Formula:

$$Surface\ Area\ (SA) = 4\pi R^2$$

CALCULATING SURFACE AREA-TO-VOLUME RATIO:

Once the surface area and volume are known, the Surface Area-to-Volume ratio is simply:

$$Ratio = \frac{SA}{V}$$

FOR STUDENT OR EDUCATOR

EXPLORING THERMOREGULATION

FOR STUDENT

Bergmann's Rule notes that deer of the same species tend to be bigger and fatter the farther North they live and smaller and leaner the farther South. This is true for other animals as well. This all has to do with surface area, volume, and the role they play in maintaining an animal's temperature.

PREDICT:

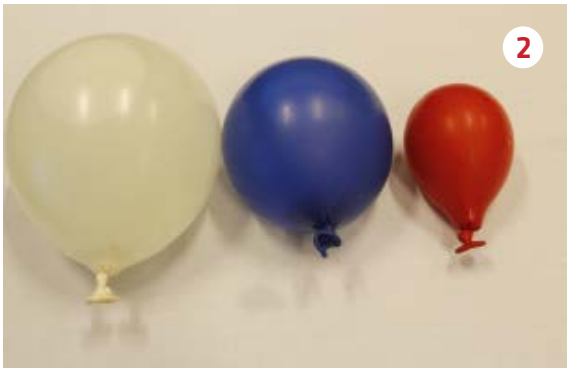
Which balloon will be warmer after 20 minutes?

MATERIALS:

- Water Balloons
- Warm Water
- Beaker
- Thermometer
- Measuring Tape
- Scissors
- Plastic Cups (do not use Styrofoam or anything else that acts as an insulator!)

WHAT TO DO:

1) Leave the hot water running until the temperature stabilizes.
2) Take 3 water balloons and fill one each up with different amounts of warm water. Fill one as much as you dare, one that just makes the balloon round, and one in between. Tie off the balloons and note what time it is. It may be a good idea to put the balloons into cups to keep them stable. Make sure balloons are several inches apart so they do not influence each other's temperature.
3) Put some of the same temperature water in a cup or beaker. Take the temperature of the water and record what it is.
4) Next, calculate the surface area-to-volume ratio of each balloon. We are going to assume the water balloons are spheres to make our calculations easier. Ask your teacher how he or she would like you to determine the surface area-to-volume ratio.
5) After about 20-30 minutes have passed after filling the water balloons, empty the water into the cups. It is best to put the balloon in the cup and cut quickly by where you tied it off. To be safe, empty into the cup, in a sink. Take the temperature of the water from each balloon and record the information.



RECORD SHEET – Bergmann's Rule

FOR STUDENT

Record information for your balloon(s) as well as others

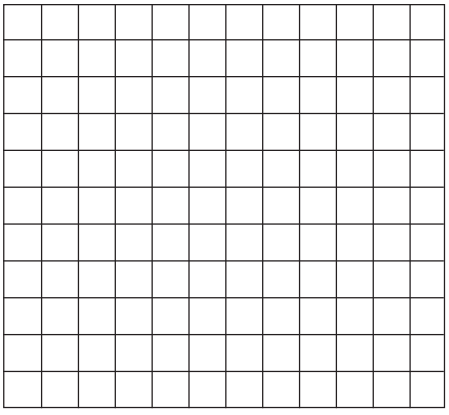
Start Time: _____ **End Time:** _____ **Time Elapsed:** _____ **Start Temperature:** _____

Balloon Circumference (cm)	Volume (cm^3)	Surface Area (cm^2)	Surface Area-to-Volume Ratio	End Temperature

Workspace:

Circumference (C) $= 2\pi R$ *Volume(V)* $= \frac{4}{3}\pi R^3$ *Surface Area (A)* $= 4\pi R^2$

$$Ratio = \frac{SA}{V}$$



**Be sure to label axes*

QUESTIONS TO THINK ABOUT

1) Compare your results with others in the classroom. Which balloons cooled off faster, the ones with more volume or less? Why do you think that is?

2) How does surface area change in relation to volume?

3) What is the relationship between the Surface Area-to-Volume ratio and the ability of a balloon to retain water?

4) Which is more responsible for retaining heat? Surface area or volume? How do you know that?

5) How is this activity a model for the deer of differing sizes? What are the strengths and weaknesses of this model?

6) Which is more responsible for radiating heat away? Surface area or volume? How do you know that?

7) Which animals would need to cool off more, stay warm? How might climate affect the size of animals?

8) With global climate change, the world's temperatures are rising. How might you expect the size of deer to change in different parts of the world?

Notes:

FOR STUDENT

OTHER RESOURCES

Design Challenge
Check out our design challenges here:

http://www.fieldmuseum.org/Biomechanics/Education/DesignChallanges

We have one specifically for designing a dwelling that helps regulate temperature more energy efficiently. Have your students use what they learned here to apply to that design challenge!

More on Bergmann's Rule on the Web
Overview of Bergmann's Rule – Encyclopedia Brittanica
http://www.britannica.com/EBchecked/topic/61843/Bergmanns-Rule

Surface Area-to-Volume Ratio and Organisms – University of Tennessee:
http://www.tiem.utk.edu/~gross/bioed/bealsmodules/area_volume.html

FOR EDUCATOR

SPECIAL THANKS:

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