# TITLE: Size Matters

***Subtitle: Understanding the surface area-to-volume ratio***

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**Field tested with:** 9th grade integrated science students (Watsonville High School, Watsonville, CA)

**Module Type:** Short video and lab activity

**Duration:** 40 min (video, activity and wrap-up)

**Key materials:**

* Computer with projector (or other equipment used to project video)
* Worksheet: “Size Matters: Understanding Surface to Volume Ratio”

**Concepts:** Surface area, volume, surface area to volume ratio, diffusion, cell size

**Skills:** In this mini-module students will learn about the relationship between surface area and volume and why this relationship is important for cells in our body.

**Science Education Standards:**

**National:** Science as Inquiry, Life Science Standards, Science and Technology, Science in Personal and Social Perspectives

**California:** Investigation and Experimentation

**NGSS:** HS-LS1: From Molecules to Organisms: structures & processes**,** HS-ETS1-2; HS-LS1-2; HS-LS1-6; HS-LS1-7

# Overview:

This mini-module is an opportunity for students to understand:

* Surface area, volume, and the surface area-to-volume ratio
* Why surface area to volume ratios are important in our everyday life
* How surface area changes relative to volume for various simple geometric shapes (illustrative of cells in this case)

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# Background for Teachers

**Why this matters:** The surface area-to-volume relationship is important for the structure and function of both living things (ex: lung anatomy, tree roots, cell size, brain vascularization) and many human-made objects (ex: car radiators, air conditioning units). By understanding that surface area increases at a slower rate than volume as objects get larger (for most three-dimensional shapes like the cubes in the worksheet), students can appreciate: why small cell size is advantageous; why plants benefit from a branched network of stems, leaves and roots; and why a variety of everyday objects are shaped and sized the way they are. Heat dissipation, surface exposure to a benign or harsh environment, diffusion of nutrients or wastes, and many other processes depend greatly on the surface area-to-volume ratio of the given structure.

**Assumed background:** This mini-module is extremely basic and very little previous background knowledge is required. The supplemental worksheet provides all of the needed background information. Here is a summary of the knowledge used.

* Some prior exposure to the concept of diffusion (the passive movement of a solute across a membrane from a region of high concentration to one of low concentration)
* Simple geometric shapes (cube, sphere, cylinder, etc) have unique equations to describe their surface areas and volumes
* Basic arithmetic…e.g. v = s3

**Special context:** The structure of many biological shapes is strongly influenced by underlying biophysical laws and patterns. For a cell, the ratio of cellular surface area to volume is important because efficient trans-membrane diffusion of molecules (nutrients or wastes) into or out of the cell must occur rapidly enough to sustain cell function. Understanding the basics of how surface area and volume change with cell size is perhaps most fundamental for recognizing how this simple mathematical relationship scales up and influences a myriad of macroscopic structures (e.g. gills in fish, microvilli in the digestive tract, nerve cell anatomy)

**Scaffolding supplements:** The link below takes you to a 5 min video that accompanies this module, the video presents important background information on the surface area to volume ratio.

**https://www.youtube.com/watch?v=DM8mLV6-MUw**

# Module Description

## Materials:

* Projector/computer or other equipment capable of showing a video to students
* Video: https://www.youtube.com/watch?v=DM8mLV6-MUw
* Size Matters worksheet

## Preparation:

* Make sure the video on surface are to volume will play
* Photocopy “Size Matters” worksheet

## Timeline:

1. Video: 5 min
2. Worksheet activity: 30 min
3. Wrap-up discussion: 5 min

## Starting Point For Inquiry:

This module is perhaps most effectively introduced with a series of curiosity-driven questions that perhaps many of the students can relate to. Some examples are provided here:

* Have you ever wondered why cells are so tiny?
* How large can an organism be?
* Why do trees have hundreds of thousands of leaves? Why are most trees not huge trunks like a cactus (which is a swollen stem)?
* How does the brain stay cool?
* Why are elephant ears so large?
* Why does a car radiator have so many tiny folds?
* What do all these diverse topics have in common?

These and similar questions will get the students thinking about commonalities/structural convergence and can be a great spring-board to introduce the activity with cube SA/Vol ratios.

## Detailed Procedure:

1. Introductory Video (5 min):

* Outstanding examples (photos) of structures that exploit the surface area-to-volume relationship
* A demonstration depicting agar cubes made with the acid-base indicator phenolphthalein
* Ends with: “Can you think of examples of the SA:Vol ratio in your own life?”

1. Worksheet activity: (30 min)
   1. Brief segway from introduction to worksheet…looking at SA:Vol ratio for cubes
   2. Discuss definitions of the following (listed on worksheet)
      1. Surface area
      2. Volume
      3. Surface area-to-volume ratio (SA:V)
   3. Students complete worksheet alone or with a partner
2. Wrap-up (5 min)
   1. Several simple assessment questions (e.g.: “So for the cube, did the SA:Vol increase or decrease with increasing cube size length? Explain.”)
   2. Ask students to think of, and then share with the class, examples from their daily lives in which the surface area-to-volume ratio plays an important role.

## Assessment Methods:

* Students demonstrate understanding by:
  + Completing the worksheet correctly
  + Providing examples of SA:VOL during the post-activity class discussion/wrap-up
  + Answering a quiz, or test, question similar to the cube example from the activity (ex: describe SA:VOL for a cylinder (equations for SA and Vol provided) and how it changes with cylinder size)

## Possible pitfalls:

One possible pitfall of this mini-module is the lack of a hands-on component and subsequently, potentially less student interest and engagement. We sought to minimize this by creating a short (and hopefully entertaining) introductory video that depicts a broad range of biological and man-made systems in which SA:Vol is of important significance.

The math involved in calculating SA, Vol, and SA:Vol for a cube is not difficult and the equations are provided, but students may need help remembering what it means to “cube” a number (for the cube shape, the length of one side is cubed in order to calculate volume).

## Glossary:

**Surface area (SA)** is the area of material that would be needed to cover an object (e.g. the amount of wrapping paper to wrap a really expensive gift for your science teacher).

**Volume (V)** is the amount of space inside an object (e.g. how much water inside a mug).

**Surface area-to-volume ratio (SA:V)** is the proportion, or ratio, of the surface area of an object to the volume of that same object. This ratio can change if the size of the object changes, or it’s shape changes.

## Optional:

Integrates well with the “*Predict This!* “ mini-module as it provides another example of how simple mathematical relationships can be insightful for seeing correlations between variables, testing hypotheses, or understanding patterns in nature. Also integrates with any graphical/statistics module.

Teachers with motivated/high achieving students can take this activity to the next level by graphing volume as a function of surface area for cubes of various side lengths, then deriving the 3/2 exponent from the linear relationship after log-transforming the axes. See below:

# Science Education Standards Addressed

* + D1: ESP3, 4, 5, 6, 7, 8
  + D2: CC1 Patterns, 2, 3, 6
  + D3: PS1 A, B; LS1A Structure & function

CCSS:

* ELA: P1, 2, 5, 6
* Math-Prac: M2, 4
* Math-Cont: NS, MD, RP, G/Geometry

**National Science Standards (NSES)**

A. Science As Inquiry (p.175-176)

B. Life Science Standards (p. 181-187)

C. Science and Technology (p.192-193)

D. Science in Personal and Social Perspectives (p.198-199),

**California Public Schools Standards (SCSCPS)**

Mathematics**,** Higher Mathematics Courses: Geometric Measurement and Dimension.

**a.** Students explain volume formulas and use them to solve problems (p. 74).

Investigation and Experimentation, 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:

**a**. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

**c**. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

**Next Generation Science Standards (NGSS)**

Cross-cutting concepts- patterns; systems & system models; scale, proportion & quantity; structure and function.

# Guide to supplemental materials

**Lectures**

**Graphics**

**Labs (or Activities)**

**Worksheets**

Size matters

**Videos**

SurfaceAreaVolume (<https://www.youtube.com/watch?v=DM8mLV6-MUw>)

**Assessment Materials**