Geometry of Marine Invertebrates

How does the surface area to volume ratio affect the ability of marine invertebrates to obtain oxygen?

Overview

Students in math classes often ask, "When am I ever going to use this?" This integrated math and science unit offers students an opportunity to discover for themselves why geometry in living organisms is both adaptive and essential.

Learning Goals

Students will learn the following:

- *Marine invertebrates are aerobic organisms that take in dissolved oxygen from the surrounding seawater.*
- *Oxygen absorption is easier when the respiratory organ has a high surface area to volume ratio.*
- *The geometry of body and organ shapes may help predict how an animal will fare during low-oxygen environmental conditions.*

Introduction

Scientists can analyze the geometric shapes of respiratory structures to make educated estimates about the function and efficiency of those organs. In aerobic organisms, oxygen enters animal bodies through diffusion. In general, both animals that obtain oxygen from the air with lungs (like humans), and those that obtain oxygen from water with gills (like fish), have respiratory structures with high surface area to volume ratios (SA:V). The greater surface area helps them more easily absorb oxygen. In addition, many marine invertebrates have respiratory tissues covering large parts of their anatomy, so even the body shapes and sizes of these animals can impact their respiration efficiency.

As more hypoxic (low oxygen) events occur in the waters off the Oregon coast, geometrically efficient respiratory structures may be key to an organism's survival. In this lesson, students explore relationships between SA:V in marine invertebrate bodies and make predictions about which geometric shapes are likely contribute to respiratory efficiency.

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Grade Level

7-8

Anchoring Phenomenon

Geometry of Marine Invertebrates

Driving Question

How does surface area to volume ratio affect the ability of marine invertebrates to obtain oxygen?

Time

Two weeks

Standards

Next Generation Science Standards

LS1.C – Organization for Matter and Energy Flow in Organisms
PS3.D – Energy in Chemical Processes and Everyday Life
LS4.C - Adaptation
ESS3.C – Human Impacts on Earth Ecosystems

Common Core Math Standards

7.RP.A
7.G.F
8.G.I

Learning Objectives

Students will be able to:

1. *Calculate the surface area to volume ratio of a variety of marine invertebrates,*
2. *Graph and evaluate data sets to compare two populations,*
3. *Discuss potential impacts of hypoxia on marine invertebrates.*

The anchoring phenomenon of this lesson centers around the relationship between surface area to volume ratios (SA:V) in marine invertebrate physical structures and their ability of those organisms to survive hypoxic ocean conditions. Students begin by observing the intriguing body shape of basket stars. They learn more about the ways basket stars and other marine invertebrates obtain oxygen from seawater, making comparisons to the respiratory structures of other organisms with which they may be more familiar. Students then use geometric formulas to calculate SA:V for a variety of marine invertebrates and compare the population density of basket stars in pre-hypoxia and post-hypoxia habitats. Finally, students use evidence to predict whether organisms will be able to survive hypoxic events.

Essential Questions:

- *What is the relationship between body shape and surface area?*
- *Is the surface area to volume ratio adaptive for marine invertebrates?*
- *What is ocean hypoxia?*
- *How are different organisms affected by ocean hypoxia events?*

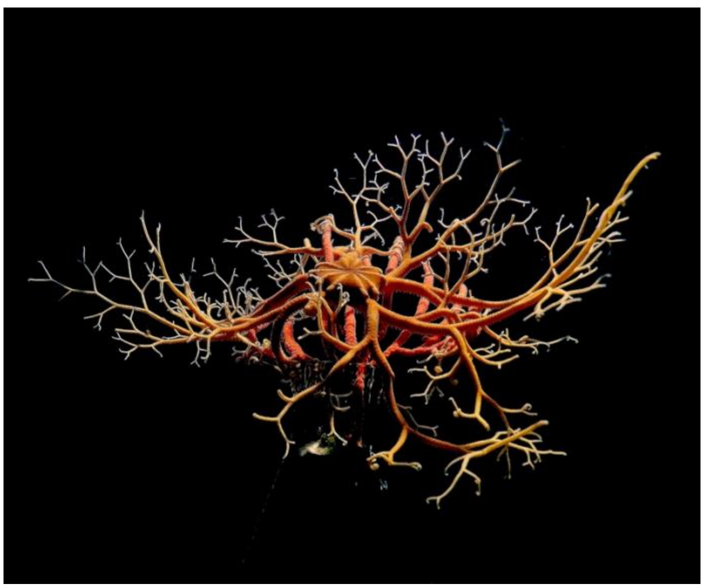


Image: MacKenna Hainey

Vocabulary

- *aerobic*
- *surface area*
- *volume*
- *ratio*
- *invertebrate*
- *respiration*
- *hypoxia*

Image: MacKenna Hainey

Why Study Basket Star Respiration?

Mild seasonal hypoxia along the Oregon coast is normal. However, climate change has resulted in hypoxic events that have increased in duration, magnitude, and intensity.

Basket stars can deal with normal, seasonal hypoxia by increasing the rate of body pumping (bursal ventilation) to compensate for a lower dissolved oxygen concentration in the water. However, they may not be able to cope with the more dramatic hypoxia events recorded recently and predicted for the future.

Because basket star populations are relatively under-studied, we do not know how the population will fare in the face of climate change. This is concerning to ecologists and stakeholders alike as the basket star is a food item for many important species such as Dungeness crabs, skates, rockfish, and sea otters.

Lesson Procedure

ENGAGE

Begin the lesson by showing students a video about a *Freakish Sea Creature* caught off Singapore. Ask students to watch video quietly, and then share with a classmate what they think the thing in the video is (and how do they know). After a minute of table talk time, have students share out what they hypothesize is in the video, and what evidence supports their claims.

Then, share the narrated Nautilus Live video *Beautiful Basket Stars,* which will provide the students with more information.

EXPLORE

In this section, students learn more about the biology and ecology of basket stars and other marine invertebrates, including some of the ways these animals obtain oxygen from seawater.

Activity: Guided Research

Small groups or individuals use designated online research websites to explore the biology and ecology of basket stars and complete a *student worksheet*. At the end of this section, students will be able to explain where basket stars are found and how they breathe. The poster *Functional Morphology of Basket Star Ventilation* provides additional information about the unique ways in which basket stars can pump their bursae to increase the flow of oxygenated water into their bodies.

Activity: Breathing Underwater

Three *Breathing Underwater* resources from researcher MacKenna Hainey are provided to help students learn how various marine invertebrates obtain oxygen from surrounding seawater: 1) video, 2) slide deck, and a 3) short reading. From this exploration, students learn that the surface area to volume ratio of marine invertebrate bodies is important to understanding respiration efficiency.

Activity: Marine Invertebrate Geometry

Connect math and biology using the presentation *Why Surface Area to Volume Ratio is Important in Biology.*

In small groups or individuals, have students use posters created by MacKenna Hainey to examine the geometric properties of various marine invertebrates. For each different invertebrate, students will identify the approximate 3D shape of the animal and identify formulas that can be used to calculate volume and surface area for that shape.

LESSON RESOURCES

Videos:

- *Freakish Sea Creature*
- *Beautiful Basket Stars*

Image: MacKenna Hainey

Guided Research

- *Basket Star student worksheet*
- *Poster: Functional Morphology*

Breathing Underwater

- *Video and student worksheet*
- *Slides*
- *Reading: How do marine invertebrates obtain oxygen?*

Marine Invertebrate Geometry

- *Presentation: Why SA:V is Important in Biology*
- *Posters: Volume of Marine Invertebrates*
- *Student Worksheet (to print)*

Image: MacKenna Hainey

A Simplified Model

Many marine invertebrates have respiratory structures that cover large parts of their external anatomy. For the purposes of this lesson, students will use estimated whole-animal SA:V ratios to make predictions about relative respiratory efficiency.

EXPLAIN

This section was designed as a Distance Learning (DL) unit. Use teacher-created math lecture videos and Khan Academy lessons and problem sets to cover the following surface area and volume topics:

- 7th Grade: Area and Circumference of Circles
- 7th Grade: Area of Triangles
- 7th & 8th: Volume of Rectangular Prisms
- 7th & 8th: Volume of triangular prisms, cylinders, cones, and spheres
- 7th & 8th: Surface Area of prisms, cylinders, cones
- 7th & 8th: Finding Surface Area to Volume Ratio (SA:V)

Students should watch the videos and complete practice problems for each concept. Additional practice worksheets are provided.

ELABORATE

Activity: Pre and Post-Hypoxia Populations

Low oxygen levels in the water off the Oregon coast, commonly called *hypoxia*, is occurring more frequently than in the past. In this section, students complete a *Population Densities* worksheet to compare the number of basket stars found in a sample site before and after hypoxia events.

Activity: Field trip or classroom visit

Visit a tidepool or marine science museum or invite an invertebrate biologist to bring marine invertebrates to class. Students will take measurements of the animals and calculate surface area to volume ratio.

EVALUATE

Students will be able to apply their understanding of geometry to oxygen consumption and hypoxia effects on marine invertebrates.

Activity: How well will they fare?

Ask to students to use their calculations of marine invertebrate SA:V and population data to make predictions about the animals' ability to survive hypoxic events.

Activity: Surface Area to Volume Ratio Topic Presentations

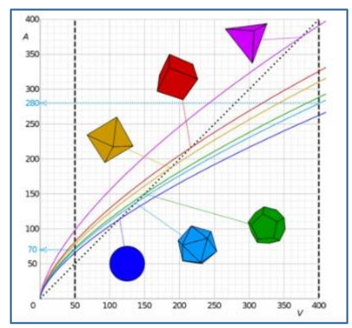
Students follow *SA:V Presentation Instructions* to create videos or slides on the importance of SA:V in a biological topic of their choice.

Math Lecture Videos

- *Circles and Triangles*
- *Volume, Part one*
- *Volume, Part two*
- *Cylinder Surface Area*
- *SA:V Ratio*
- *Khan Academy links*

Practice Worksheets

- *Cylinder SA practice*
- *SA:V questions*



Images: Screenshot from Ms. Almasi's math video

Hypoxia Impacts

- *What is hypoxia?*
- *Population densities*

Presentation

- *SA:V Presentation instructions*

About the Researcher

MacKenna Hainey participated in the ORSEA cohort while she served as a United Communities AmeriCorps Member at the University of Oregon's Charleston Marine Life Center. She recently received her MS from the UO's Oregon Institute of Marine Biology, and is currently a PhD student at Oregon State University.

Next Generation Science Standards

Science & Engineering Practices:

- *Asking questions and defining problems*
- *Developing and using models*
- *Using mathematics and computational thinking*
- *Obtaining, Evaluating, and Communicating Information*

Disciplinary Core Ideas:

7th Grade
MS.LS1.C: Organization for Matter and Energy Flow in Organisms
Interdependent Relationships in Ecosystems
MS.PS3.D: Energy in Chemical Processes and Everyday Life

8th Grade
MS.LS4.C: Adaptation
MS.ESS3.C: Human Impacts on Earth Systems

Crosscutting Concept:
Structure and Function
Patterns
Cause & Effect
Scale, Proportion and Quantity

Math Practices:

- *Model with mathematics*
- *Attend to precision*
- *Look for and make use of structure*

CCSS Math Content Standards:
7.RP.A – Use proportional relationships to solve problems.
7.G.F – Solve problems involving surface area and volume.
8.G.I – Solve problems involving volume of cylinders, cones, and spheres.

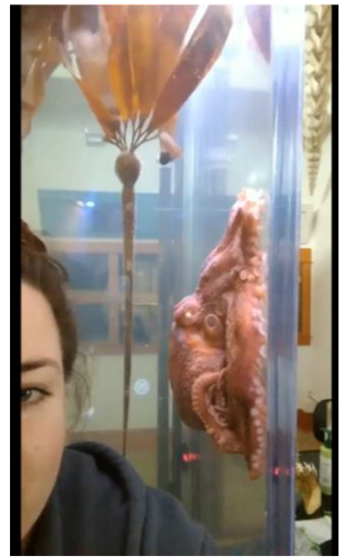


Image: MacKenna Hainey

Acknowledgments

The 2019-20 ORSEA materials are based upon work supported by Oregon Sea Grant and the Oregon Coast STEM Hub, as well as the National Science Foundation Regional Class Research Vessels under Cooperative Agreement No. 1333564 Award: OCE-1748726. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

See more lessons on the [ORSEA webpage]