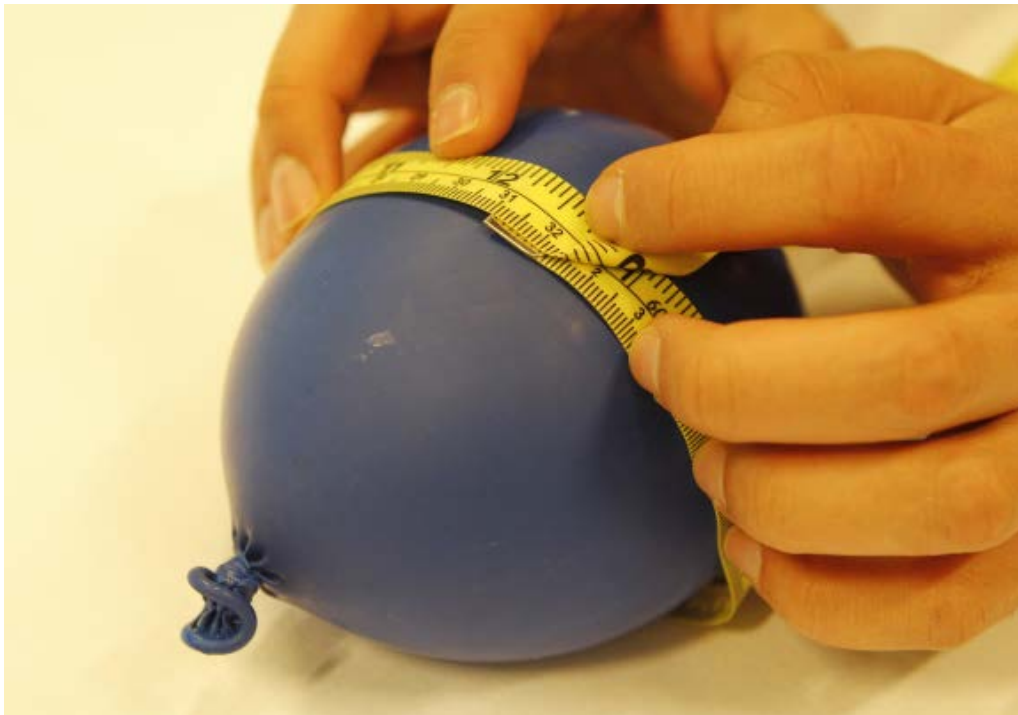




# BERGMANN'S RULE ACTIVITY GUIDE

*How does size affect temperature regulation?*



© The Field Museum / Photo by Kate Webbinck

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<br>School | Middle<br>School | High<br>School |
|---------------------------------------------------------|----------------------|------------------|----------------|
| <b>PS1.A</b> Structure and Properties of Matter         | X                    |                  |                |
| <b>PS3.A</b> Definitions of Energy                      |                      | X                |                |
| <b>PS3.B</b> Conservation of Energy and Energy Transfer | X                    | X                | X              |
| <b>LS1.A</b> Structure and Function                     | X                    |                  |                |
| <b>LS4.C</b> Adaptation                                 | X                    | X                | X              |

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PRESENTED BY THE FIELD MUSEUM EDUCATION DEPARTMENT

**BERGMANN'S RULE / THE MACHINE INSIDE: BIOMECHANICS ACTIVITY GUIDE**

The Field  
Museum



# BERGMANN'S RULE - Introduction for Educators

## OVERVIEW

An interesting phenomenon is seen with deer species across the Western Hemisphere. Those in the Northern regions tend to be bigger and heavier. 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

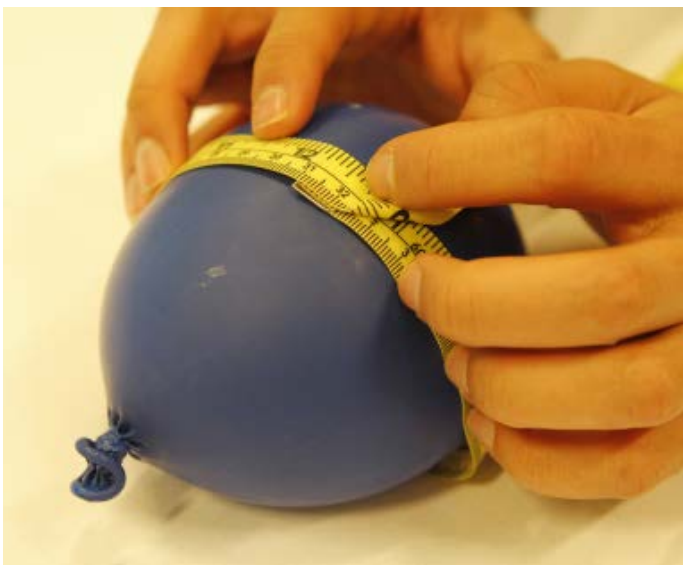
- You may need to explain the difference between surface area and volume.
- Have your students put the balloons in cups (not Styrofoam!) to keep them stable and separated so they do not insulate each other.
- A possible useful variation is to give all students one balloon each and then combine everyone's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

$$\begin{aligned} \text{Circumference (C)} &= 2\pi R \\ R &= \frac{C}{2\pi} \end{aligned}$$

### Use what you found for R in Volume Formula:

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

### Use what you found for R in Surface Formula:

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

## CALCULATING SURFACE AREA-TO-VOLUME RATIO:

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

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



## EXPLORING THERMOREGULATION

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:

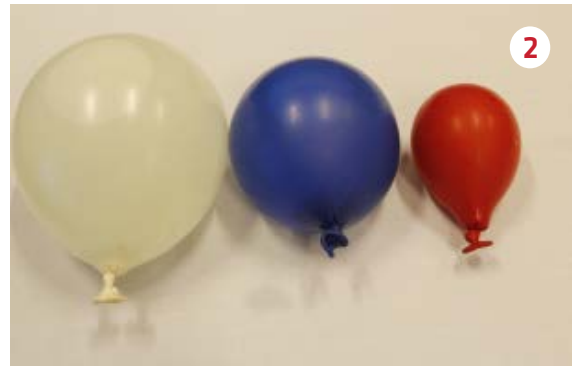
- Water Balloons
- Warm Water
- Beaker
- Thermometer

- 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

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

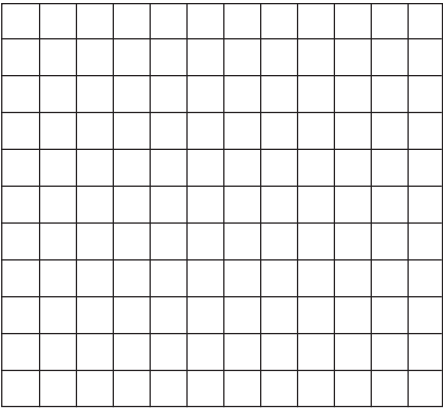
Start Time: \_\_\_\_\_ End Time: \_\_\_\_\_ Time Elapsed: \_\_\_\_\_ Start Temperature: \_\_\_\_\_

| Balloon Circumference (cm) | Volume (cm³) | Surface Area (cm²) | Surface Area-to-Volume Ratio | End Temperature |
|----------------------------|--------------|--------------------|------------------------------|-----------------|
|                            |              |                    |                              |                 |
|                            |              |                    |                              |                 |
|                            |              |                    |                              |                 |
|                            |              |                    |                              |                 |
|                            |              |                    |                              |                 |
|                            |              |                    |                              |                 |
|                            |              |                    |                              |                 |

FOR STUDENT

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

[illegible]



## OTHER RESOURCES

### Design Challenge

Check out our design challenges here:

<http://www.fieldmuseum.org/Biomechanics/Education/DesignChallenges>

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 Britannica

<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](http://www.tiem.utk.edu/~gross/bioed/bealsmodules/area_volume.html)

FOR EDUCATOR

## SPECIAL THANKS:

*The Machine Inside: Biomechanics* was developed by The Field Museum, Chicago, in partnership with the Denver Museum of Nature & Science.

Funded by:  THE CHICAGO COMMUNITY TRUST AND AFFILIATES

**The Searle Funds**  
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