Marine Science

SEA Publishing

Blair H. Lee, MS

Marine Science

The Hands-On Science Series

Written by Blair H. Lee, M.S.
University of California, San Diego

This course is dedicated to those who look out at the ocean and see not just waves, but endless possibilities. To the scientists who dive deep to uncover its secrets, and to every learner who dares to ask, What's down there?

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The R.E.A.L. Science Odyssey titles are recommended in the 4th edition of The Well-Trained Mind, by Jessie Wise and Susan Wise Bauer.

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The publisher and author have made every attempt to state precautions and ensure all activities and labs described in this book are safe when conducted as instructed, but assume no responsibility for any damage or person caused or sustained while performing labs and activities in this course. Parents and teachers should supervise all lab activities and take necessary precautions to keep themselves, their children, and their students safe.

Blair H. Lee

Blair received her B.A. in general chemistry and her B.S. in biology from the University of California, San Diego. She loved San Diego so much, she stayed at the University of California, San Diego where she obtained her M.S. in chemistry with a focus on environmental chemistry and earth science. Blair has taught courses in chemistry and biology at community college in San Diego. She has taught a range of science subjects to learners in grades 1 through 12. Blair is the author of several courses focused on a range of science topics. She also writes about the benefits of an academic learner centered approach to education.

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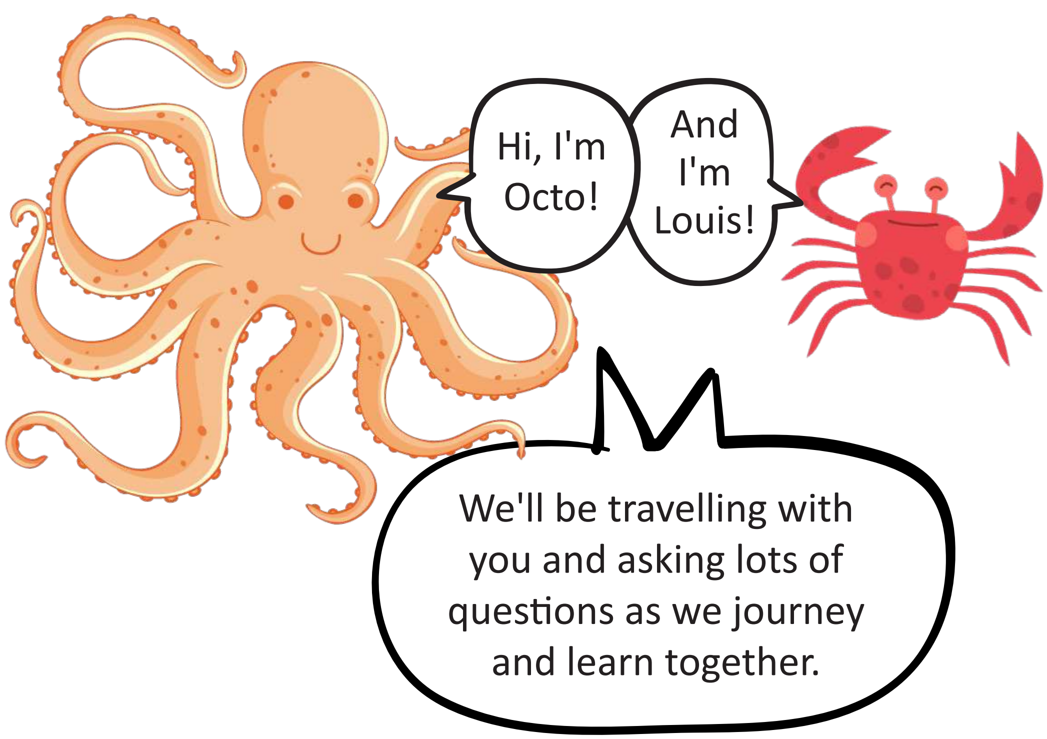
Some of the other characters you'll meet along the way



How to Use this Course

ABOUT THE COURSE

Marine Science is an 18-chapter, interdisciplinary science course written for upper elementary and middle-grade learners with an interest in oceanography and marine biology. With most of Earth's organisms living in the ocean, marine science is both fascinating and essential—an area of science every student deserves to explore.

This course takes an integrated approach, weaving together **ocean chemistry, marine geology, physical oceanography, evolution,** and **ecosystem science** to create a rich and immersive learning experience. From the properties of water and energy transfer to deep-sea biodiversity and global climate impacts, students develop a layered understanding of the ocean's systems and their connection to life on Earth. The course supports Next Generation Science Standards and incorporates Common Core-aligned reading, writing, and math tasks.

Marine Science delivers content through a **multimodal approach**. Every chapter includes **engaging narrative text, color photographs, diagrams, and over 90 curated and custom-designed animated video**s. Hands-on labs, modeling activities, scaffolded questions, and gameschooling activities help reinforce core science concepts. Several chapters also feature optional fiction extensions, along with projects that incorporate **writing, history, math, and art**.

Scientist spotlights and real-world case studies connect students with ongoing marine research, while writing tasks are designed to build strong analytical and science communication skills.

This course is written to be **flexible in format**, suitable for homeschoolers, microschools, and classrooms alike. It emphasizes **conceptual progression** and **cross-topic integration**. Students don't just memorize facts; they learn to observe, question, and think like scientists.

Whether a student dreams of becoming an oceanographer or marine biologist or is simply curious about the ocean, **Marine Science invites learners to wonder, investigate, and care**. It nurtures critical thinking and creativity while building scientific literacy because understanding is the first step toward protecting our blue planet.

THE 18-CHAPTER COURSE IS DIVIDED INTO 5 UNITS:

Unit 1: Introduction

1. Introduction: Science for a Blue Planet

Unit 2: Oceanography

2. Marine Geology and Geography: One Big Ocean
3. Marine Chemistry: The Shape of Water
4. Physical Oceanography (Part 1): Liquid Energy
5. Physical Oceanography (Part 2): Diving through Ocean Zones

Unit 3: Evolution and Adaptation in the Ocean

6. Adapting to Life in the Ocean
7. The Evolution and Adaptation of Marine Mammals: Back to the Water
8. The Microscopic Ocean

Unit 4: Ocean Ecosystems

9. Coastal Ecosystems
10. Coral Reefs
11. Kelp Forests
12. The Open Ocean
13. The Deep Ocean
14. Polar Ocean Ecosystems

Unit 5: Environmental Science

15. Overfishing & Habitat Destruction
16. How a Warming Ocean Is Changing the Climate
17. Ocean Pollution
18. Protecting Ocean Life

Glossary

PDF Appendices

All materials in the appendix are included with the purchase of the Student Text.

1. Materials List
2. Answer Key
3. All Consumable Pages
4. Glossary
5. Citations
6. Where *Marine Science* Meets the Standards (NGSS)

WHAT IS MARINE SCIENCE?

Engaging Videos, Thought Provoking Questions, and Hands-On Projects Are Woven Throughout the Text

Chapter 1

Science for a Blue Planet

It's a Big World Out There, and Most of It Is Under Water!

The ocean is Earth's largest ecosystem, covering more than 71% of the planet's surface and stretching from bright, shallow waters to dark, unexplored depths miles below. Within this watery world lies an incredible range of life, landscapes, and forces that shape our planet in ways scientists are only beginning to understand.

An **ecosystem** is a community of living things, like plants, animals, and tiny organisms, that interact with each other and the nonliving parts of the environment.

Each chapter opens with a lesson that covers **foundational science facts, theories, & vocabulary**.

71% of Earth's surface is covered by the ocean.

To understand how the ocean works, scientists use **oceanography**—a combination of biology, chemistry, geology, and physics focused on the sea

The ocean teems with life, from microscopic plankton drifting near the surface to the enormous blue whale, the largest animal on Earth, swimming through open waters. In the deep, some fish glow with their own light, while others hide beneath the sand, waiting to ambush a passing meal.

THE VIDEOS

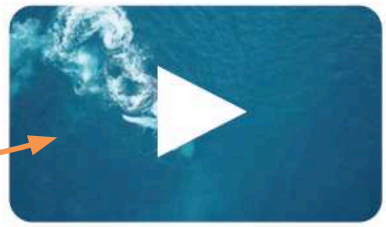
Several years ago, I had the idea for a new type of science course. In addition to the text and hands-on labs and activities there would be videos chosen and developed for the text. I wanted a course that had teaching videos with specific teaching points and vocabulary, that were entertaining as well as educational.

CURATED VIDEOS

There are **curated videos** with narration to highlight important topics and give learners a look at relevant footage.

HOW DO YOUR LIMBS MOVE?

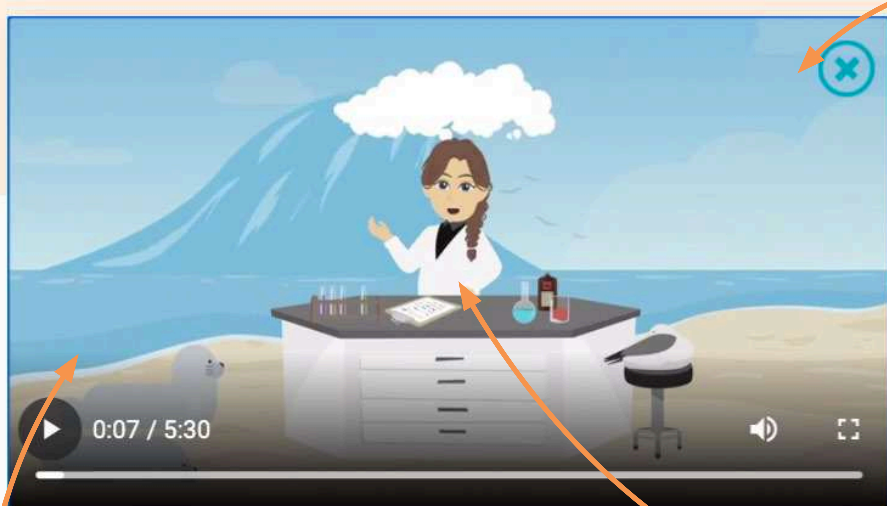
When you study marine biology, you will learn interesting facts, like how whales swim. Whales are mammals, just like you are. Think about how you move your arms and legs when you swim. Is the way you move your limbs more like how a whale swims or how a fish swims? What about the way you walk? Do you walk side-to-side or back-and-forth? Think about other species of mammals, and how whales move in comparison. Even though whales now live in water, they retain the basic body plan and movement patterns of their land-dwelling ancestors.



Watch

V1-2:
How Does a Whale Move?

ANIMATED VIDEOS



fer energy, how temperature and wind affect currents, and how wave action reshapes coastlines. By simulating these ocean motions, you'll uncover the forces that shape Earth's oceans and coasts every day.

Part 1: Modeling Wave Motion

This activity demonstrates how waves transfer energy across the surface of the ocean, while the water molecules and floating objects move mostly in place. This helps model the circular motion of water molecules in waves.

Each chapter includes **animated teaching videos** that highlight important scientific concepts. These were developed to incorporate and reinforce the vocabulary and topics in the chapter.

The video tutorials include instructions from author, Blair Lee, where learners can watch as she guides them through science practices and procedures.

Each **lab and activity** begin with an animated video that examines the purpose of doing the lab. The videos also include instruction concerning the **science practices and lab techniques that are used**.

QUESTIONS ARE INCORPORATED THROUGHOUT THE TEXT

Learning is strengthened when there is **real-time engagement with concepts**. To actualize this learning, *Marine Science* includes sections with **review questions**, **vocabulary checks**, and the **independent creation of hypotheses** built into each chapter.

Math in Context

There are 5.7×10^{21} cups of water in the ocean. Each cup holds about 4,732 drops of water (4.732×10^{3}). If you multiply these two numbers, (5.7×10^{21}) x (4.732×10^{3}), you get **2.7×10^{25} drops of water in the ocean.**

If each drop contains one million microbes. That's 1×10^{6} tiny organisms per drop. Multiply that out, and you get a mind-blowing estimate: **2.7×10^{31} microbes living in the ocean**!

Look up the number of stars astronomers estimate in the universe and compare that to the number of microbes estimated to be in the ocean.

THOUGHT QUESTION

Finish the sentence below to form a hypothesis about what would happen to Earth's tides if there were no moon. Use what you know about gravity and tidal forces to explain your thinking.

If there were no moon, I predict ______________________________

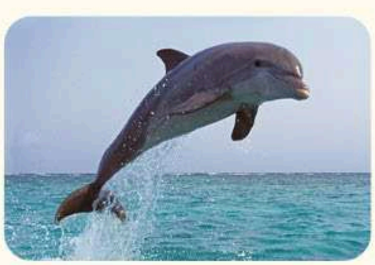
______________________________ would happen to tides on

Earth because ______________________________

____

CHECK FOR UNDERSTANDING

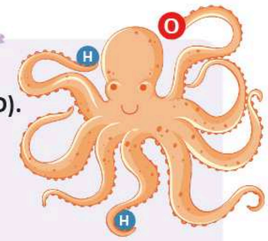
Look at the dolphins in the picture. What adaptations do they have that make them better suited for marine life versus life on land?



HANDS-ON PROJECTS AND SCIENTIFIC MODELING ARE INTEGRATED THROUGHOUT THE TEXT

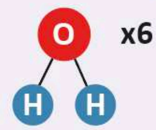
In every chapter, **topical information** is followed **by hands-on application of that information**. This creates a **kinesthetic, visual connection** to the information that encourages mastery of core science topics.

SCIENTIFIC MODEL IN 3-D: THE SHAPE OF WATER



Using blue and red clay and toothpicks, build 6 water molecules (H_2O).

1. Roll two small balls of clay, about the size of marbles, in one color. These represent hydrogen (H).
2. Roll one slightly larger ball of clay in a different color. This represents oxygen (O).
3. Use toothpicks to connect the two hydrogen balls to the oxygen ball, forming a V-shape.
4. Repeat this process to create six water molecule models.
5. Watch the video all the way through, pausing when asked.



END-OF-CHAPTER PROBLEM SETS

Each chapter has a problem set with multiple-choice questions and short answer questions.

CHAPTER 7: PROBLEM SET

Multiple-Choice Questions

1. **What is a marine mammal?**
   - o A mammal that spends all or part of its life in the ocean
   - o A cold-blooded animal that lives in water
   - o A fish with lungs that can survive on land
   - o An ocean animal that lays eggs
2. **Which of the following is a trait that all mammals share?**
   - o They lay eggs
   - o They breathe underwater with gills
   - o They produce milk to feed their young
   - o They have scales instead of fur

Short Answer Questions

1. What adaptations do marine mammals have that land mammals do not?
2. What are two physical adaptations and two physiological adaptations that help marine mammals thrive in their environments?
3. Why do you think different groups of marine mammals (like cetaceans, pinnipeds, and sirenians) evolved different adaptations, even though they all live in or near the ocean?

LABS AND ACTIVITIES

Learning science requires *doing science*. This course has 28 labs and activities to help facilitate the learning of marine science.

Gameschooling

Keystone Species Jenga: Understanding Ecosystem Balance

Watch

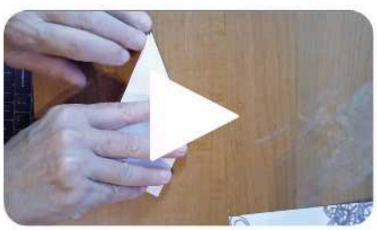
Chapter 11 Activity:
Keystone Jenga: Understanding Ecosystem Balance

In this activity, we will use a Jenga tower to represent the impact a keystone species can have on an ecosystem. Each block will represent a different part of the ecosystem: primary producers, primary consumers, secondary consumers, decomposers, and a keystone species. The game represents a kelp forest ecosystem where kelp, sea urchins, and sea otters interact. However, it could represent any ecosystem with a keystone species, including starfish in tide pools.

As blocks are removed, you will see how ecosystems change, including what happens if you remove the keystone species? Will the ecosystem stay stable, or will it collapse?

Scientific Modeling

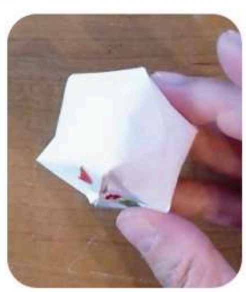
Make a Coccolithophores Modeling Activity



Watch

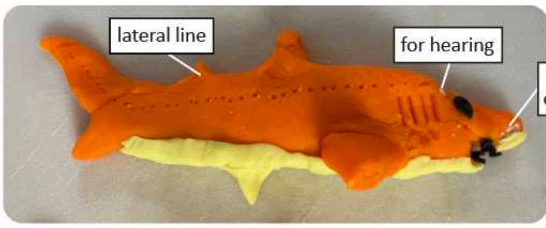
Chapter 8:
Activity Guess

Tiny **coccolithophores**, a type of **microscopic phytoplankton**, are covered with circular plates made of calcium carbonate. When coccolithophores die, their plates sink to the ocean floor. Over millions of years, these plates accumulated in massive quantities in an area that is now part of the coastline in the United Kingdom. This process created the White Cliffs of Dover, which are about 1,150 feet (350 meters) thick!



In this activity, you will create a **3D origami model of a coccolithophore**. You will use paper to build your model and decorate it with patterns representing the plates coccolithophores use to cover themselves. Ready to get started?

8. Add the external features
   - Make the **eyes**
     - Poke a small hole where the eye will go.
     - Attach the eye.
   - Add the lateral line and **sensory pores:**
     - Use a toothpick to poke small holes from the tail, along the body, and toward the nose. *These small holes represent the lateral line, which helps sharks detect movement in water.*
     - Use a fine-tip marker to add a small hole behind the eye. *This hole is part of the **inner ear system**.*
     - Make three small holes on the lighter-colored nose. *These are the **ampullae of Lorenzini**, which help sharks detect electrical signals from prey.*



Art

Part 3: Internal Anatomy

6. Organ Identification

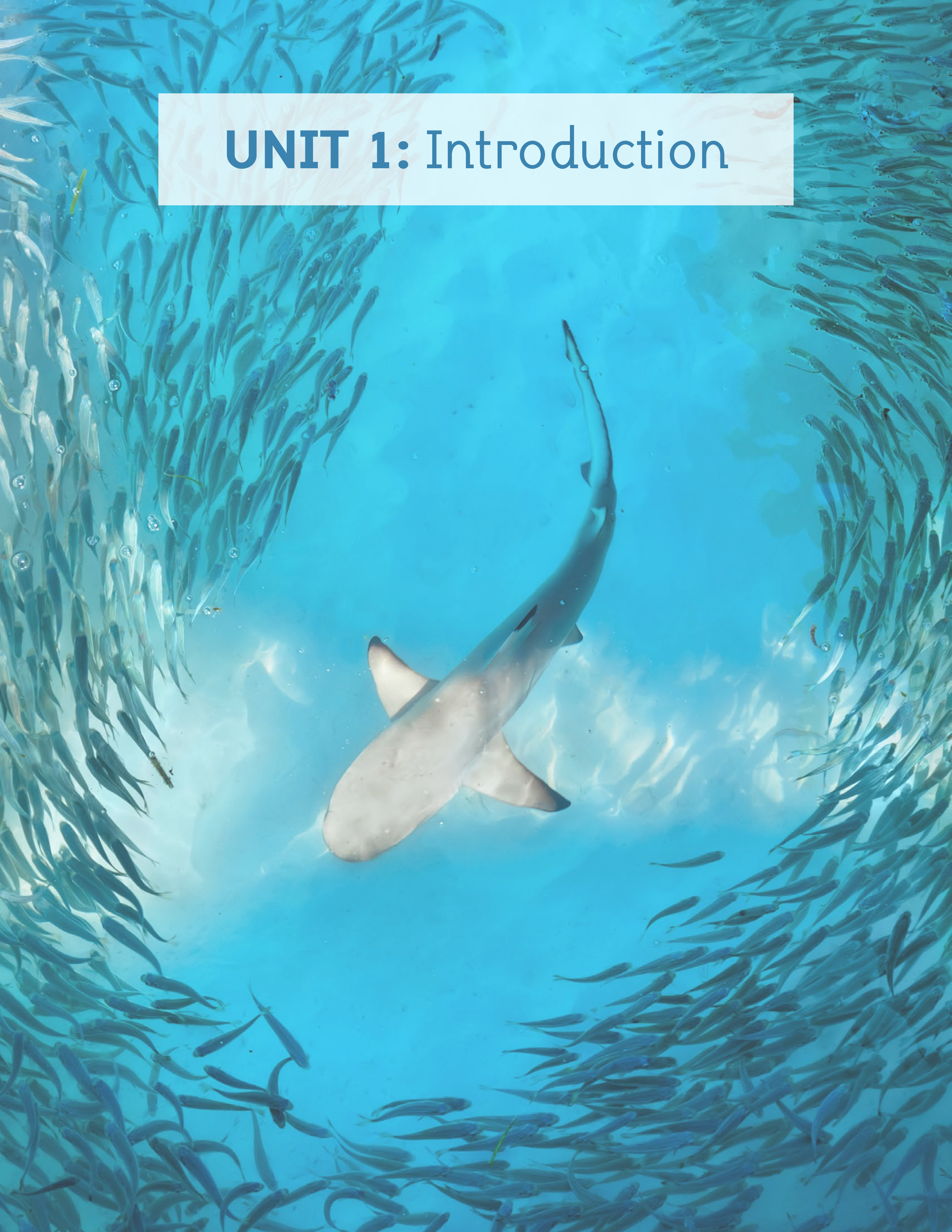
- Make a precise incision following the diagram on your lab sheet to expose the internal organs. Be careful not to damage any structures.
- Observe the arrangement of the organs.

Dissection Lab

PDF APPENDIX

1. How to use this course.
2. Materials List: The materials list is organized by chapter and alphabetically for all materials in a single list.
3. Answer Key
4. All Consumable Pages: Whether you purchase the print version or the eBook, the consumable pages for this course are included in the PDF.
5. Problem Sets
6. Glossary

UNIT 1: Introduction



Chapter 1

Science for a Blue Planet

It's a Big World Out There, and Most of It Is Under Water!

The ocean is Earth's largest ecosystem, covering more than 71% of the planet's surface and stretching from bright, shallow waters to dark, unexplored depths miles below. Within this watery world lies an incredible range of life, landscapes, and forces that shape our planet in ways scientists are only beginning to understand.

An **ecosystem** is a community of living things, like plants, animals, and tiny organisms, that interact with each other and the nonliving parts of the environment.

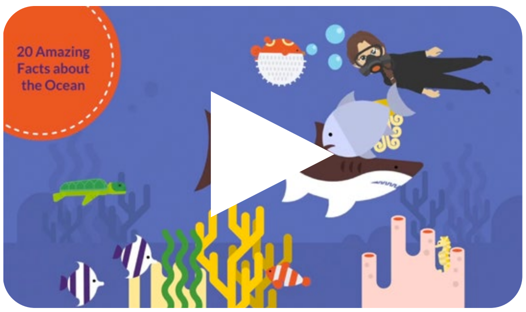
71% of Earth's surface is covered by the ocean.

To understand how the ocean works, scientists use **oceanography**—a combination of biology, chemistry, geology, and physics focused on the sea.

The ocean teems with life, from microscopic plankton drifting near the surface to the enormous blue whale, the largest animal on Earth, swimming through open waters. In the deep, some fish glow with their own light, while others hide beneath the sand, waiting to ambush a passing meal.

Underwater landscapes are just as diverse. Bright coral reefs, built by tiny animals over thousands of years, burst with color and life, while towering seamounts rise from the ocean floor, shaped by underwater volcanoes. At mid-ocean ridges, new seafloor forms, creating rift valleys. In the deepest parts of the ocean, such as the Mariana Trench, the land plunges farther below the ocean's surface than Mount Everest rises above it.

The forces at work in the ocean are powerful and far-reaching. Currents flow like underwater rivers, moving massive amounts of water and affecting weather and climate worldwide. The ocean floor experiences underwater earthquakes and volcanic eruptions that can trigger tsunamis or form new land over time. Tides, caused by the moon's gravitational pull, make sea levels rise and fall each day, shaping shorelines and coastal ecosystems.

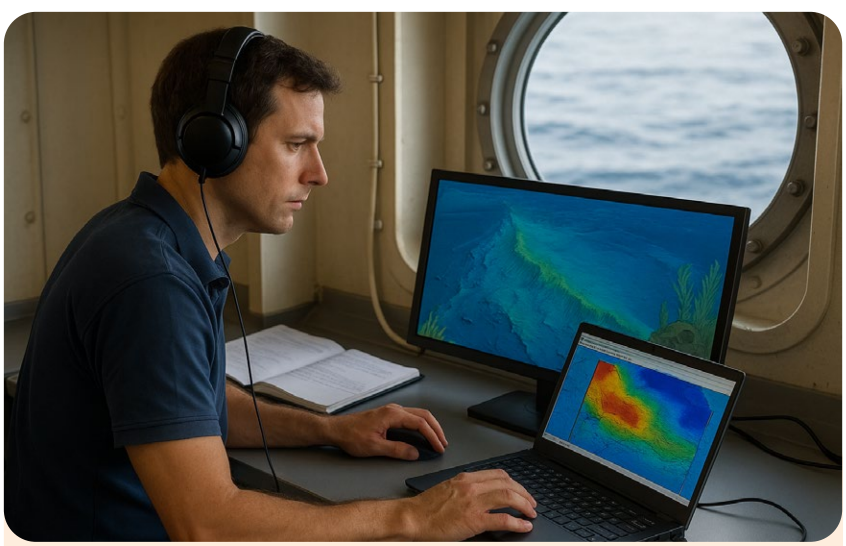


Watch

Video 1-1: 20 Amazing Ocean Facts about the Ocean

Oceanography

Understanding the natural and physical processes of our ocean-covered planet requires learning about oceanography. **Oceanography** explores the ocean as a system, encompassing the fields of marine geology, marine chemistry, physical oceanography, and marine biology. By integrating these areas of study, oceanography helps us uncover the complex interactions that shape our oceans and sustain life on Earth.



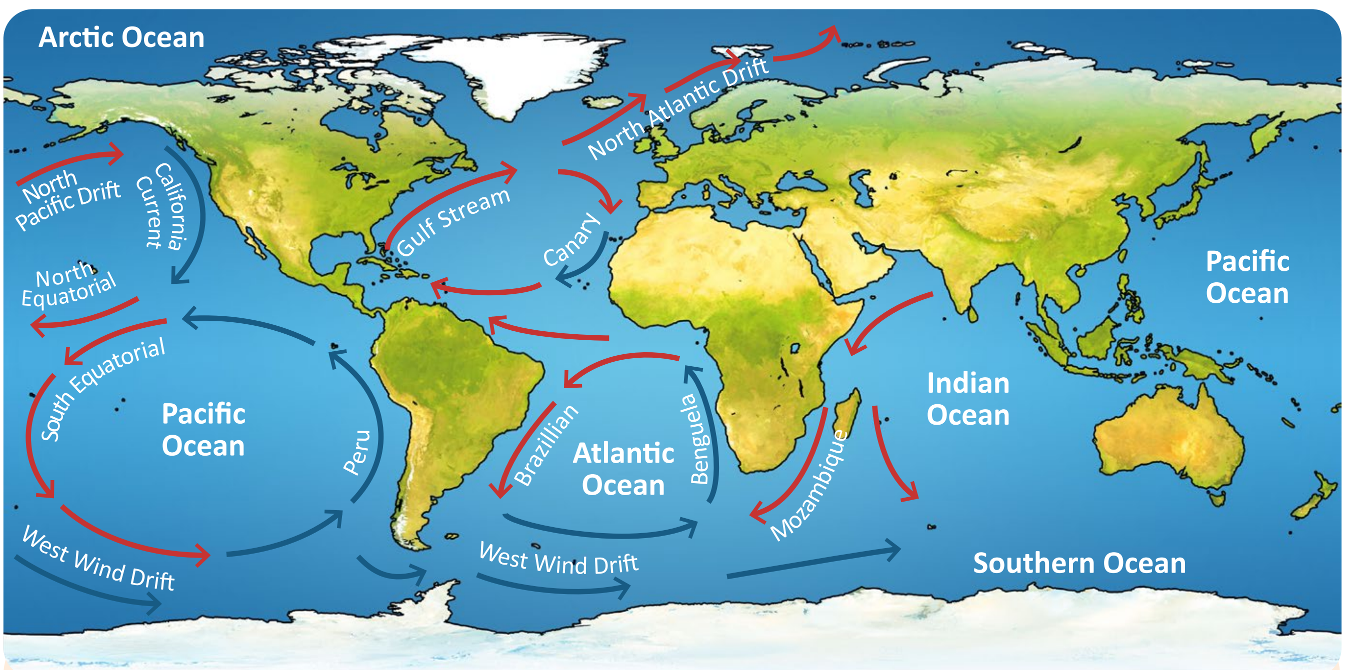
This oceanographer is studying marine geology while mapping the ocean floor.

Marine geology focuses on the structures of the ocean floor, including underwater volcanoes, deep-sea trenches, and layers of sediment that build up over time. By studying these features, scientists learn about Earth's geological history and how the ocean floor has changed over millions of years. Processes such as volcanic eruptions, earthquakes, and sediment movement that slowly shape the seafloor are also studied.

A marine chemist might study how the changing chemistry of the ocean is affecting marine organisms.

Marine chemistry focuses on the chemistry of seawater and the substances found in it. Marine chemists study how these substances interact with each other, marine life, and the physical and geological processes of the ocean. They also investigate how human activities, such as pollution and climate change, affect the ocean's chemistry, including oxygen levels, acidity, and nutrient cycles. By studying these changes, marine chemists help us understand how to protect and preserve ocean ecosystems.

Physical oceanography is the study of how the ocean moves and changes. It focuses on currents, waves, and tides. Physical oceanographers study how these processes work together to move water, affect weather and climate, and support marine life. They also examine how conditions vary at different depths. Their work helps us understand the powerful systems that shape our ocean-covered planet.



Oceanographers study how currents in the ocean affect climate and weather.

Marine biology is the study of life in the ocean, focusing on how species adapt to saltwater environments, find food, reproduce, and survive. Marine biologists also study how marine organisms interact with each other and their surroundings, helping us understand the delicate balance of life in our oceans.

HOW DO YOUR LIMBS MOVE?

When you study marine biology, you will learn interesting facts, like how whales swim. Whales are mammals, just like you are. Think about how you move your arms and legs when you swim. Is the way you move your limbs more like how a whale swims or how a fish swims? What about the way you walk? Do you walk side-to-side or back-and-forth? Think about other species of mammals, and how whales move in comparison. Even though whales now live in water, they retain the basic body plan and movement patterns of their land-dwelling ancestors.

Watch

Video 1-2: How Whales Move

SCIENTIST SPOTLIGHT: SYLVIA EARLE

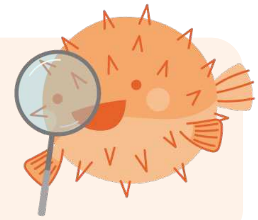
Sylvia Earle is a famous marine biologist and oceanographer known as "Her Deepness" for her record-breaking dives. In 1979, she set a world record by diving 1,250 feet (381 meters) solo in a special diving suit off the coast of Hawaii. This was deeper than anyone dived before or since. Over her career, Earle has led more than 50 expeditions and spent over 7,000 hours underwater. She was the first woman to serve as chief scientist for NOAA (National Oceanic and Atmospheric Administration) and has tirelessly advocated for **Hope Spots**, which are protected marine areas worldwide. Earle believes understanding the ocean helps us protect it for future generations.

Fun Fact: Sylvia Earle once lived underwater for two weeks as part of an experiment called **Tektite II**, where scientists studied ocean ecosystems up close. She and her team were known as "aquanauts" and were among the first to spend an extended period living and working beneath the waves!

Earle displays samples from Tektite II.
Photo credit: NOAA

Thought Question

If you could explore any part of the ocean, where would you want to go and why?



Interconnecting Spheres

Scientists often divide Earth into four connected spheres: the **hydrosphere** (water), **atmosphere** (air), **geosphere** (solid earth), and **biosphere** (all living things).

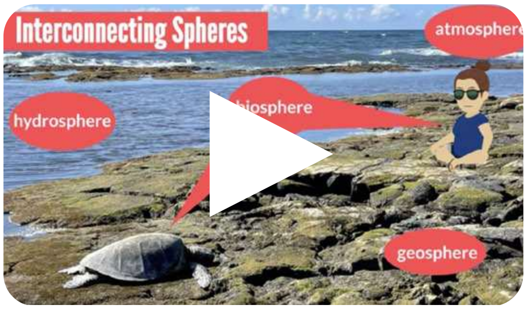
While the focus of this course is on the hydrosphere, you will learn that the ocean is closely connected to the other three spheres, creating a dynamic, interconnected planet.

Kaloko-Honokōhau National Historical Park

Imagine standing at the Kaloko-Honokōhau National Historical Park on the north Kona coast of Hawai'i, surrounded by these four spheres. The air the turtles and you breathe is part of the **atmosphere**. The ocean influences the atmosphere in powerful ways. Look up at the clouds floating in the sky. Those clouds are made of water, likely evaporated from the nearby ocean, now floating miles above in the atmosphere. This air layer also contains molecules that protect the planet from harsh solar radiation, a fortunate shield for the turtles sunning on the shore.

Then there is the **geosphere**. It includes the rocks, soil, sand, and lava that make up the island of Hawaiʻi. The crashing waves break down bits of this solid Earth. These rocky fragments, called **sediments**, are swept along the coastline and eventually settle on the ocean floor. This ongoing process not only shapes the shoreline but also affects ocean chemistry in ways essential to marine life.

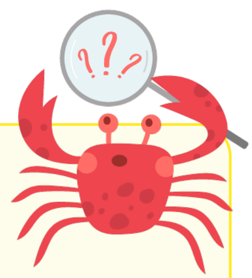
The turtles (can you see both?) and green algae on the rocks are part of the **biosphere** that depends on the ocean. In this course, you'll explore the many forms of life that call the ocean home, from tiny plankton drifting in the water to large predators like sharks and orcas. Some organisms, such as coral and sponges, attach to the seafloor, while others, like turtles and fish, move freely through the water. Each plays a role in the marine food web, helping to keep ocean ecosystems in balance.



Watch

Video 1-3: Interconnected Spheres

An **ecosystem** is a community of living things, including plants, animals, and tiny organisms, that interact not only with each other but also with the **nonliving parts of their environment**. Thinking about Earth as a system of **interconnected spheres** – the **atmosphere** (gases), **biosphere** (life), **hydrosphere** (water), and **geosphere** (land) – helps us understand that ecosystems are dynamic units within these larger spheres. For example, a forest ecosystem (part of the biosphere) relies on rainfall from the hydrosphere, gases from the atmosphere, and nutrients from the geosphere. These interactions drive the flow of energy and the cycling of matter within the ecosystem.



Check for Understanding

Image Credit NASA

Did you know that Earth is nicknamed the **"Blue Marble"**? It got this name because of how it looks from space. The bright blue color you see in the photo comes from the ocean. Even the white, swirling clouds are made of water!

On Earth, all living things need water—including humans. That's why, when scientists at NASA look for life on other planets, they search for signs of water.

In the photo there are **three spheres you can see and one you cannot**. From the list, label the three spheres you can see and name the one that is not visible.

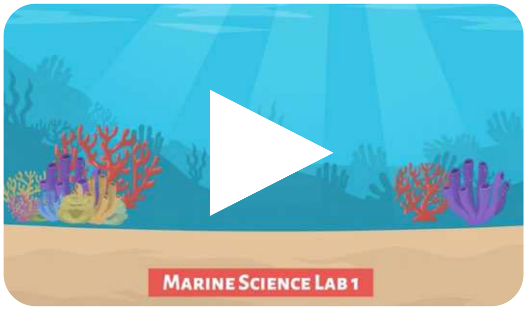
List: Hydrosphere, Atmosphere, Geosphere, Biosphere

Hint: *Clouds are part of the hydrosphere. They are also part of another "sphere."*

How many of Earth's spheres can you observe in your backyard? Next time you step outside, look closely for examples of each one. Can you find a place where water, plants, animals, air, and rocks all come together?

LAB 1:

Water Cycle Lab



Watch

Chapter 1 Lab: Modeling the Water Cycle

Water: Everywhere and Essential

You might not realize it, but water is all around you. Every organism, including you, contains water in every one of its cells. Water is also in the air you breathe and in the ground below you, as **groundwater**. Since Earth's formation, over 4.56 billion years ago, water has continuously cycled through the environment.

Understanding Evaporation, Condensation, and Precipitation

The movement of water through Earth's environment is called the **water cycle**. The three main processes that drive this cycle are evaporation, condensation, and precipitation.

- **Evaporation** happens when the sun heats water, turning it into vapor or steam that rises into the air.
- **Condensation** occurs when the vapor cools, changing back into tiny droplets of liquid water and forming clouds.
- **Precipitation** happens when these droplets grow too heavy to stay in the air and fall to Earth as rain, snow, sleet, or hail.

Each stage of the water cycle helps distribute water across Earth, keeping ecosystems alive and balanced.

The Role of Scientific Models

In this lab, you will create a **scientific model** to explore how water moves through the water cycle. Your model will show water transitioning through its different states: solid (ice), liquid, and gas (vapor). Using a lamp to mimic the sun, you will observe how heat causes evaporation and how cooling leads to condensation.

Scientific models like this one help us study complex systems by recreating them in a simpler way. By observing and interacting with the model, you will gain a better understanding of the processes that drive the water cycle, including evaporation, condensation, and precipitation.

You will also add salt to your model to investigate whether salt moves with water as it evaporates. Does the condensation remain salty or is it fresh? Think about how rain or snow tastes. What do you think will happen to the salt in the water cycle?

MATERIALS

- ☐ Clear plastic container (large enough to hold water and a small funnel)
- ☐ Plastic wrap (to cover the container tightly)
- ☐ Desk lamp with a heat-producing bulb (to simulate the sun)
- ☐ Measuring cup (for accurate water measurement)
- ☐ Teaspoon (for measuring salt)
- ☐ Warm water (enough to fill the container to a depth of 2 inches)
- ☐ Salt (2 teaspoons for every 1 cup or 250 mL of water)
- ☐ Spoon (for stirring and dissolving salt)
- ☐ Ice (1½ cups, with more available if needed for extended observations)
- ☐ Small zip-top bag (filled with 1 cup of ice)
- ☐ Short funnel or a small, tall container like a glass spice bottle (to mimic a mountain or drainage point)
- ☐ Lab sheet and pencil (for recording observations and data)
- ☐ Optional: Food coloring (to make the water more visible)
- ☐ Optional: Ruler (for measuring water depth)
- ☐ Optional: Tape (to secure plastic wrap in place)

PROCEDURE

1. **Optional: Mark the Container**
   From inside the container, measure 2 inches from the bottom and mark the spot to guide your water measurement.

2. **Measure the Water**
   Use the measuring cup to pour water into the container until the water reaches a depth of 2 inches. For easier calculations, round measurements to whole numbers. A slight variation in depth is acceptable.
   - Record the amount of water used to reach the 2-inch depth on the lab sheet.
   - Taste the water and describe its flavor on the lab sheet.
   - Use the calculation section on the lab sheet to determine the amount of salt needed.

3. **Prepare the Saltwater**
   Add the calculated amount of salt to the water and stir until the salt dissolves.
   - Taste the saltwater and record your observation on the lab sheet.
   - (Optional) Add 10 drops of food coloring to make the water more visible.

4. **Set Up the Funnel**
   Place the funnel or improvised funnel (e.g., a spice bottle) inside the container, positioning it against one corner so it stands upright and stable.
5. **Taste the Ice**
   Taste a piece of ice and describe its flavor on the lab sheet.
6. **Add Ice to the Saltwater**
   Place 1½ cups of ice directly into the saltwater in the container.
7. **Light and Heat**
   Cover the container tightly with plastic wrap. Position the desk lamp so it shines directly onto the surface of the water. Ensure the lamp is close enough to warm the container but not so close that it becomes a safety hazard.
8. **Optional: Secure the Plastic Wrap**
   Use tape to secure the plastic wrap to the edges of the container if needed.
9. **Prepare the Lid**
   Place the zip-top bag, filled with 1 cup of ice, on top of the plastic wrap, centered over the container. This simulates a cold cloud layer above a warm ocean.
10. **Start Observations**
    Turn on the lamp. **Caution**: The lamp will become hot during use.
    - Write your hypothesis on whether the condensation (simulated rain) will be saltwater or freshwater.
    - Draw your setup on the lab sheet.
11. **Monitor Changes**
    Check the setup at intervals of 30 minutes, 60 minutes, and 2 hours.
    - Observe and record when condensation forms on the underside of the plastic wrap and starts to drip back into the container or funnel.
    - If the ice melts, add more ice to the bag.
    - If condensation is slow to form, leave the setup overnight. If you do so, turn off the lamp.
12. **Taste the Condensation**
    Once enough condensation has formed, carefully collect a sample and taste it. Record your observation on the lab sheet.
13. **Discussion and Conclusion**
    Complete the lab sheet. Then, discuss the following:
    - Why is the condensed water not salty? (Salt does not evaporate with water).
    - How does this explain why rain is fresh, even when it comes from ocean water?
    - What is the role of the ice on the lid? (It represents cooler atmospheric temperatures.) What might happen if this ice melted into a saltwater body?
14. **Save the Saltwater**
    Remove 1 cup of saltwater from the container and set it aside for use in Chapter 3. Do not cover it or add more water.

Modeling the Water Cycle: Lab Sheet

MEASUREMENTS AND CALCULATION

Amount of Water Measured (cups): ______________________

For every cup of water, add two teaspoons of salt. Use the formula below to calculate how much salt to add:

Number of cups * 2 = ______________________ teaspoons of salt

DATA AND OBSERVATIONS

Record your observations as you taste and examine each part of the experiment:

Taste	Observation
Freshwater	
Saltwater	
Ice	
Condensation	

HYPOTHESIS AND SETUP

Hypothesis on Condensation: Complete the following sentence.

I predict the condensation will be____,

because ____

____

____

____.

Setup Drawing or Photo: Draw a picture or take a photo of your setup.

CONDENSATION MONITORING

Record the time when condensation first appears: ________________________________

Describe the changes observed over time: ______________________________________

Did you see "rain" in your container?

If yes, do you think the "rain" is freshwater or saltwater? Complete the following sentence:

I think the rain is ____________________________, because _______________________

____

____.

DISCUSSION AND CONCLUSION

The Water Cycle

1. How does the amount of heat from the lamp affect how quickly evaporation happens?

   ____

2. You should have observed condensation and precipitation.
   - **Where did you see condensation?**

     ____

     ____

   - **Where did you see precipitation?**

     ____

     ____

Relating this Model to the Atmosphere, Hydrosphere, and Geosphere

Atmosphere

The lamp acts like the sun, warming the water in the container and causing it to evaporate, turning from liquid to gas.

- How does this relate to the formation of rain and snow? *(Hint: Think about what happens to water vapor when it cools.)*

  ____

  ____

  ____

- What do you think would happen if you moved the lamp closer to or farther away from the water? Why?

____

____

____

Hydrosphere

The water in the container models the ocean, and the salt added represents the average salinity of ocean water.

- How do oceans help influence weather?
  (Hint: Think about the sun's effect on the ocean.)

____

____

____

Geosphere

The funnel models a mountain, and the condensation dripping down the funnel represents rainwater traveling over the geosphere.

- How might minerals and salts from the geosphere dissolve into the water, affecting its composition?

____

____

____

Real-World Applications

Changes on our planet, like melting ice and rising sea levels, show how all these factors are interconnected.

- What might happen to places that rely on glaciers for water if the glaciers melt? Why?

____

____

____

Chapter 5

Diving through Ocean Zones

Imagine diving through the ocean's surface to the bottom. At first, sunlit water surrounds you. But as you go deeper, light fades, the temperature drops, and the pressure from the water above you builds. Eventually, you reach a depth where sunlight no longer penetrates. The water is near freezing, and the pressure is so high it is dangerous for a human without specialized equipment.

In this chapter, you'll see how those physical forces shape where and how marine organisms survive. To study these changes, scientists divide the ocean into zones that help explain why conditions, and the life they support, differ from the surface to the seafloor.

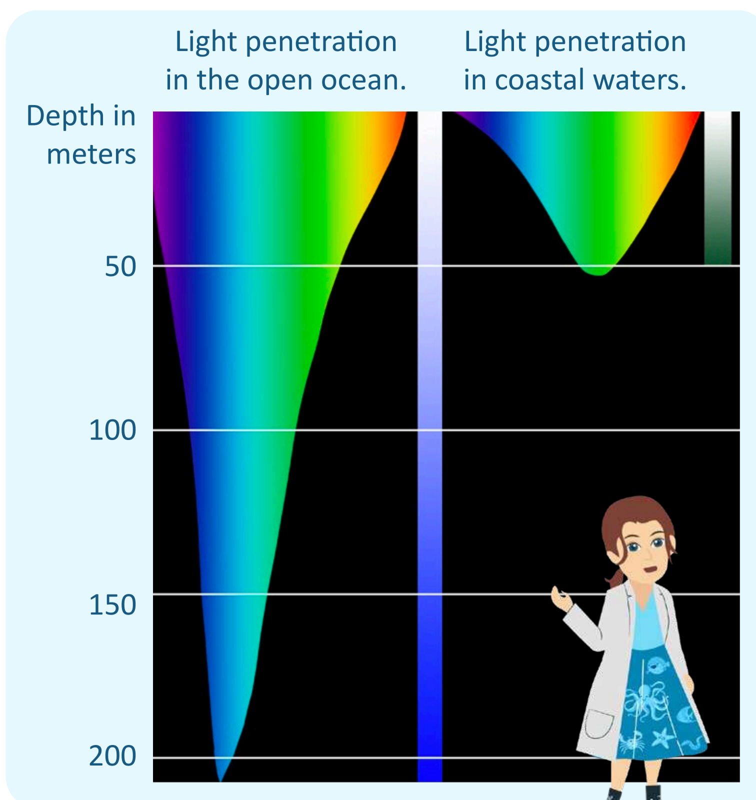
Light and Energy: The Power of the Sun

Watch

Video 5-1: Sunlight Through Water

In the ocean's uppermost layer, the **sunlight zone,** photosynthesis supports a wide range of marine life. However, this zone makes up only about 3 to 5% of the ocean's volume, and photosynthesis happens only where sunlight can reach.

Below the sunlight zone, where light is absent, some organisms rely on organic matter that sinks from above. Others depend on **chemosynthesis**, a process in which bacteria use chemical energy from compounds like **hydrogen sulfide** instead of light to fuel the chemical reaction that makes food.

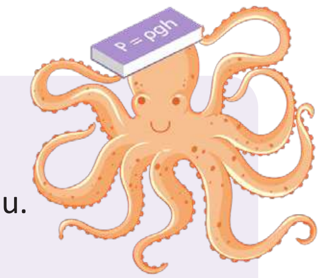


Depth and Pressure: The Weight of Water

The deeper you go, the greater the pressure. That is because the weight of the water above increases. At sea level, the pressure is 1 atmosphere. Every 10 meters (33 feet) deeper adds another atmosphere of pressure.

By the time you reach the **Hadalpelagic Zone,** more than 6,000 meters deep, the pressure is so extreme it could crush a submarine without proper protection. These extreme pressures affect the types of organisms that can survive in the deep ocean.

HANDS-ON LEARNING



You can explore how pressure builds when something presses down from above, just like the water does in the ocean, by layering books on top of you.

You will need a stack of books, a blanket (optional), and another person.

Instructions

1. Lie down on your back. If you're using a blanket, have it draped over you.
2. Ask your partner to gently place books one at a time on your torso.
3. Pay attention to how the pressure increases as more books are added. Can you feel the weight pressing down?

MATH IN CONTEXT

At sea level, you experience 1 atmosphere of pressure. For every 10 meters (33 feet) you go deeper, the pressure increases by 1 atmosphere.

Formula for Calculating Pressure at Depth:

1. Divide the depth (in meters) by 10.
2. Add 1 (for the atmosphere of pressure at sea level).

Example:
How much pressure would you experience at 100 meters?

1. 100 ÷ 10 = 10 (added atmospheres)
2. 10 + 1 = 11 atmospheres

Answer: At 100 meters, you would experience 11 atmospheres of pressure.

Practice Problems:
Use the formula to calculate the pressure at the following depths:

1. How many atmospheres of pressure would you feel at 500 meters?

2. How many atmospheres of pressure would you feel at 1,000 meters?

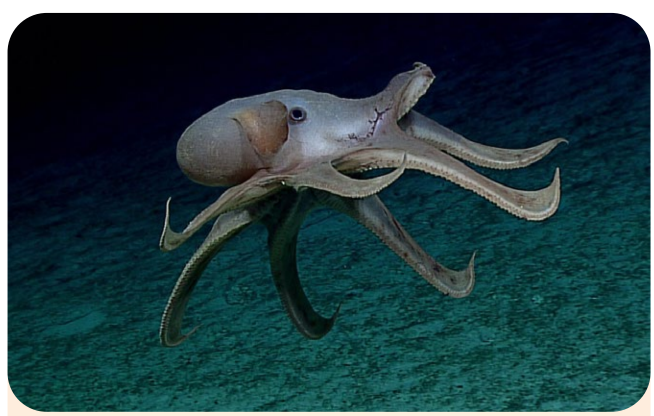
The deep-sea siphonophore Marrus orthocanna has a flexible body that can withstand high pressure at depth.

The Major Ocean Zones

There are five major ocean zones. Each zone has both **pelagic** (open water) and benthic (seafloor) sections. **Pelagic organisms** swim or drift through the water column. **Benthic organisms** live on or in the seafloor. This difference—between drifting or swimming in open water and living on the seafloor—is one way scientists classify marine life, no matter the depth.

For example, a Whiplash Squid swimming through the Midnight Zone is considered a pelagic organism. A Dumbo Octopus crawling along the bottom of the Midnight Zone is considered a benthic organism.

The Whiplash Squid is a pelagic organism.



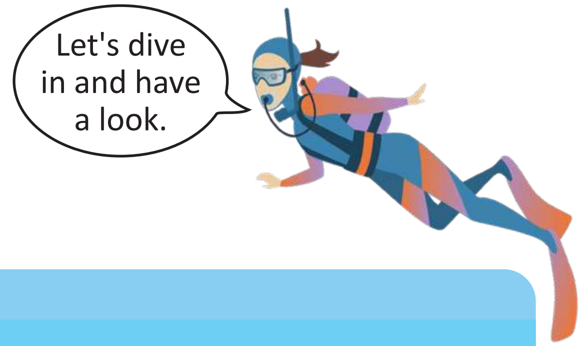
The Dumbo Octopus is a benthic organism.

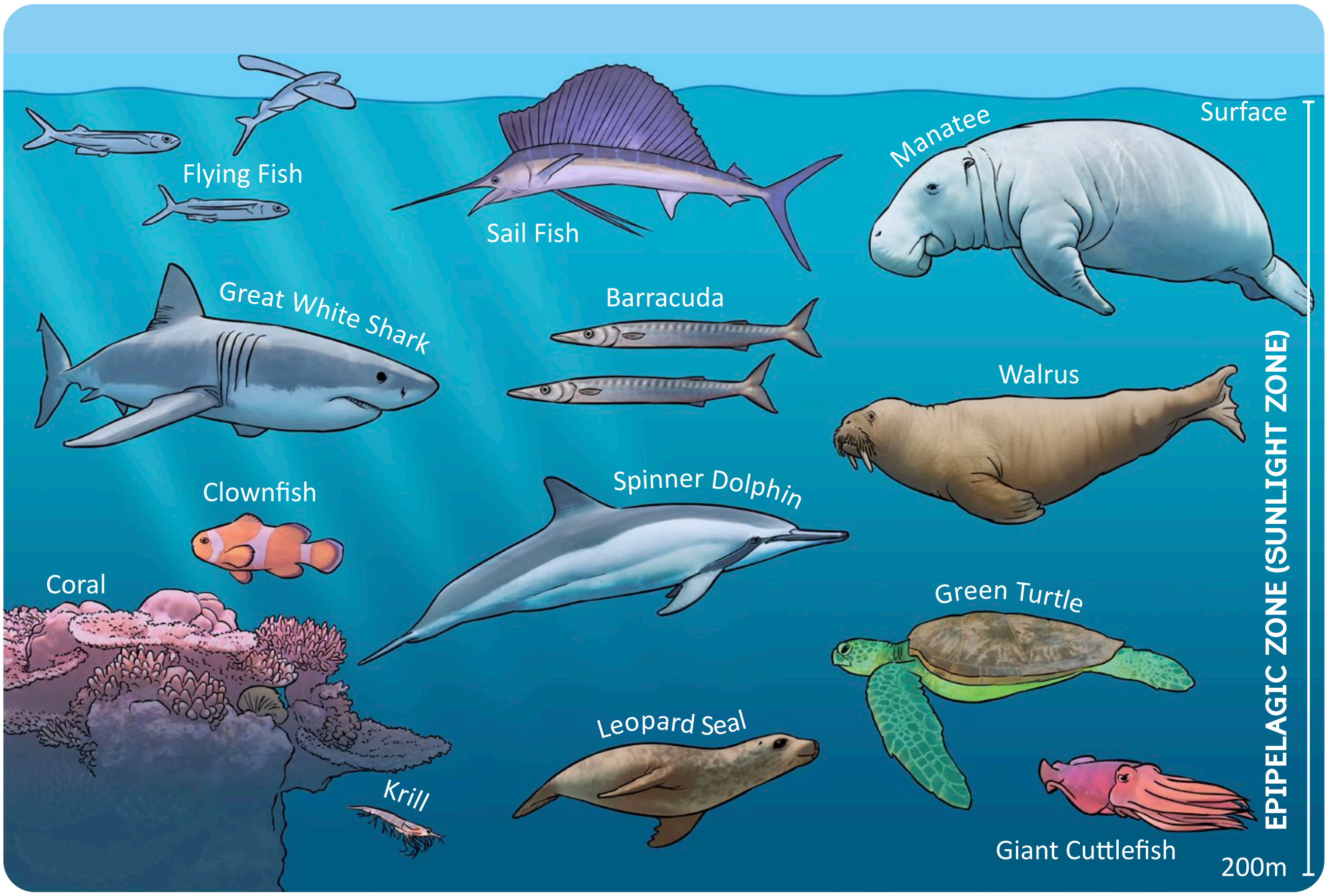
Images courtesy of Journey into Midnight: Light and Life Below the Twilight Zone.

1. EPIPELAGIC ZONE (SUNLIGHT ZONE)

Epi-: meaning "upon" or "at the surface"

Pelagic: meaning "open sea"





The **Epipelagic Zone, or Sunlight Zone**, stretches from the **surface to 200 meters (650 feet)**. It has the warmest temperatures, lowest pressure, and least dense water of any ocean zone. These conditions support mixing and drive surface currents that help transport heat and nutrients around the globe.

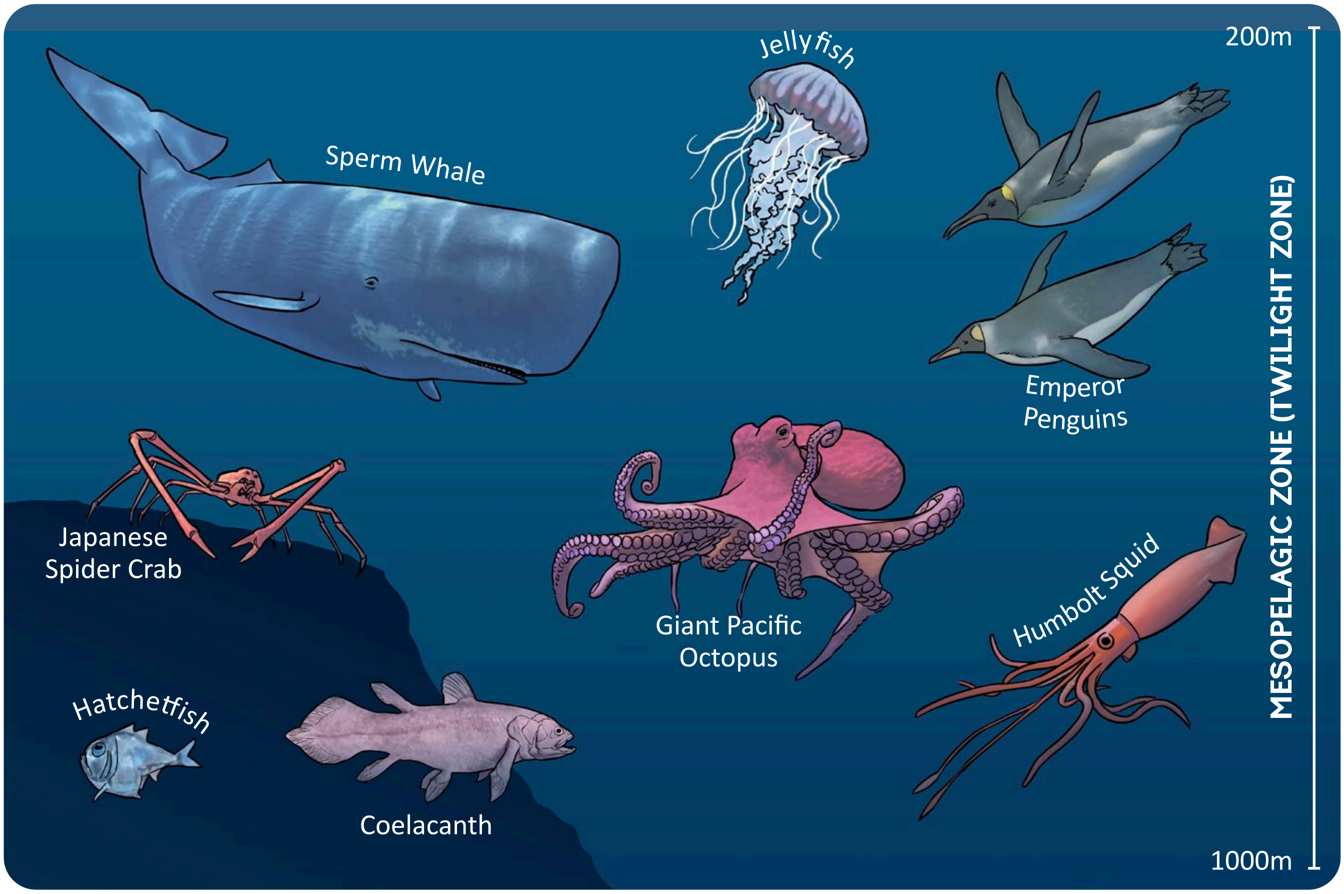
Abundant sunlight fuels photosynthesis, making this zone rich in life. The Epipelagic Zone plays a critical role in Earth's systems. Scientists estimate that up to **50% of the oxygen we breathe is produced through photosynthesis in this zone**, making it essential to the planet's health.

Watch

Video 5-2: O_2 and Life in the Sunlight Zone

2. MESOPELAGIC ZONE (TWILIGHT ZONE)

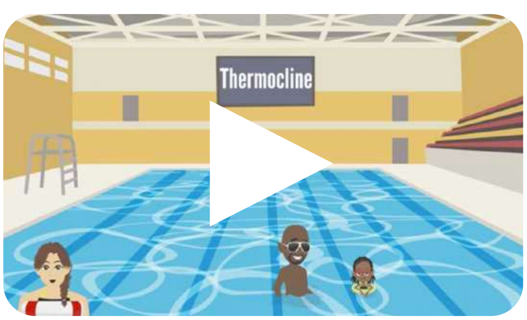
Meso-: meaning "middle"



The **Mesopelagic Zone**, or **Twilight Zone**, extends from **200 to 1,000 meters (650 to 3,300 feet)**. Light fades quickly here, with only dim blue-green wavelengths reaching this depth, too little for photosynthesis.

As depth increases, pressure builds, and temperature drops rapidly. This zone includes the **thermocline**, a boundary layer where temperature changes rapidly. Water becomes colder and denser, and internal waves along the thermocline help transport nutrients downward.

Though sunlight is scarce, life is abundant. The Mesopelagic Zone acts as a link between surface productivity and the deep ocean, supporting nutrient cycling and global carbon movement.

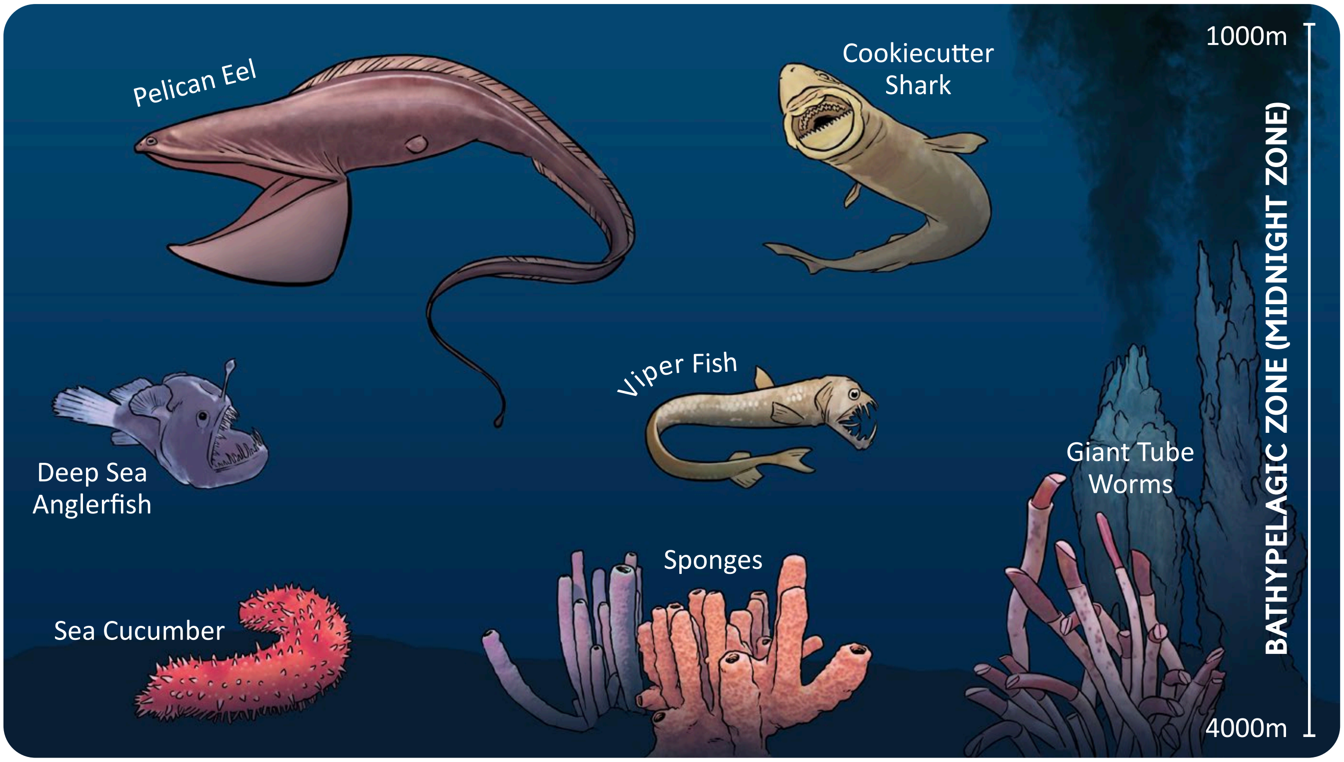


Watch

Video 5-3: Thermocline

3. BATHYPELAGIC ZONE (MIDNIGHT ZONE)

Bathy-: meaning "depth" or “deep”



The **Bathypelagic Zone**, or **Midnight Zone**, stretches from **1,000 to 4,000 meters (3,300 to 13,000 feet) deep**. No sunlight reaches this zone, leaving it in total darkness.

Temperatures are **just above freezing (0–4°C or 32–39°F)**, and pressure is hundreds of times greater than at the surface.

Without sunlight, organisms rely on food drifting down from above or on chemical energy from the seafloor. Many species move slowly, conserve energy, and have adaptations to survive extreme pressure and low food availability.

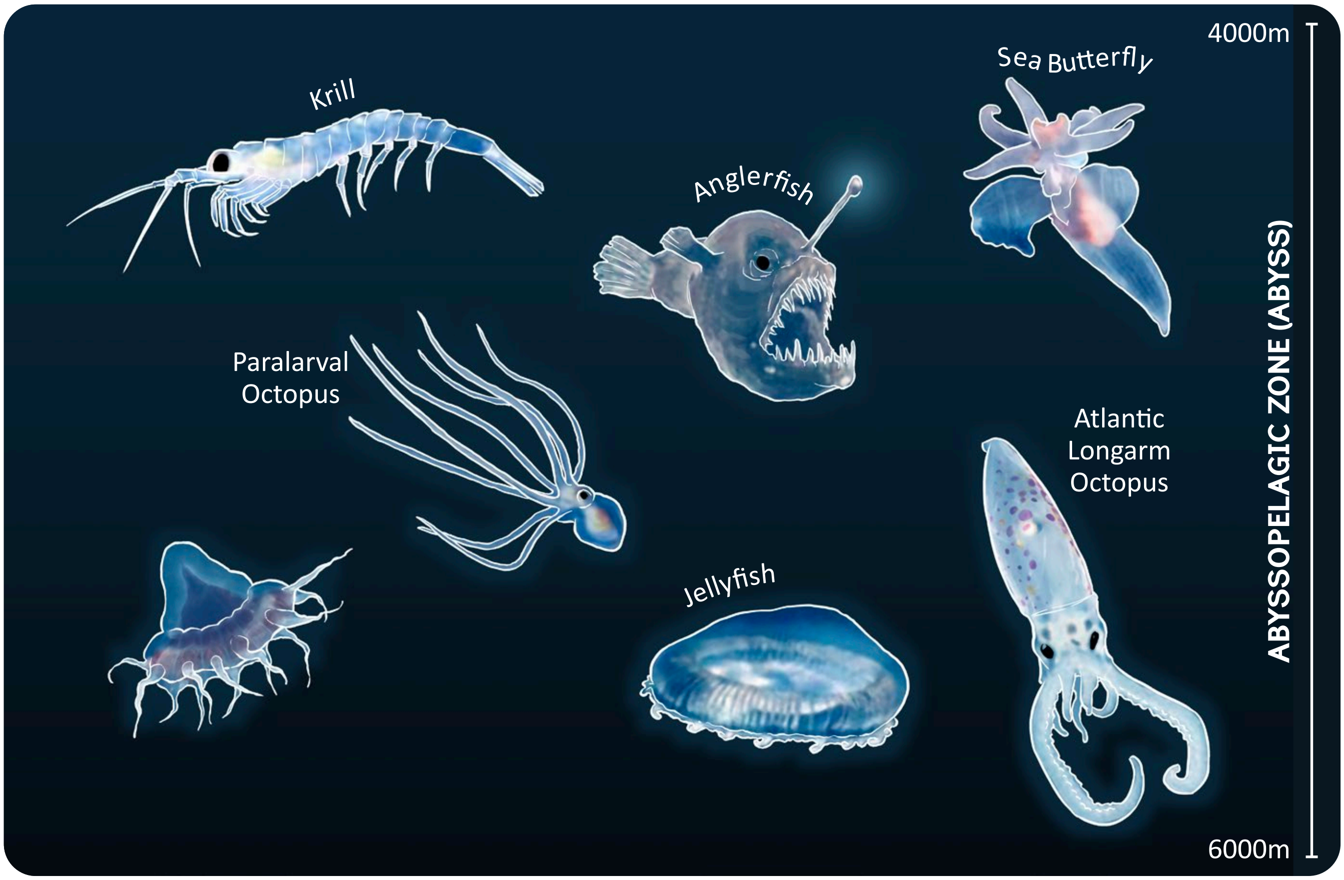
The Bathypelagic Zone plays a key role in the **global conveyor belt (thermohaline circulation)** described in Chapter 4. Cold, salty water sinks and flows along the ocean floor, helping move nutrients and oxygen across the globe and supporting deep-sea ecosystems.

Watch

Video 5-4: Global Conveyor Belt and the Deep Ocean

4. ABYSSOPELAGIC ZONE (ABYSS)

Abysso-: meaning “bottomless” or “immeasurably deep”



The Abyssopelagic Zone, or Abyss, ranges from **4,000 to 6,000 meters (13,000 to 20,000 feet)** and stretches across much of the deep ocean floor. This zone is in complete darkness. Temperatures are **near freezing**, typically between **0–3°C (32–37°F)**, and pressure is more than 600 times greater than at sea level. The water here is cold, dense, and extremely stable, with minimal vertical movement between layers.

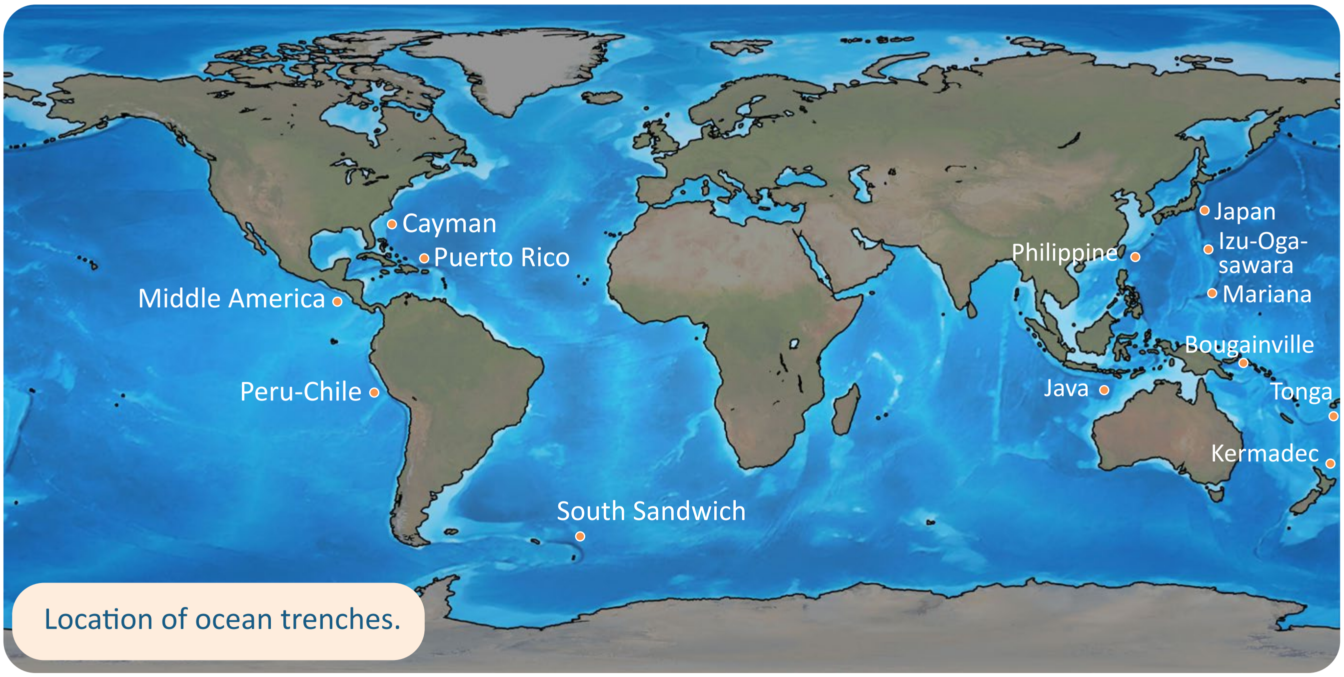
Although energy is scarce in most parts of the Abyss, some regions host hydrothermal vents. Around these vents, entire ecosystems thrive without sunlight.

Elsewhere in the Abyss, organisms survive by feeding on marine snow and the remains of animals that sink from higher layers. These slow, cold conditions allow organic matter to break down gradually, making this zone important for carbon storage and global climate regulation.

5. HADALPELAGIC ZONE (TRENCHES)

Depth: Greater than 6,000 meters (20,000 feet)

Hadal-: meaning “pertaining to the underworld” or “the deepest parts”



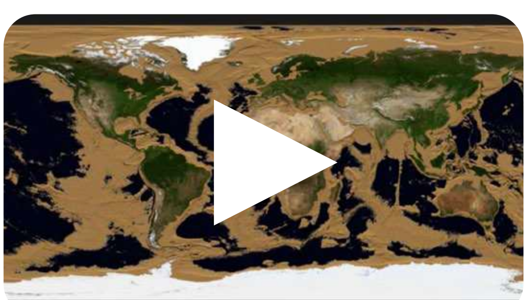
Location of ocean trenches.

The Hadalpelagic Zone, named after **Hades**—the Greek god of the underworld—includes the ocean trenches deeper than **6,000 meters (over 20,000 feet)**. Though it makes up less than 2% of the ocean, this zone holds Earth’s deepest locations, including the Mariana Trench.

No sunlight penetrates this zone. **Temperatures remain near freezing**, and pressure surpasses 1,000 times that of the surface. The water is extremely dense due to the combination of intense pressure and cold temperatures.

Many of the organisms who live here are adapted for isolation, feeding on marine snow or the slow accumulation of organic material that sinks from above.

Despite its small size, the Hadal Zone plays an important ecological role. It stores carbon and organic debris and may host unique ecosystems still being discovered by deep-sea exploration.



Watch

Video 5-5: Ocean Trenches

SCIENTIST SPOTLIGHT:
DR. EDITH WIDDER

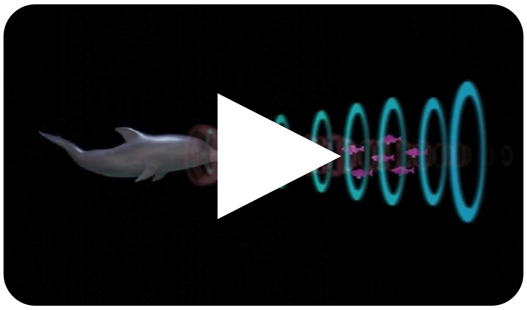
Edith Widder in the Johnson Sea Link submersible.

Dr. Edith Widder is a marine biologist who studies the deep ocean. She co-developed the Eye-in-the-Sea, a special camera designed to capture footage of deep-sea life without disturbing it. Her work led to the first video of a giant squid in its natural habitat, helping reveal life's secrets in the ocean's darkest parts. Dr. Widder's work helps scientists observe life in the Bathypelagic and Abyssopelagic Zones without disturbing it.

Fun Fact: Dr. Widder's research showed that the squid moves with grace and control, not the violent thrashing once assumed. Earlier ideas portrayed it as aggressive, but the video revealed a calm, stealthy approach.

LAB 5:

Tracking Sound Waves



Watch

Chapter 5 Lab: Tracking Sound Waves

Have you ever wondered how animals find food in the pitch-black depths of the ocean? Sperm whales dive thousands of feet into the bathypelagic zone to hunt giant squid. Down here, no sunlight reaches, so the whales can't rely on their eyes. Instead, they use echolocation—sending out clicks that bounce off objects and return as echoes. By listening to these echoes, sperm whales can tell where the squid are, even in total darkness.

Sound is especially powerful in the ocean. Unlike light, which fades quickly in water, sound can travel hundreds of miles. Many marine animals rely on sound to communicate, find food, and avoid predators. Echolocation is one of the most precise tools: animals like dolphins, porpoises, and whales make sounds that return as echoes, giving them a kind of "sound picture" of the world around them.

Humans have borrowed this idea through SONAR (Sound Navigation and Ranging). SONAR sends sound waves through the water to map the seafloor or locate objects. But human-made noise—like ship engines, oil exploration, and underwater explosions—adds extra sound to the ocean. This can confuse or disturb marine animals that depend on sound to survive.

In today's lab, you'll try a sound-location challenge yourself. By closing your eyes and carefully listening for sounds coming from different directions, you'll get a sense of how echolocation helps animals navigate and hunt in the dark ocean.

Materials

- ☐ 1 helper who can snap their fingers
- ☐ 1 blindfold
- ☐ 1 pen or pencil
- ☐ Lab sheets
- ☐ Colored pencils or crayons (for graphing)

Procedure

1. Sit in a quiet location with minimal background noise. Ensure the area is clear so that someone can move freely around you.
2. Place your hand gently on your throat. Make different sounds—high-pitched, low-pitched, loud, quiet, and moderate. Feel how your vocal cords vibrate differently with each sound. Then, make sounds for the letters d, t, b, g, p, s, l, m, h, y, z, and notice the vibrations. Answer the related questions on your lab sheet.
3. Complete the hypothesis section on your lab sheet.
4. The helper should prepare the observation sheet and have a pencil ready to record guesses and results accurately.
5. Sit down in the middle of the location. The helper should stand quietly to avoid giving hints.
6. Put on the blindfold and ensure it blocks out all light. **DO NOT PEEK!**
7. The helper will snap their fingers **three times** at random in each of the following locations:
    - **Front**, **Back**, **Left**, and **Right** sides.
    - Maintain the same distance from the test subject for each snap.
8. After each set of snaps, guess the sound's direction (front, back, left, or right). The helper will record each guess on the observation sheet.
9. Repeat this until there have been **12 snaps total** (3 for each location).
10. Tally the number of correct and incorrect guesses for each direction.
11. Use your results to complete the bar graph in the data section.
12. Answer the conclusion questions and reflect on how echolocation and SONAR use Sound Waves.

Tracking Sound Waves – Lab Sheet Page 1

Learning More Before Making My Hypothesis (Educated Prediction)

1. Did you feel a difference in the vibrations of your vocal cords when you made different sounds? (Circle one): Yes / No
2. Which sounds caused your vocal cords to vibrate the most?

____

3. Which sounds caused your vocal cords to vibrate the least?

____

4. **Hypothesis**: Complete the sentence below:

*I think I **(will / will not)** be able to guess the locations of the Sound Waves coming from four different directions.*

If you think you may not guess all the locations correctly, rank the directions in order from those you assume to be the easiest to those you assume to be the hardest:

- _______________________________ (most likely to be accurate)
- _______________________________
- _______________________________
- _______________________________ (least likely to be accurate)

Lab Sheet Page 2: Observations

Record the guesses made during the lab in the table below. The helper should snap three times for each direction but mix up the order. For each snap, write down the guess as "Front," "Back," "Left," or "Right," then mark whether the guess was correct or incorrect.

Location	Guess	Right?	Wrong?
Left side			
Front			
Back			
Right side			
Right side			
Back			
Left side			
Back			
Front			
Left side			
Front			
Right side			

Lab Sheet Page 3: Results & Graphing the Data

Tally the Data

Calculate the total number of correct and incorrect guesses for each direction and fill in the table below:

Direction	Correct Guesses	Incorrect Guesses
Front		
Back		
Left side		
Right side		

Graphing the Data

In the bar graph below, color in the total number of correct guesses for each direction. Use a different color for each bar. Leave the column blank if there are no correct guesses.

3				
2				
1				
	Front	Back	Left side	Right side

Lab Sheet Page 4: Conclusion

1. Which direction had the highest number of correct guesses?

   ____

2. Which direction had the lowest number of correct guesses?

   ____

3. Was your hypothesis correct?
   (Circle one): Yes / No

4. Were some directions easier or harder to identify than others? What factors do you think contributed to this difference?

   ____

   ____

5. After learning about Sound Waves, do you think SONAR and human made noise are a problem for ocean animals? Why or why not?

   ____

   ____

Chapter 10

Coral Reefs

Coral reefs are biodiverse coastal ecosystems that provide food and shelter to millions of species. They exist in shallow, nutrient-poor waters near the equator, yet they teem with life.

Large ecosystems, like coastal ecosystems, are made up of many smaller ecosystems. It's a bit like a city made up of different neighborhoods. Each one has its own look and feel, but they are all part of the same city. Coral reefs are a great example of this. They are part of the coastal ecosystem.

Hard and Soft Coral

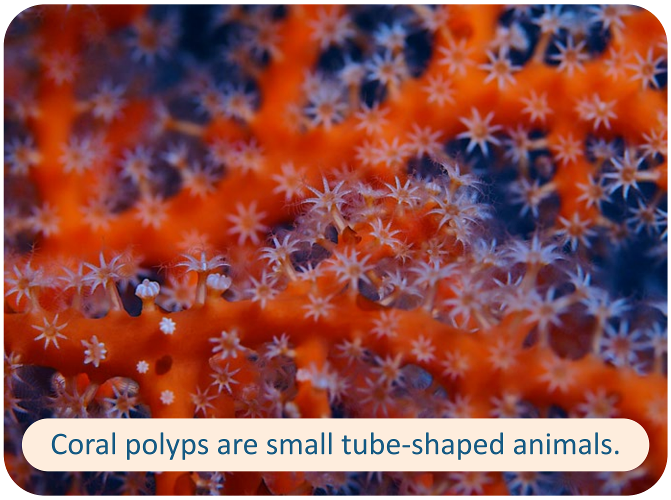
Coral reefs are built by small tube-shaped animals called **coral polyps** that attach themselves to hard surfaces in the ocean. Over time, they grow in colonies, creating large structures that provide food and shelter for thousands of marine species.

There are two main types of corals: hard corals and soft corals.

Hard corals are the reef builders. They create skeletons out of calcium carbonate, the same material that makes limestone. As colonies of hard coral grow together, they form the strong, rocky foundation of coral reefs, providing shelter for fish, crabs, sea turtles, and many other organisms.

Soft corals do not build stony skeletons. Their outer layers are supported by a flexible protein called **keratin**, the same material found in your hair and nails. Soft corals sway with the movement of the water and create additional places for marine life to live and hide within the reef.


Hard Corals at the Great Barrier Reef, Australia.

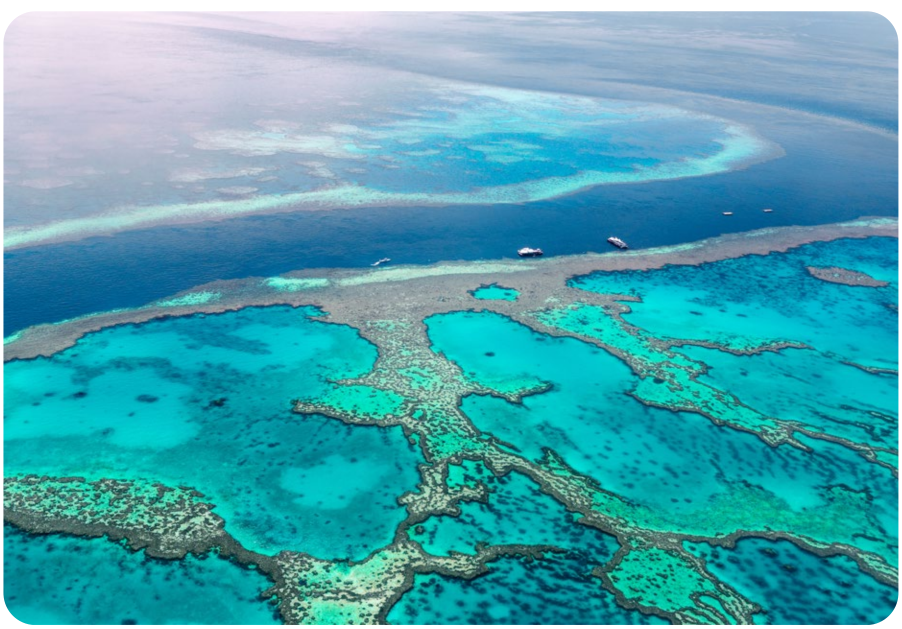

Coral polyps are small tube-shaped animals.

Coral Reef Formations

Coral reefs can form in different shapes, depending on where and how they grow. There are three main types of reef formation: fringing reefs, barrier reefs, and atolls. Each type of reef supports diverse marine life and plays a role in its coastal ecosystem.

Fringing reefs grow directly from a shoreline and are common around volcanic islands like those in Hawai'i.

This aerial photo shows the fringing reefs that encircle the island of Mauritius. These reefs protect it from the sea, forming shallow lagoons between the land and the reef.

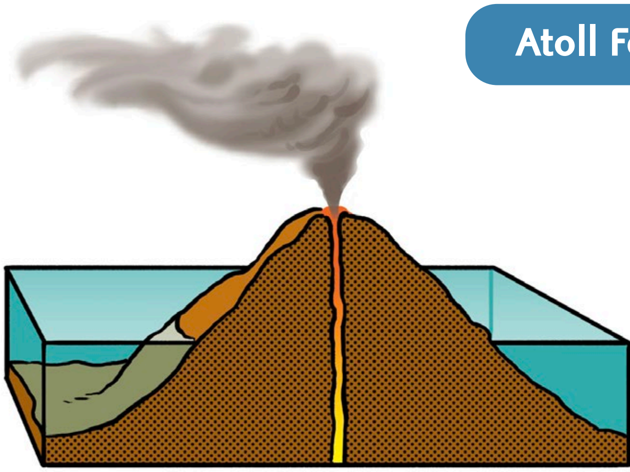


Barrier reefs also form along shorelines, but they are separated from the land by a lagoon of open water. The most famous example is the **Great Barrier Reef** off the coast of Australia, which is so large it can even be seen from space.

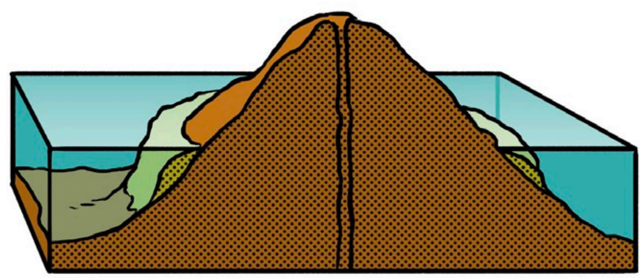
Atafu Atoll in Tokelau: *Photo Credit: NASA*

Atolls are ring-shaped coral reefs that surround a central lagoon. They begin as fringing reefs along the edges of volcanic islands. Over millions of years, as the volcanic island sinks and erodes, the coral continues to grow upward toward the sunlight. Eventually, the island disappears below the surface, leaving behind a ring of coral around a shallow lagoon. A classic example is the **Atafu Atoll** in **Tokelau**.

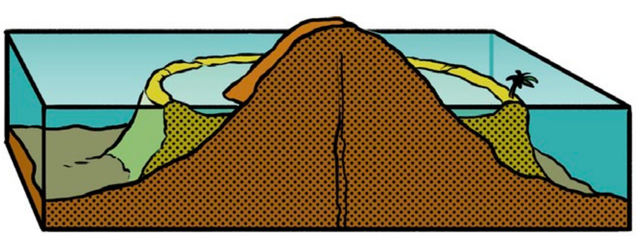
Atoll Formation



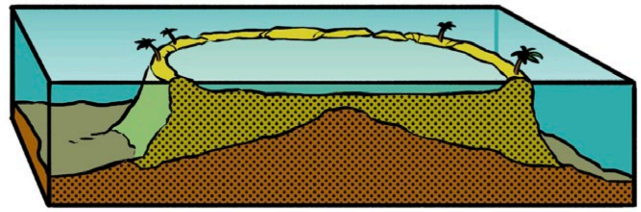
1. An underwater volcano pierces the surface of the ocean.



2. A coral reef forms around the volcano island.



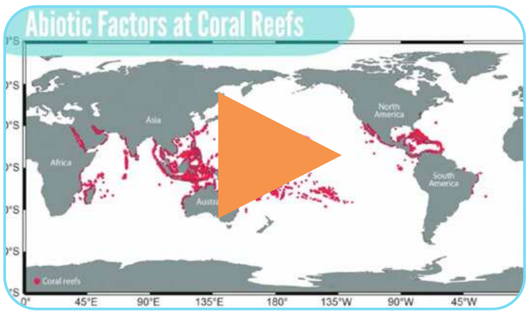
3. A fringing reef surrounds a volcanic island as it erodes.



4. A barrier reef protects a lagoon as the island completely erodes.

Abiotic Factors in Coral Reefs

Coral reefs depend on very specific abiotic conditions to survive. They need a hard surface to anchor and grow. The water must be salty and stable; too much freshwater from rain or rivers can stress or kill the corals. Reefs thrive in warm tropical waters, but even slight temperature increases can cause coral bleaching. Moderate wave action supports reef health, though strong storms can break apart coral structures.

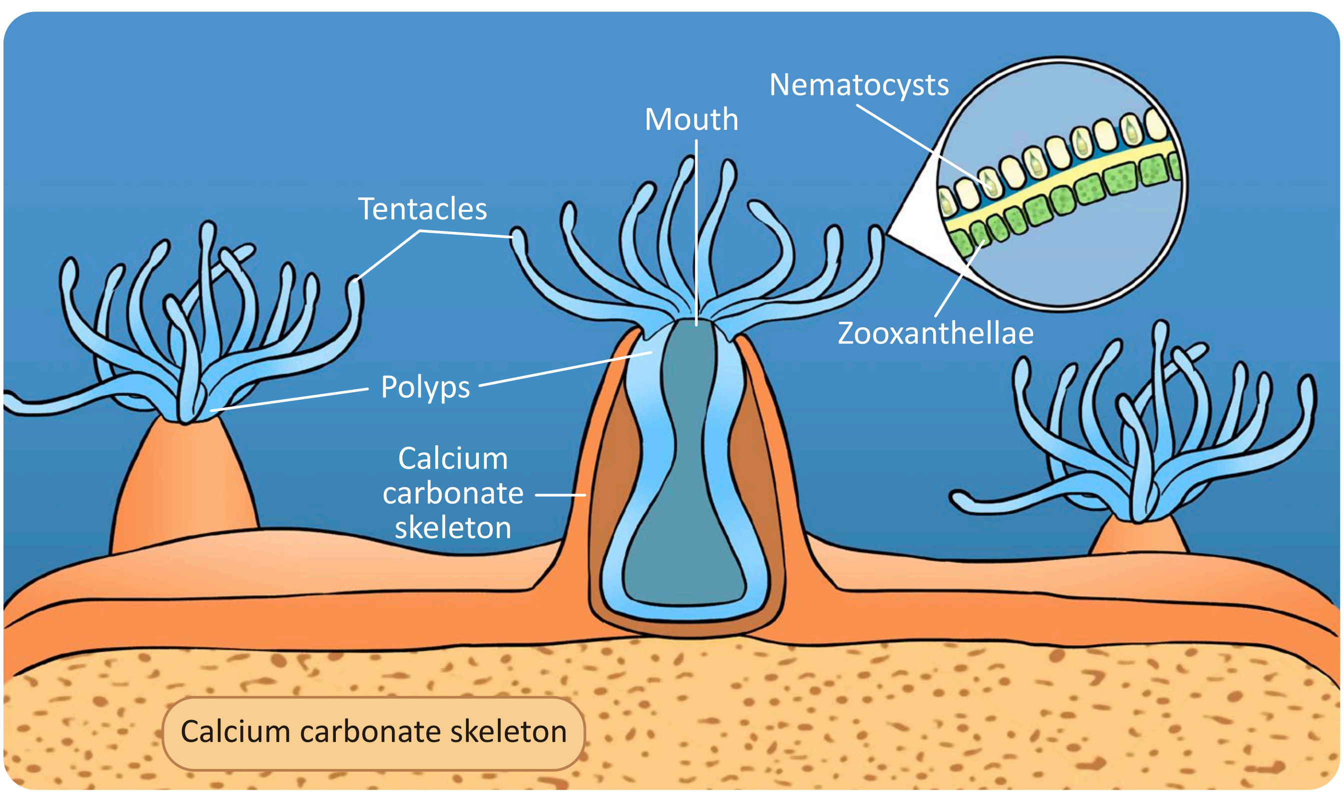


Watch

Video 10-1: The Goldilocks Zone of the Ocean

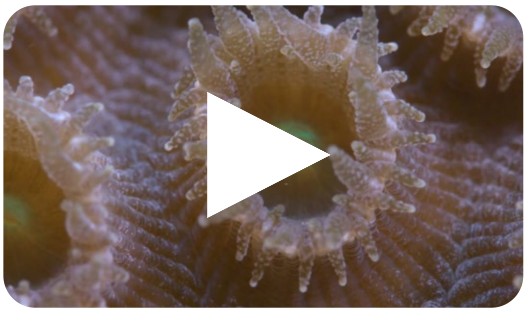
The Coral–Zooxanthellae Partnership

Around 25% of all known fish species spend at least part of their lives in a coral reef. This high level of biodiversity is possible because of a tiny but powerful partnership happening inside the coral polyps themselves. Living within the tissues of coral polyps are microscopic algae called **zooxanthellae** (pronounced "zo-zan-THEL-ee"). Like many marine microbes, they play a crucial role in cycling nutrients and driving energy flow at the base of the food web.



When two unrelated species form a close relationship, it is called **symbiosis**. The relationship is known as **mutualism** if both species benefit, as with coral and zooxanthellae**.** Coral polyps provide the zooxanthellae with protection and access to sunlight. In return, the zooxanthellae use sunlight to produce food through photosynthesis and share it with the coral. Thanks to this partnership, coral reefs thrive even in the nutrient-poor waters of tropical oceans.

However, the relationship is delicate. When corals become stressed, most often because of pollution or high water temperatures, they expel the zooxanthellae from their tissues. Without the colorful algae, the coral turns white, a phenomenon known as coral bleaching. Bleached corals are weaker, more vulnerable to disease, and may eventually die if conditions do not improve.



Watch

Video 10-2: Zooxanthellae & Coral Symbiosis

Energy at the Reef

Healthy coral reefs aren't just built by teamwork. They also rely on energy moving from one trophic level to the next. Every reef has a complex food web, connecting primary producers like zooxanthellae to large predators like sharks. Decomposers such as bacteria and fungi recycle waste and dead matter into nutrients, keeping energy flowing even after organisms die.

Adaptation for Life at the Reef

Other Types of Symbiosis

Not all symbiotic relationships benefit both species. Two other important types of symbiosis are parasitism and commensalism.

Parasitism occurs when one species experiences harm and the other benefits. A common parasite in coral reefs is the flatworm *Cymothoa exigua,* which attaches itself to fish and feeds on their blood or tissues. Over time, this weakens the fish, making it a clear example of a parasitic relationship.

Commensalism occurs when one species benefits from the relationship, and the other is neither harmed nor helped. For instance, the small fish called goby take shelter inside sea sponges or coral crevices, gaining protection from predators and a safe place to live. Meanwhile, the sponge or coral remains unaffected.

A goby stares out from the safety of a coral reef.

Check for Understanding

How do coral polyps and zooxanthellae both benefit from their mutualistic relationship?

Niches

Coral reefs are like crowded cities, home to many different organisms living close together. Each organism has a specific role, called a **niche**, that helps it survive and thrive. A niche includes what the organism eats, where it lives, and how it interacts with other species. Together, these roles form the biotic structure of the reef, with each species helping to maintain the health of the whole ecosystem.

Having different niches reduces competition for resources. For example, **cleaner wrasses** eat parasites off larger fish, helping keep them healthy, while **parrotfish** graze on algae growing on coral. Because each species fills a unique role, they do not compete for the same food.

Check for Understanding

Choose the correct answer.

When cleaner wrasses eat parasites off larger fish, the wrasses feed. Which type of symbiotic relationship is this an example of? *Hint: Think in terms of both organisms.*

- Mutualism
- Parasitism
- Commensalism

Watch

Video 10-3: Niches & Reef Maintenance

Coloration

Many reef species use coloration in ways that build on the adaptations you explored in Chapter 6. Let us take a closer look at how color helps reef organisms survive in this densely populated, high-competition environment.

One example is **mimicry**, where one organism looks like another to deceive predators or prey. The **cleaner wrasse** has distinctive markings to signal its role in removing parasites from other fish. The **false cleaner blenny** mimics these markings to trick fish into letting it approach—then takes a quick bite from a fin and escapes with a mouthful of food.


False Cleaner Blenny

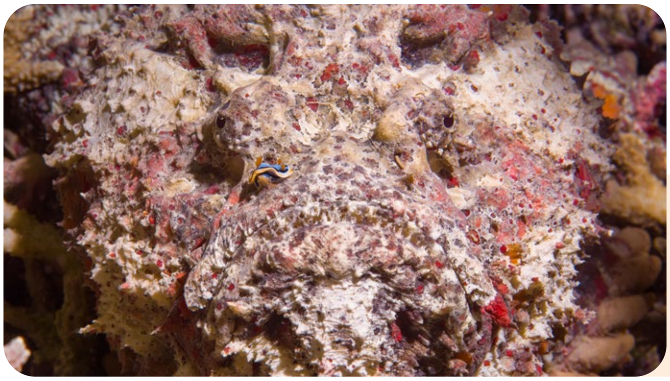

Cleaner Wrasse

Check for Understanding

Why don't fish usually eat cleaner wrasses?

- ☐ Cleaner wrasses are too small to eat.
- ☐ Fish recognize cleaner wrasses as helpful and avoid harming them.
- ☐ The false cleaner blenny is faster than most fish.
- ☐ Cleaner wrasses hide in coral where predators can't reach them.

How does this help the false cleaner blenny's mimicry succeed?



Some organisms use **camouflage** to blend into their surroundings and hide from predators.

The reef stonefish, one of the most venomous animals, uses camouflage to hide from predators and ambush prey. Can you find it in the photo?

Others use **warning coloration,** bright, bold colors that signal they are toxic or dangerous. For example, the **flamboyant cuttlefish** flashes colors like yellow-brown, white, and purple-red to confuse or warn predators.

Flamboyant Cuttlefish walking on the sand.

Body Shape

Moray eels, like this one, are common at coral reefs.

Body shape is an adaptation that helps reef organisms survive. Fish such as the moray eel have long, thin bodies that allow them to hide deep inside rocky crevices to avoid predators. Others, like the pufferfish, can inflate like a balloon when threatened, making themselves seem too big or dangerous to eat.

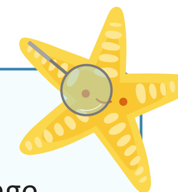
Different body shapes allow reef organisms to find shelter, escape predators, and make the most of the crowded, competitive reef environment.

Reproductive Adaptation

Clownfish and parrotfish have an unusual **reproductive adaptation**: the ability to change sex. Clownfish start life as males and live in social groups with one dominant female and several smaller males. When the female dies, the largest male transitions to female, ensuring the group can continue reproducing.

Parrotfish, on the other hand, live in groups led by a dominant male. When he dies, the largest female transitions to male and takes over as leader. This flexibility helps ensure the survival of the group under changing conditions.

Clownfish: *Photo credit: Nhobgood is licensed under CC BY-SA 4*



SCIENTIST SPOTLIGHT: DR. DAVID KLINE

Dr. David Kline is a marine biologist specializing in coral reef ecology, climate change, and the impacts of human activity on marine ecosystems. As a researcher at the Smithsonian Tropical Research Institute, Dr. Kline has pioneered innovative techniques to study coral reefs, including underwater "labs" that simulate future ocean conditions affected by climate change. His work focuses on understanding how coral reefs respond to stressors like ocean acidification, rising temperatures, and pollution while identifying solutions to protect these vital ecosystems.

Fun Fact: Dr. Kline helped develop "ReefSense," a system that uses imaging and sensors to monitor coral health in real-time, offering insights for reef conservation efforts worldwide.

LAB 10:

Build a Coral Reef

Watch

Chapter 10 Lab: Coral Reef Model

Like all healthy ecosystems, coral reefs develop through a series of stages. In this activity, you will create a fun, edible model of a coral reef, following its formation step by step. You can use Rice Krispy Treats for an edible model or substitute clay or baked dough for a non-edible version.

Materials

- ☐ Rectangular cake pan or cookie sheet
- ☐ Ingredients for Rice Krispy Treats (See recipe in the Teacher's Guide)
- ☐ ½ cup frosting
- ☐ Gummy fish and other sea-animal-shaped candies (or cut fruit roll-ups into shapes)
- ☐ Oreos
- ☐ Toothpicks
- ☐ Skewers

Procedure

Stage 1: The Hard Surface

A biofilm forms on the surface and is made of bacteria and algae. This biofilm must cover the surface before coral can form.

1. **Prepare the surface:**
   - If using a cake pan, frost the entire bottom.
   - For a cookie sheet, frost only the section where you plan to build your reef.
2. **Make the Rice Krispy mix:**
   - Use low heat to avoid overcooking and add extra butter to keep the mixture soft and moldable.
3. **Add phytoplankton and seaweed:**
   - Shape green phytoplankton and seaweed using Rice Krispy mix or fruit roll-ups. Place them on the frosted surface.

Stage 2: Early Reef Inhabitants

Pioneer species like sponges, algae, and mollusks are the first reef inhabitants. Add snails, barnacles, and clams (all mollusks) to represent these species. These organisms provide shells where coral larvae can settle and grow, a process that takes about one year.

4. **Create and add these organisms:**
   - Use Oreos for clams.
   - Make snails and barnacles from gummies, Rice Krispy mix, or fruit roll-ups.

Stage 3: Primary Coral Formation

Fast-growing primary corals move in, covering the reef over seven years. These corals rely on symbiotic algae (zooxanthellae) for the energy needed to build and grow.

5. **Build primary corals:**
   - Shape large corals with colored Rice Krispy mix, leaving space between them.
   - Refer to images of the Great Barrier Reef for inspiration.

Stage 4: Secondary Coral Support

The primary corals risk breaking due to their unstable growth and lack of support. Secondary corals to the rescue! Secondary corals grow slowly but cement the reef structure, strengthening and stabilizing the primary coral.

6. **Add secondary corals:**
    - Shape smaller, differently colored corals to fit between the primary corals.
    - Include features like stinging cells to represent their role in preventing overcrowding.
7. **Add mollusks:**
    - Use Oreos, gummies, and fruit roll-ups to make giant clams and other mollusks.
    - Position them on the corals.

Stage 5: Reef Life and Erosion

Reefs experience weathering and erosion from organisms like parrotfish, which feed on the reef, and from storm damage. Coral reefs must grow faster than they erode to survive.

8. **Create reef animals:**
    - Use toothpicks and gummies to make animals that live in, on, and above the reef.
9. **Model erosion:**
    - Act as a parrotfish by eating a piece of the reef.
10. **Repair the reef:**
    - In the location where you ate the "reef," spread frosting and then build a new piece of coral on top to repair it.