R.E.A.L. SCIENCE ODYSSEY

READ • EXPLORE • ABSORB • LEARN

Earth & Environment

LEVEL 2

GRADES 6–10

WRITTEN BY **BLAIR H. LEE, M.S.**

Pandia PRESS BOOKS

REAL Science Odyssey

Read Explore Absorb Learn

Earth & Environment 2

Try Before You Buy

This file contains a preview of RSO Earth & Environment 2 student textbook. Included in this sample are five chapters, one from each unit.

Unit I: Introduction

Chapter 1: Our Big, Blue Marble: The Four Spheres and the Scientific Method

Unit II: The Geosphere

Chapter 2: The Puzzle You Live On: Plate Tectonics

Unit III: Earth-Shaping Forces

Chapter 11: Lava You, Lava You Not: Volcanoes

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About the Author

Blair H. Lee, M.S., is the founder of Secular Eclectic Academic (SEA) Homeschoolers, a supportive community that advocates for the exclusive use of secular academic materials. Blair is the author of numerous science courses. She also writes about how to craft innovative, academic learning for students in grades K through 12. Blair earned her Bachelor's degree in Biology and Chemistry and Master's degree in Chemistry at the University of California San Diego. She has been an educator for almost 30 years.

When teaching at her local community college, Blair found that many of her students were lacking in basic foundational science upon entering college. She believes science can be and should be taught from the beginning of a child's education. She began working with her own son and his friends on methods of teaching science concepts usually reserved for high school or college students. The results of her research and writing are *RSO Chemistry*, *Biology*, *Astronomy*, and *Earth & Environment*—concept-rich, hands-on courses that engage young people's minds and lay a firm foundation of science concepts.

Blair now spends her time writing science for young people. When not homeschooling her son and writing textbooks, she loves to cook (most chemists are good cooks), read, and hike.

REAL Science Odyssey (RSO) Series

Level 1

Life, by Terri Williams
Biology, by Blair H. Lee
Astronomy, by Blair H. Lee
Earth & Environment, by Blair H. Lee
Chemistry, by Blair H. Lee
Physics, by Dahlia Schwartz

Level 2

Biology, by Blair H. Lee
Astronomy, by Blair H. Lee
The Stargazer's Notebook: A Yearlong Study of the Night Sky, by Blair H. Lee
Earth & Environment, by Blair H. Lee

Dedication

This course is dedicated to everyone who wants to learn about the wonders of our planet and the role you can play in preserving it.

Introduction

This Year, You Are an Earth and Environmental Scientist!

You did not start studying about Earth and the environment when you opened this book. You have been learning about both since you were old enough to go outside. Every day since then, you have learned a little bit more about it. This year, we will be learning about Earth in depth. Soon you will understand how mountains are built, how the oceans formed, and how fossilized organisms came to be at the top of Mount Everest. The next time you take a walk, you will understand how the land around you came to be shaped as it is. You will know how the rocks and dirt you're walking on were formed, and you will know what is under the rocks and dirt. Some of your study will be conducted inside, but like any good earth science course, you will take the time to do some field research.

You will also be learning about environmental science. There are environmental issues in the news every day. Some of these issues might seem scary and make you feel like there is nothing someone your age can do to help. The first step in helping to solve these environmental issues is to learn and understand the science explaining them. By the end of this year, you will understand this science and have a better understanding of what you can do to make a difference. You might be surprised to find out how simple some of these things are. This course starts with a look at the different components that make planet Earth. Earth is not just the air you breathe, the water you drink and play in, or the ground you walk on. When studying earth science, it is important to look at each part that makes up the Earth and how each interacts and affects the other.

After that, you will learn about geology and field research. Next, you will learn about the forces that shape Earth. Unless you live near a volcano, you might not realize that you walk, sleep, and play above a layer of fluid, melted rock. Because of this, Earth's crust is constantly moving and reshaping itself. After learning about the geosphere, the solid part of Earth, you will learn about the hydrosphere, the liquid part of Earth. You are most familiar with the geosphere, but the hydrosphere covers 71 percent of the Earth's surface. After that, you will study the atmosphere, climate, and the weather.

Environmental science is woven through the entire course. Chapters 5, 13, 18, and 23 are focused on environmental science. This will help you to understand the whole picture around environmental issues. You will need to piece together bits of science that you learned in earth science, biology, physics, and chemistry. After you have learned what you need to from these four science disciplines, you can be an environmental science puzzle-master, and understand environmental issues!

Earth and environmental scientists use math

Math: You either love it or you hate it. You won't find many people in the middle. Math is included in all science courses. Those of you who love it think it is awesome. And those of you who do not love it sometimes don't like science either because of math.

You might not have liked studying all those math facts in school. The good news is that you have been learning math so you can apply your math skills in much more interesting and meaningful ways. Scientists must deal with numbers. Math helps scientists understand how the natural and physical world works. The answers to many of the questions earth and environmental scientists are researching are answered with numerical data. For example, to understand global warming and climate change, you need to be able to interpret the data and graphs scientists have made based on that data.

Do not worry if this sounds challenging to you right now. In this course, everything is explained using words in addition to numbers. With some practice, however, you might find you prefer the way data is represented mathematically. You can learn a lot from graphs and charts. You might even discover that after using math in real-world applications, you like it and are good at it!

Earth and environmental scientists use the metric system

The metric system is used in every area of science; this course is no exception. The purpose of science is to explain how the natural and physical world works. To understand this, scientists from all over the world build on other scientists' research and discoveries, so it is important that scientists use a standardized system of measurement. The metric system was chosen as the standard because it is the easiest to use. That is because it is a base 10 system. I think you will agree it is much easier to divide and multiply by 10 than by 8, 12, or 16.

In most cases, this course also gives measurements in the U.S. system of measurement. Even if you would rather use those, why not work to learn the metric system? If this causes problems, you can go to Pandia Press's weblinks page to find a webpage that allows you to convert back and forth between the U.S. system and the metric system. Or you can just stick with it, and before you know it you will be an expert at the metric system too.

Earth and environmental scientists use scientific models

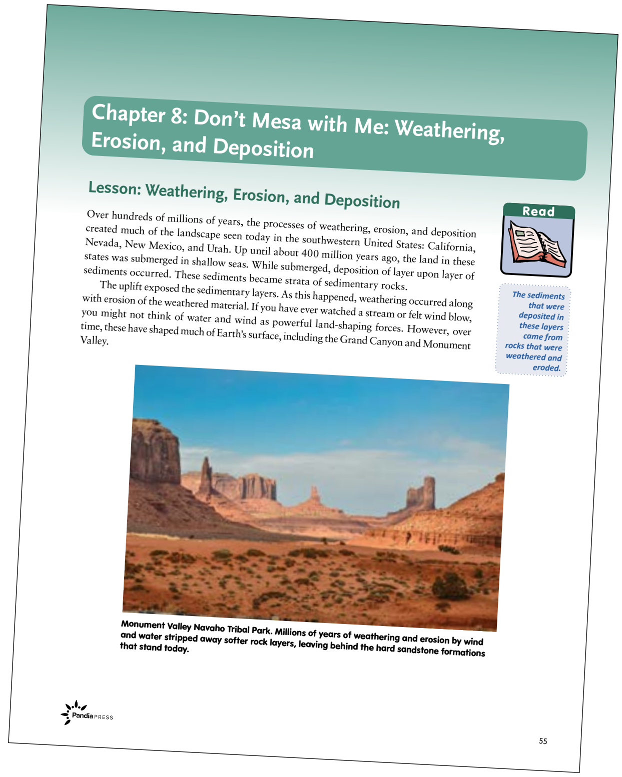
If you do not know what a scientific model is, you will by the end of this course. A scientific model is a simplified representation of a real system. Using scientific models, scientists can study large complex scientific principles and systems. All areas of science use scientific models. Woven throughout this course are labs, exercises, and activities that will help you learn how to interpret, develop, and understand scientific models. You might be surprised how a model that focuses on one aspect of a large system can help you understand the entire system better.

Earth and environmental scientists use systematic study

Your course is comprised of 23 chapters contained in five units: Our Big, Blue Marble; the Geosphere; Earth-Shaping Forces; the Hydrosphere; and the Atmosphere. This course consists of two student books: this textbook and a consumable workbook. Your textbook presents science materials in narrative-style lessons that include many colorful illustrations, figures, and charts. After carefully reading a lesson, you will apply what you've learned in your student workbook. The workbook contains geologic timeline activities, labs, research assignments, assessments, and other activities for each chapter. When completed, your workbook serves as a record of your earth and environment course.

Textbook

Each chapter in the textbook opens with a **LESSON** that provides foundational science material, ideas, concepts, and vocabulary.



Chapter 8: Don't Mesa with Me: Weathering, Erosion, and Deposition

Lesson: Weathering, Erosion, and Deposition

Read

Over hundreds of millions of years, the processes of weathering, erosion, and deposition created much of the landscape seen today in the southwestern United States: California, Nevada, New Mexico, and Utah. Up until about 400 million years ago, the land in these states was submerged in shallow seas. While submerged, deposition of layer upon layer of sediments occurred. These sediments became strata of sedimentary rocks.

The uplift exposed the sedimentary layers. As this happened, weathering occurred along with erosion of the weathered material. If you have ever watched a stream or felt wind blow, you might not think of water and wind as powerful land-shaping forces. However, over time, these have shaped much of Earth's surface, including the Grand Canyon and Monument Valley.

The sediments that were deposited in these layers came from rocks that were weathered and eroded.

Monument Valley Navaho Tribal Park. Millions of years of weathering and erosion by wind and water stripped away softer rock layers, leaving behind the hard sandstone formations that stand today.

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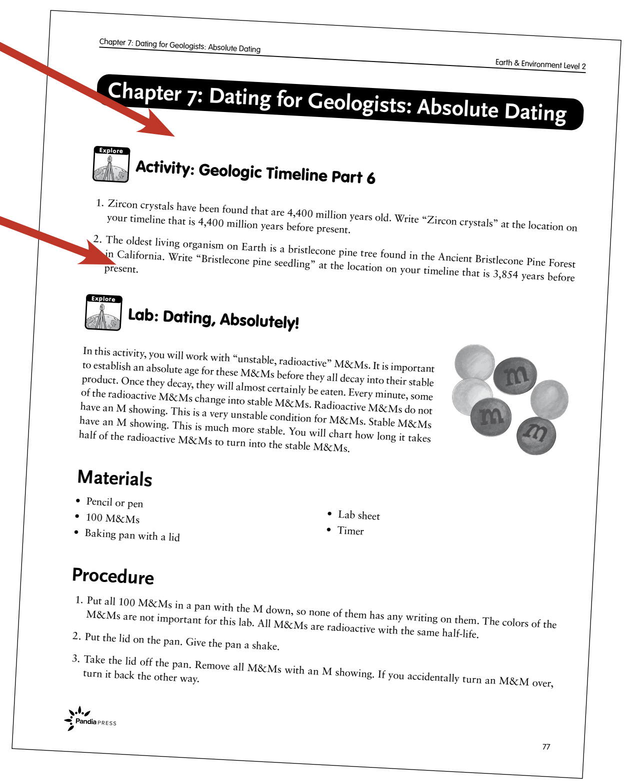
Workbook

Nineteen of the lessons are followed by a **GEOLOGIC TIMELINE ACTIVITY**. This reinforces your understanding of the development of various elements of the geosphere, hydrosphere, and atmosphere of the Earth.

Each chapter in Units II through V has one or more **LAB ACTIVITIES** that expand upon the concepts presented in the lesson. Lab results are recorded directly on the included lab sheets.



Chapter 7: Dating for Geologists: Absolute Dating

Earth & Environment Level 2

Chapter 7: Dating for Geologists: Absolute Dating

Explore

Activity: Geologic Timeline Part 6

1. Zircon crystals have been found that are 4,400 million years old. Write "Zircon crystals" at the location on your timeline that is 4,400 million years before present.
2. The oldest living organism on Earth is a bristlecone pine tree found in the Ancient Bristlecone Pine Forest in California. Write "Bristlecone pine seedling" at the location on your timeline that is 3,854 years before present.

Explore

Lab: Dating, Absolutely!

In this activity, you will work with "unstable, radioactive" M&Ms. It is important to establish an absolute age for these M&Ms before they all decay into their stable product. Once they decay, they will almost certainly be eaten. Every minute, some of the radioactive M&Ms change into stable M&Ms. Radioactive M&Ms do not have an M showing. This is a very unstable condition for M&Ms. Stable M&Ms have an M showing. This is much more stable. You will chart how long it takes half of the radioactive M&Ms to turn into the stable M&Ms.

Materials

- Pencil or pen
- 100 M&Ms
- Baking pan with a lid
- Lab sheet
- Timer

Procedure

1. Put all 100 M&Ms in a pan with the M down, so none of them has any writing on them. The colors of the M&Ms are not important for this lab. All M&Ms are radioactive with the same half-life.
2. Put the lid on the pan. Give the pan a shake.
3. Take the lid off the pan. Remove all M&Ms with an M showing. If you accidentally turn an M&M over, turn it back the other way.

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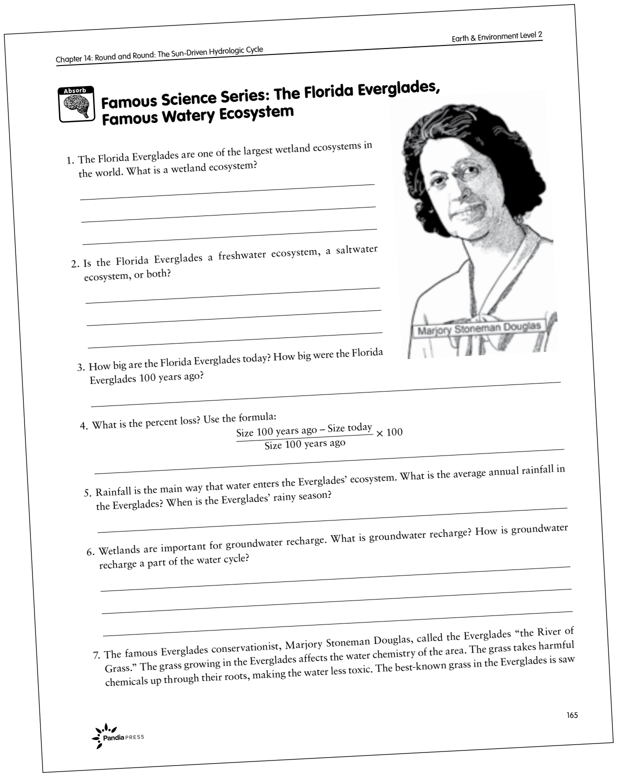
Each chapter contains a **FAMOUS SCIENCE SERIES (FSS)** research assignment. Explore the subject matter in greater depth and learn about scientists, discoveries, major events, and various geological, environmental, and technological wonders.

Each chapter ends with a **SHOW WHAT YOU KNOW (SWYK)** quiz to test your knowledge.



Chapter 14: Round and Round: The Sun-Driven Hydrologic Cycle — Earth & Environment Level 2

Famous Science Series: The Florida Everglades, Famous Watery Ecosystem

1. The Florida Everglades are one of the largest wetland ecosystems in the world. What is a wetland ecosystem?
2. Is the Florida Everglades a freshwater ecosystem, a saltwater ecosystem, or both?
3. How big are the Florida Everglades today? How big were the Florida Everglades 100 years ago?
4. What is the percent loss? Use the formula: $\frac{\text{Size 100 years ago} - \text{Size today}}{\text{Size 100 years ago}} \times 100$
5. Rainfall is the main way that water enters the Everglades' ecosystem. What is the average annual rainfall in the Everglades? When is the Everglades' rainy season?
6. Wetlands are important for groundwater recharge. What is groundwater recharge? How is groundwater recharge a part of the water cycle?
7. The famous Everglades conservationist, Marjory Stoneman Douglas, called the Everglades "the River of Grass." The grass growing in the Everglades affects the water chemistry of the area. The grass takes harmful chemicals up through their roots, making the water less toxic. The best-known grass in the Everglades is saw

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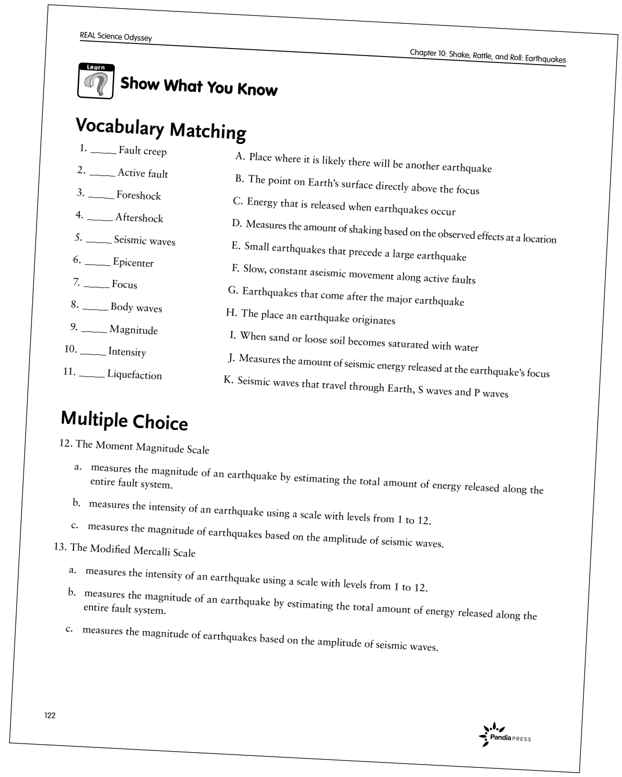

REAL Science Odyssey — Chapter 10: Shake, Rattle, and Roll: Earthquakes

Show What You Know

Vocabulary Matching

1. ____ Fault creep
2. ____ Active fault
3. ____ Foreshock
4. ____ Aftershock
5. ____ Seismic waves
6. ____ Epicenter
7. ____ Focus
8. ____ Body waves
9. ____ Magnitude
10. ____ Intensity
11. ____ Liquefaction

A. Place where it is likely there will be another earthquake
B. The point on Earth's surface directly above the focus
C. Energy that is released when earthquakes occur
D. Measures the amount of shaking based on the observed effects at a location
E. Small earthquakes that precede a large earthquake
F. Slow, constant aseismic movement along active faults
G. Earthquakes that come after the major earthquake
H. The place an earthquake originates
I. When sand or loose soil becomes saturated with water
J. Measures the amount of seismic energy released at the earthquake's focus
K. Seismic waves that travel through Earth, S waves and P waves

Multiple Choice

12. The Moment Magnitude Scale
   a. measures the magnitude of an earthquake by estimating the total amount of energy released along the entire fault system.
   b. measures the intensity of an earthquake using a scale with levels from 1 to 12.
   c. measures the magnitude of earthquakes based on the amplitude of seismic waves.
13. The Modified Mercalli Scale
   a. measures the intensity of an earthquake using a scale with levels from 1 to 12.
   b. measures the magnitude of an earthquake by estimating the total amount of energy released along the entire fault system.
   c. measures the magnitude of earthquakes based on the amplitude of seismic waves.

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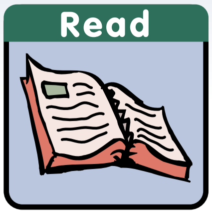
Earth and environmental scientists are interested in figuring out how to solve problems

Whether it is learning why earthquakes occur, working to solve the current environmental problems on Earth, or predicting storm patterns, earth and environmental scientists find this study of the earth and the environment fascinating. Science is best learned where there is a thoughtful pairing of theory with labs and activities that directly apply that theory. This requires some sitting while you learn the theory. After that, you will apply the theory in hands-on fashion. You will be practicing science the way every scientist does. Earth is the planet where you live. I hope you take time this year to go outside and investigate it, and I hope you learn about current environmental situations and learn simple things to do to make a difference.

Introduction

Chapter 1: Our Big, Blue Marble: The Four Spheres and the Scientific Method

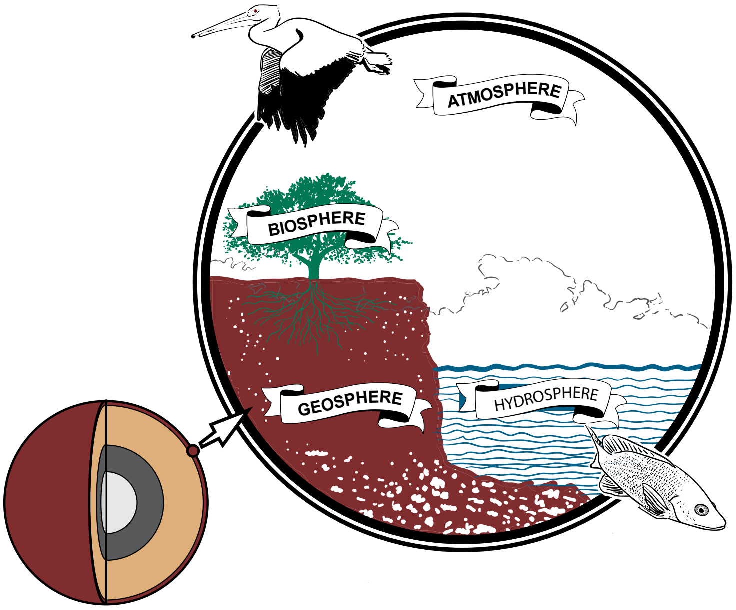
Lesson: The Four Spheres and the Scientific Method



This year in science, you will be studying Earth and the environment.

What does that mean to you? What is **earth science**? How does **environmental science** relate to it? Look outside, and think about what you will learn when you study earth science and environmental science.

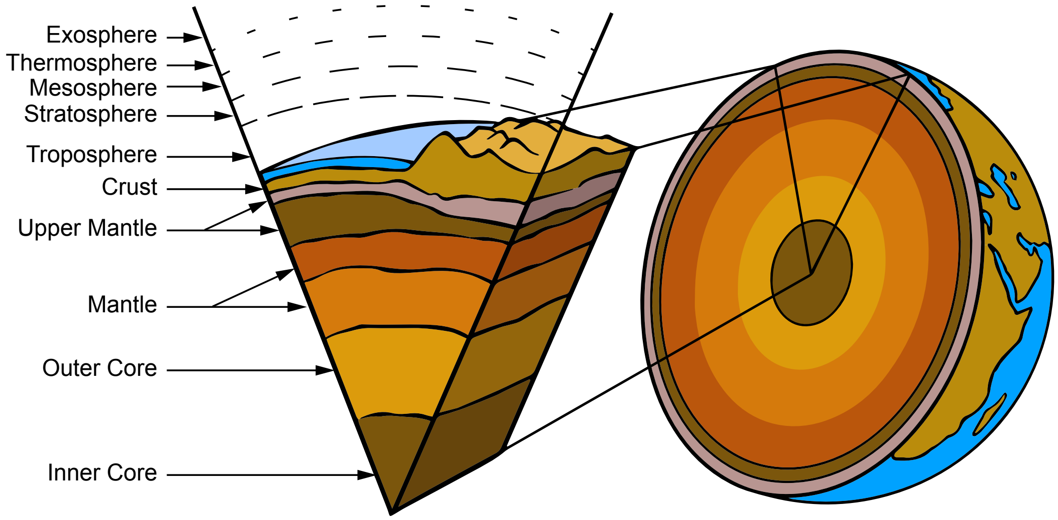
You probably already know you will be studying rocks, but that is only part of earth science. This year, you will learn about the parts that make up the planet you live on. In addition to learning about the solid, rocky parts Earth is made of, you will learn about the water that covers most of its surface, the air that blankets it, and how these create and affect weather. You will also learn about the **organisms**, living things, that evolved on Earth and the effect they have on the environment. You will also investigate the impact humans have had on the planet and learn about the scientists who are working to solve environmental issues.



One way that scientists classify Earth is to divide it into four spheres: the geosphere, hydrosphere, atmosphere, and biosphere. When you learn about earth science, you learn about all these spheres.

Geosphere (Earth-sphere)

Many people think earth science focuses on the outer rocky layer of the geosphere, the **crust**, which is the solid surface of Earth. The **geosphere** includes the crust as well as the layers below it, all the way to the inner core, the center of the Earth.

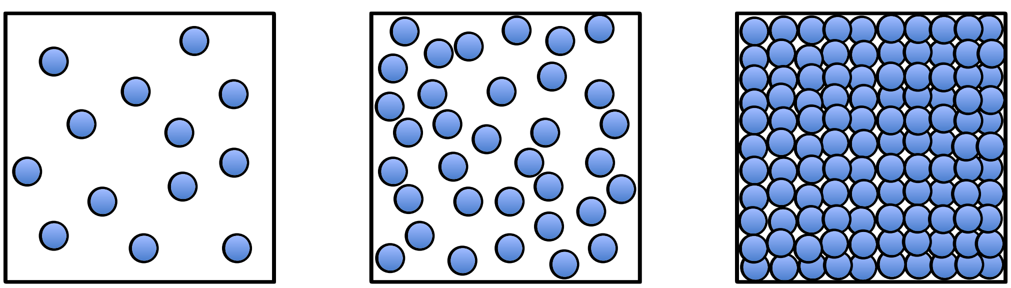


The Earth extends from the crust on the surface to the inner core at its very center.

When learning about the geosphere, you study the **lithosphere**, which is made up of the rocky crust, the uppermost mantle, and all the layers to the center of the Earth (the inner core). The geosphere is **differentiated** into layers based on the density of each layer. The geosphere (earth), hydrosphere (water), and atmosphere (air) have differentiated from each other too.

Differentiation is the separation of the matter into different layers based on the density of each layer.

Density is a measure of the number of particles in a given amount of space, the mass per volume. A good way to remember how the concept of density works is to think of the number of people in a car. A car with one person in it has a lot of empty space. If you add people to the car, the density of people inside the car increases.



Each layer going from the crust through the mantle to the inner core is denser than the layer above it. That means that each layer going from the crust to the inner core has more particles in the same amount of space than the layer above it.

Hydrosphere (Water-sphere)

The hydrosphere is the water portion of Earth. Most of Earth's surface is covered by the hydrosphere. The **hydrosphere** includes fresh and salt water, frozen and liquid water, liquid and **water vapor** (water in its gaseous state), and surface and underground water. Clouds are made of water molecules and are therefore a part of the hydrosphere. The hydrosphere is a dynamic mass of water molecules that continuously cycles throughout the environment.

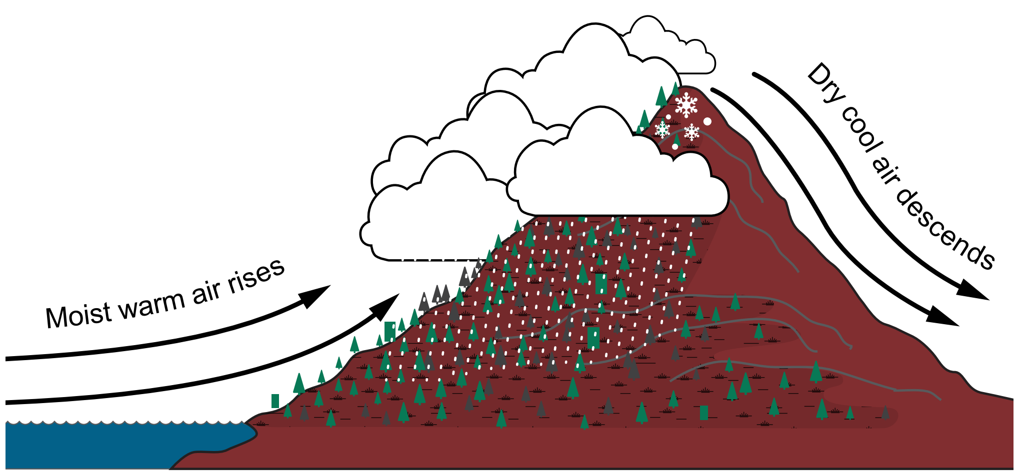
The hydrosphere is important for the biosphere. Water is considered essential for the evolution of life as we know it.

Earthrise **photo taken during the Apollo 8 mission. Astronauts call Earth the blue planet because of how it looks from space.**

Atmosphere (Air-sphere)

The **atmosphere** is the envelope of gas that surrounds Earth. It is easy to see (or rather see through) the atmosphere. This means that, with the exception of clouds, the atmosphere is the least dense of the spheres. This is why it sits on top of the other spheres. Just because you cannot see air, do not be fooled into thinking there are not many molecules in the air. There are close to one octillion (1×10^{27}) air molecules in an average size room.

When you study earth science, you study how the "spheres" interact with each other. When warm air in the atmosphere travels over water, water vapor from the hydrosphere is carried along by the air. If this air mass encounters a mountain in the geosphere, the air is forced up where temperatures are cooler. Because of the drop in temperature, clouds form, and rain and snow can fall to the ground. The water falls from the sky and runs down mountain streams with fish in them. It also soaks into the ground where the roots of plants absorb the water. The air descending the mountain has less water in it making that side of the mountain less green, because fewer trees grow where there is less water.



A warm air mass (atmosphere) contains water vapor (hydrosphere). The air mass encounters a mountain (geosphere). The air mass is pushed up at the mountain and cools. The water vapor turns to rain. The rain is needed by organisms (biosphere).

Biosphere (Life-sphere)

Have you ever thought about what an amazing thing it is to be on Earth? About 3.5 billion years ago, the first life evolved. Since that event, evolution has resulted in the many species of organisms that have lived in the past, present, and future. If you think that sounds like a biology lesson, you are right. The **biosphere** is the entire area of Earth where organisms live. The biosphere includes **abiotic** (the non-living parts of the environment and **biotic** (the living parts of the environment) components.

The biosphere includes abiotic and biotic components.

Abiotic conditions on Earth favor the evolution of life. Without abiotic conditions, such as liquid water and a suitable climate as is found on Earth, scientists do not think life would have evolved. Organisms have affected the abiotic parts of Earth too. Organisms have caused changes to Earth's atmosphere, hydrosphere, and geosphere. They have had a big effect on the environment over Earth's 4.56 billion year history.

When studying environmental science, you learn about the natural processes and interactions between the geosphere, hydrosphere, atmosphere, and biosphere. You also learn of the **anthropogenic**, human-caused, processes and interactions that are affecting the geosphere, hydrosphere, atmosphere, and biosphere.

Scientific Modeling and Method

A **scientific model** is a simplified representation of a real system. Scientific models make it possible to study large, complex scientific principles and systems and to study, predict, and explain outcomes for scientific phenomena and systems. Scientists in every area of science use scientific models. Earth and environmental scientists use scientific models to:

1. Predict the weather;
2. Study the water cycle;
3. Identify the source of pollution in a water supply;
4. Learn how volcanic eruptions affect the atmosphere; and
5. Determine what Earth looked like 200 million years ago.

In this course, you will use scientific models as a tool that will help you make sense of the facts, theories, and principles that explain how the natural and physical world works. You will learn how to develop and understand scientific models. You will use scientific models to predict outcomes and come to a better understanding of complex systems.

Scientific models make it possible to study, predict, and explain complex scientific phenomena.

Scientists work to piece together explanations for how the natural and physical world works. The **scientific method** is the logical road map they use for building scientific models and theories that are at the center of these explanations. First, they make keen **observations**, carefully noting what's happening around them. Next, they conduct **experiments**, testing different possibilities. Finally, they put the pieces together through **reasoning**, drawing conclusions based on their observations and experiments. Each step builds upon the last, leading to a clear picture of how things work: the scientific model or theory!

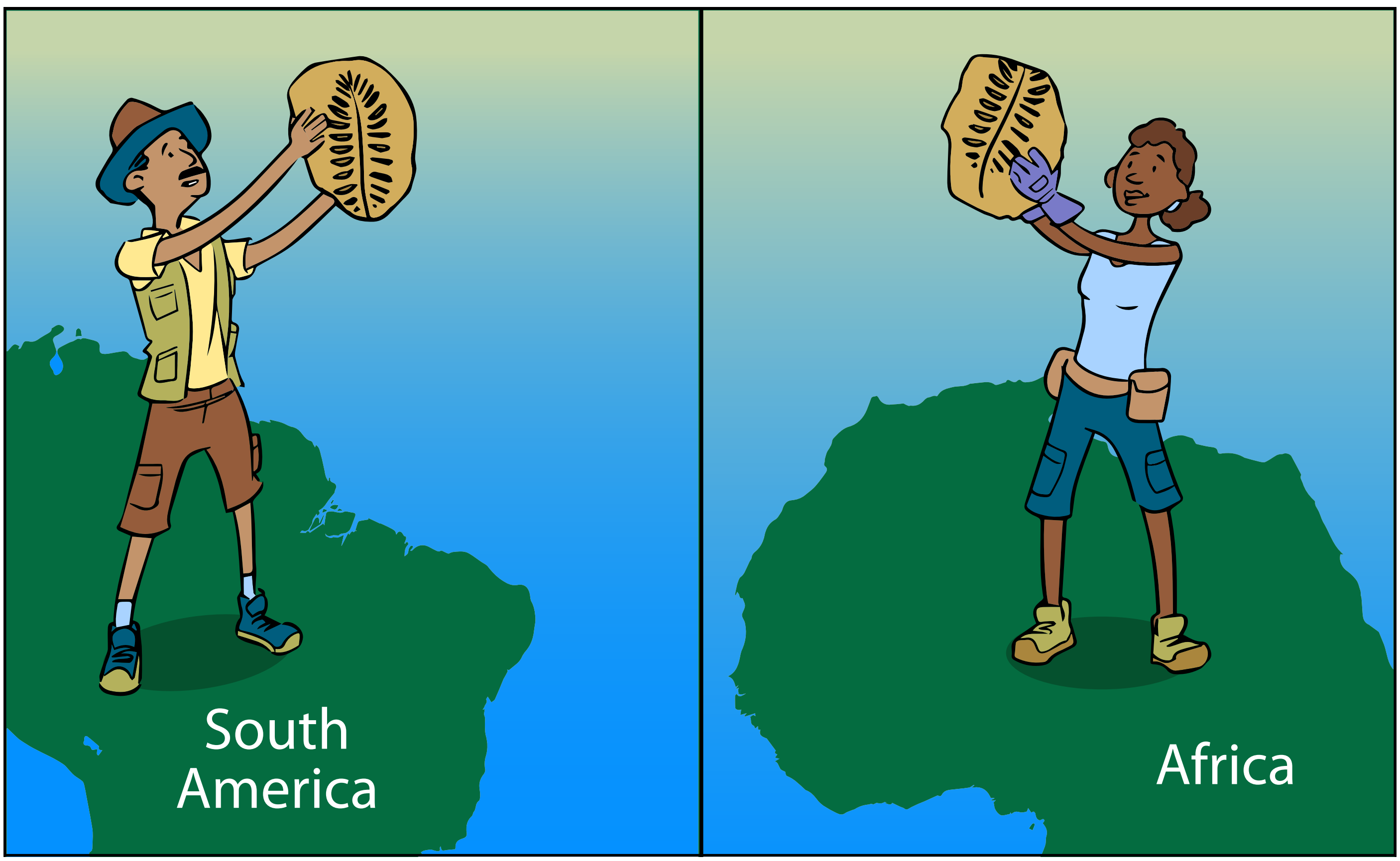
All scientific models must 1) explain data and observations, and 2) predict new observations as they develop.

Imagine it like a giant jigsaw puzzle. **Scientific facts** are the individual pieces, single observations confirmed through careful study, like the fact that water freezes at 0°C. **Hypotheses** are testable predictions, like wondering "Why does water freeze at that temperature? Hypothesis: Maybe at 0°C, water molecules slow down and lock together?" Next, scientists test their hypothesis through many experiments, collecting data, and gathering evidence. But sometimes, a single piece doesn't explain the whole picture. That's where **scientific laws** come in. Think of them as puzzle patterns: They describe how things behave under specific conditions but don't explain the "why" just yet. For example, Newton's third law, which states that "for every action, there is an equal and opposite reaction" explains how a ball bounces when dropped, but it doesn't tell you why the bounce happens. So, the scientific method keeps chugging along, collecting more and more pieces until a complete picture emerges: a **scientific theory!**

A scientific theory is an in-depth explanation of the observed phenomenon. It is built on proven hypotheses, facts, and even laws, finally answering the "why" behind the puzzle. Evolution, for example, is a theory explaining how life changes over time, using extensive evidence to paint a picture of why we see such diverse life on Earth.

So, remember, facts are the building blocks, hypotheses are the curious questions, laws are the observed patterns, and theories are the expansive explanations that unite them all.

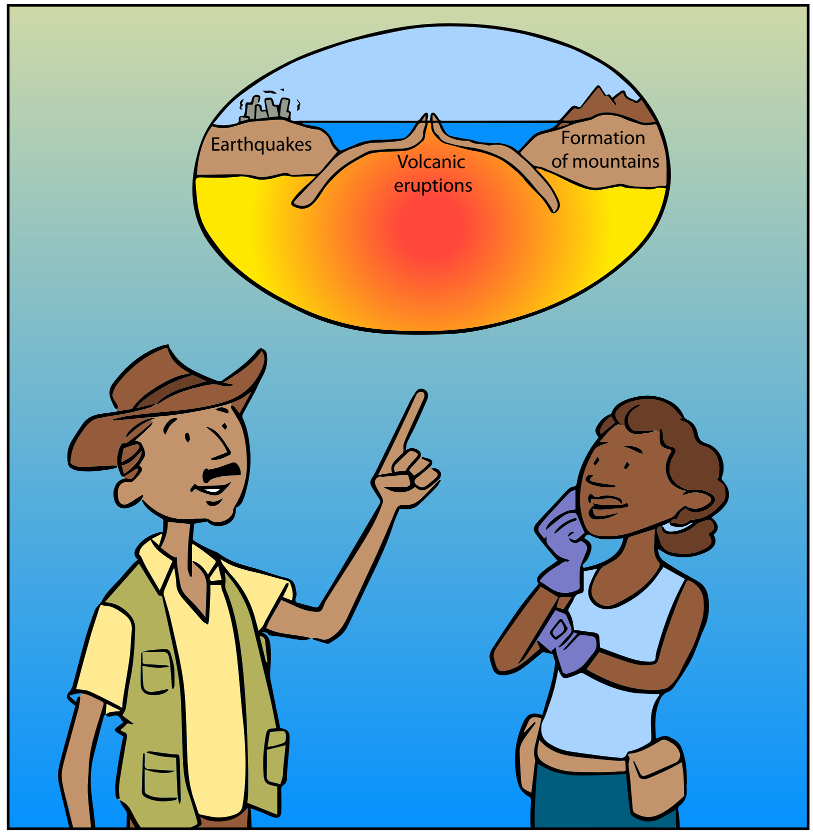
Phenomenon (observable evidence): Professor X finds a plant fossil in South America. Professor Y finds a plant fossil in Africa.



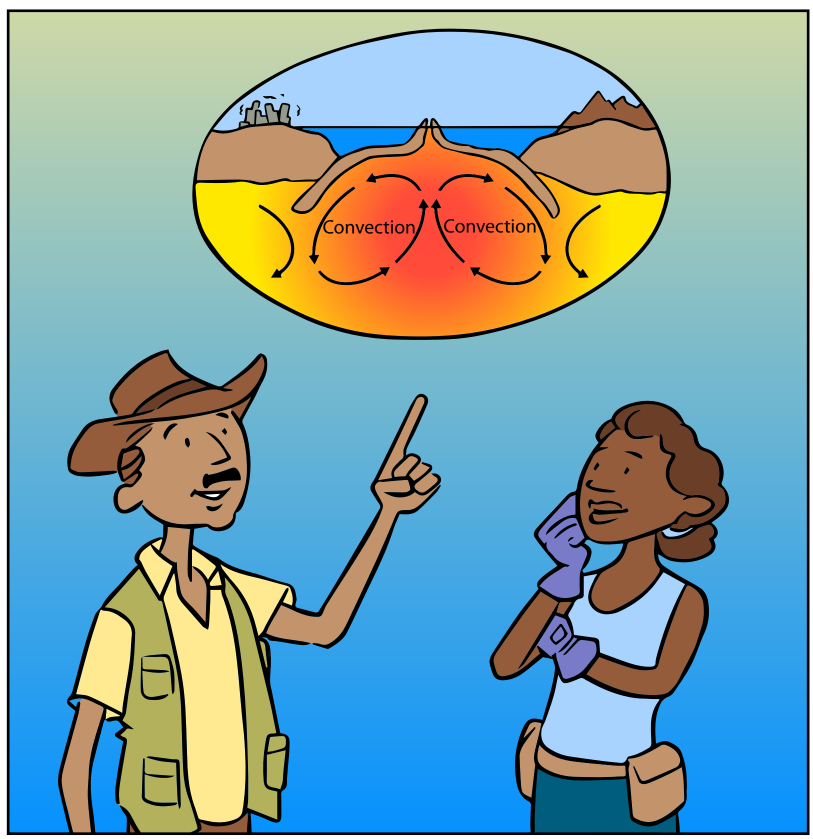
Scientific Fact (undisputed observation): Fossils of the same ancient plant species have been found by many people on continents now separated by vast oceans.

Hypothesis (educated guess based on what is known): Professors X and Y hypothesize that continents move across the Earth's surface over millions of years, explaining how the same fossils came to be found in both South America and Africa. This hypothesis would also explain how the western edge of South America and the eastern edge of Africa fit together.

Scientific Law (the how): Plate tectonics describes the observed movement of Earth's surface and how it causes observed geologic phenomena, such as earthquakes, volcanic eruptions, and the formation of mountain ranges. This, however, does not explain the cause of any of these observed movements.



Scientific Theory (the why): The theory of plate tectonics proposes that convection currents in the mantle create forces that drive the movement of these tectonic plates and explain the occurrence of observed geologic phenomena, such as earthquakes, volcanic eruptions, and mountain formation.

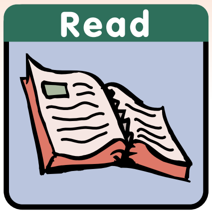


Unit II

The Geosphere

Chapter 2: The Puzzle You Live On: Plate Tectonics

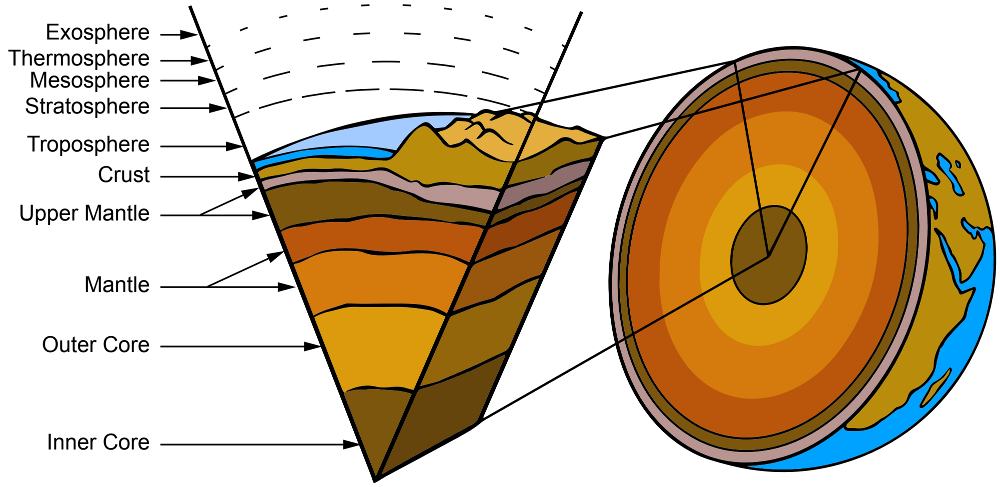
Lesson: Plate Tectonics



You live on the top layer of Earth's surface, its crust. Earth's crust and upper mantle form the lithosphere. Review the figure below as you read through the following list of Earth's layers:

- The **lithosphere** is the solid, outer layer and uppermost solid mantle.
- The **asthenosphere** is below the lithosphere and is partially melted.
- Below that is the bulk of the **mantle.** The mantle is thick and oozing.
- The **outer core** is hot enough that the metal iron is melted and liquid.
- The **inner core** is the hottest layer, but the squeezing pressure is so great that this layer is a solid. It is the densest layer.

You might be surprised to learn that the crust, along with the rest of the lithosphere, is like a puzzle where the pieces are constantly moving and rearranging themselves. There are fifteen to twenty pieces, called **tectonic plates**. There have been more plates and fewer during the 4.56 billion years Earth has existed. The number of plates will change in the future too.

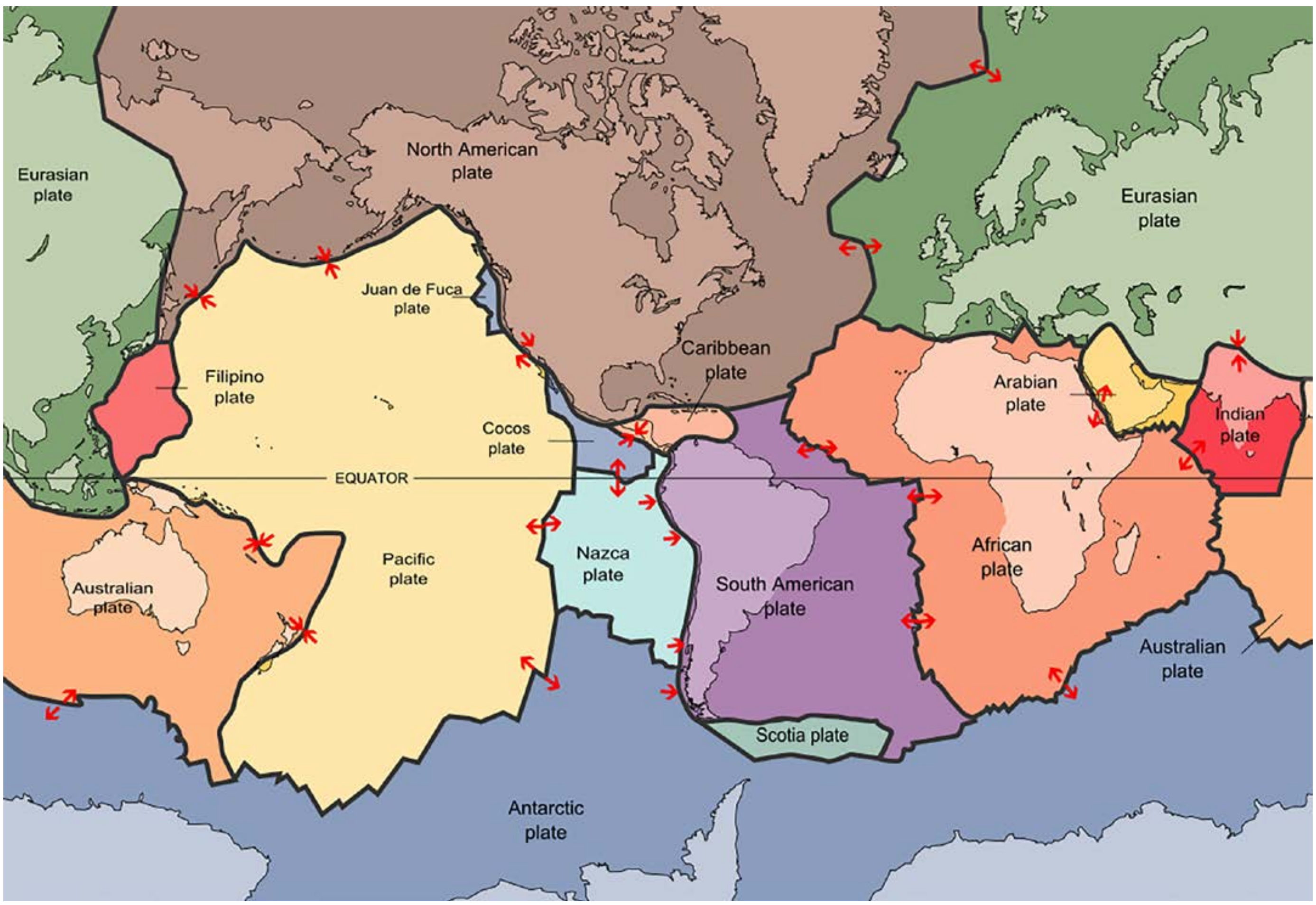


The lithosphere is composed of tectonic plates. The theory of plate tectonics describes the movement of these plates and also explains why earthquakes happen, volcanoes erupt, and mountains form.

Theory of Plate Tectonics

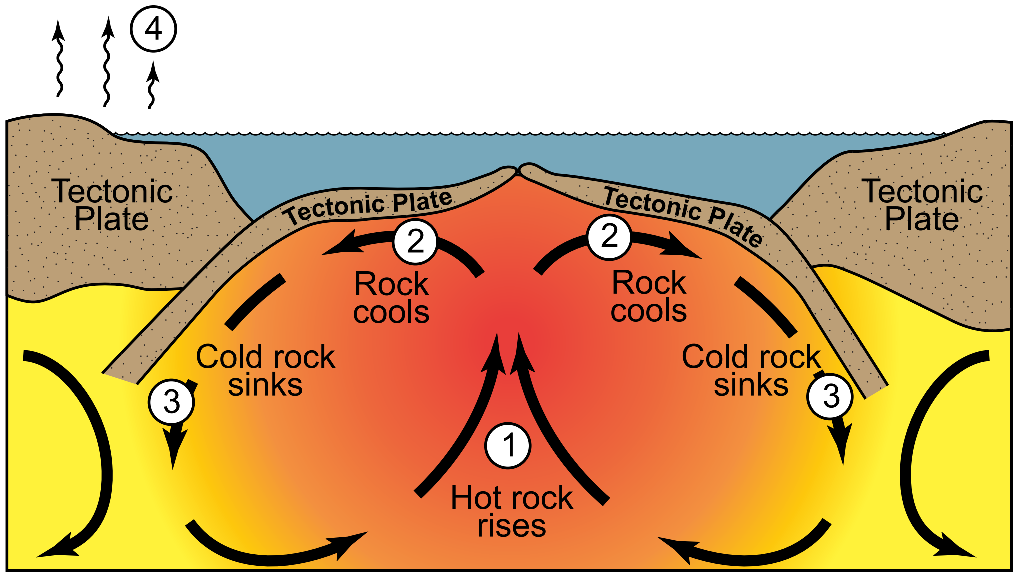
The **theory of plate tectonics** states that:

- The lithosphere is broken into large rigid pieces called tectonic plates (or simply plates).
- There are currently several major tectonic plates. The plates are different sizes and have irregular shapes.
- The tectonic plates move in different directions and at different speeds ranging from 2 cm (about 0.79 in.) per year to 15 cm (about 5.91 in.) per year.
- Tectonic plates can have both continental and oceanic crust on them.



Fifteen of the largest tectonic plates. The fluidity of the asthenosphere allows the plates to move in different directions. On average, plates move as fast as fingernails grow.

Hot material rises and cool material sinks. This process is called **convection**. Convection is the mechanism driving the movement of tectonic plates. Convection of the molten (melted) material under the lithosphere causes the movement of fluid matter. Differences in density cause cool, denser matter to sink and hot, less dense matter to rise. This creates a cycle as the less dense hotter rock rises and replaces the cool rock, and the denser cooler rock sinks and replaces the hot rock.



1. Less dense, hot, molten rock rises.

2. It is cooler at Earth's surface than it is at Earth's core. When molten rock rises toward Earth's surface, it cools and escapes to Earth's surface.

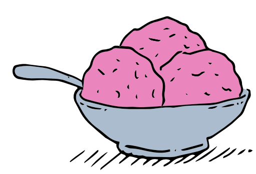
3. When it cools, the rock becomes denser and sinks.

4. The heat escaping from Earth's interior causes movement below Earth's surface, resulting in the movement of tectonic plates.

The lithosphere and asthenosphere are made of rocks. The rocks making the lithosphere are cooler, solid, and rigid, and the rocks making the asthenosphere are hotter. They are still solid. They are not liquid, but they can deform and move in response to pressure. Ice cream can help you understand this.

1. When ice cream comes out of a cold freezer, it is frozen solid and hard to spoon out. *This is like the lithosphere.*

2. As ice cream softens, it is still solid, but becomes easier to spoon. *This is like the asthenosphere.*



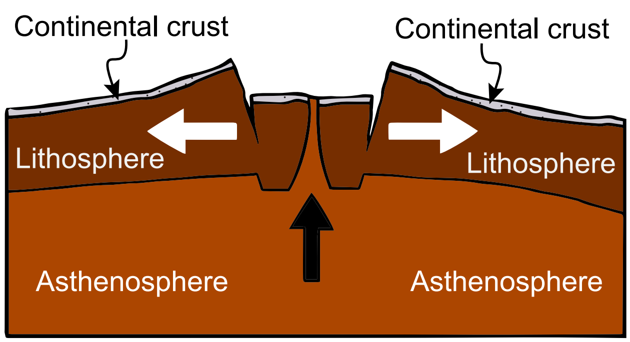
Like puzzle pieces, tectonic plates have boundaries. Unlike puzzle pieces, the pieces are in constant motion, rearranging themselves. Tectonic plates move apart from, collide into, or slide past each other. The three different types of movement at plate boundaries define the type of boundary. Most of these boundaries are in the ocean. The reason for this is that 71 percent of Earth is covered by the oceans.

Divergent Boundaries

When two plates move apart, the boundary is called a **divergent boundary**. When the boundaries move apart, convection occurs as hot material from the mantle comes up through the opening. This material cools to form new crust. The old crust on each side of the boundary is pushed away. Along divergent boundaries in the ocean a **rift valley** and an **ocean ridge** form. Rift valleys are long, narrow valleys. New material oozes through the boundary, forming ocean ridges, raised areas in the ocean. **Mid-ocean ridges** form a continuous mountain chain through the ocean floor with rift valleys running alongside them. The Mid-Atlantic Ridge runs along the floor of the Atlantic Ocean and is part of the longest mountain chain on Earth.

When divergent boundaries occur on continents, a continental rift forms. An example of this is the East African Rift.

Divergent Boundary



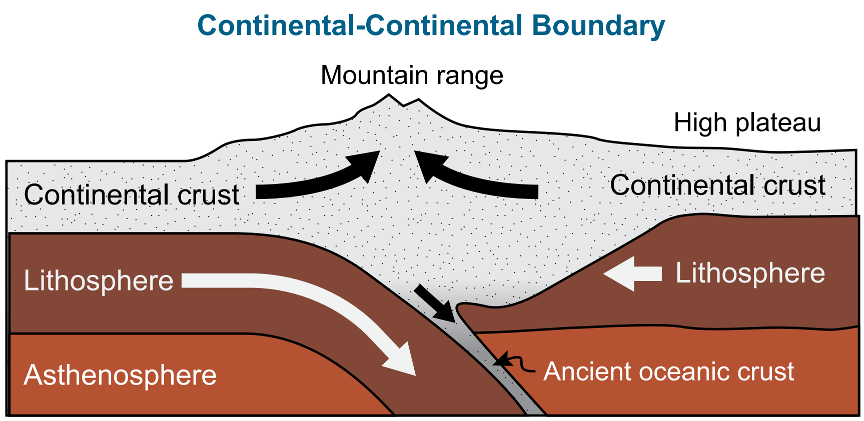
Divergent boundaries: There is high heat flow, earthquakes, and volcanic activity, creating rifts in the crust. Thingvellir National Park in Iceland sits in the Mid-Atlantic Ridge, which splits the country onto the North American and Eurasian plates. This is an example of a divergent boundary.

Convergent Boundaries

Convergent boundaries occur where two plates are moving toward each other, bumping and colliding into each other. What happens at convergent boundaries depends on the density of the rocks at those boundaries.

Convergent Continental-Continental Boundaries

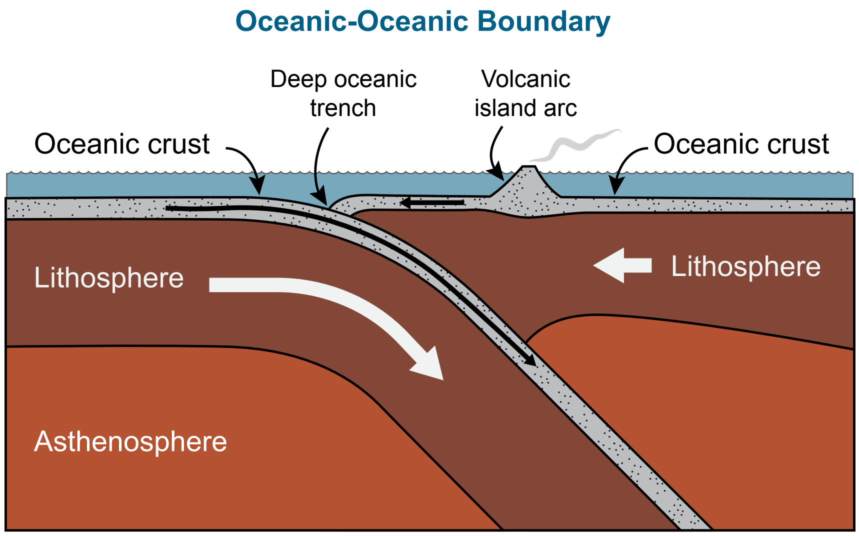
As continental crust collides with continental crust along a continental-continental boundary, mountains form. The continental crusts on both plates crunch together and fold up, forming tall mountain ranges. The Himalayas formed when the Indian continental plate collided with the Eurasian continental plate 40 to 50 million years ago.



Convergent continental-continental boundaries: The two continents are made of rocks with similar densities. This causes the rocks to push against each other and make mountains. The Himalayas are an example of a convergent continental-continental boundary.

Convergent Oceanic-Oceanic Boundaries

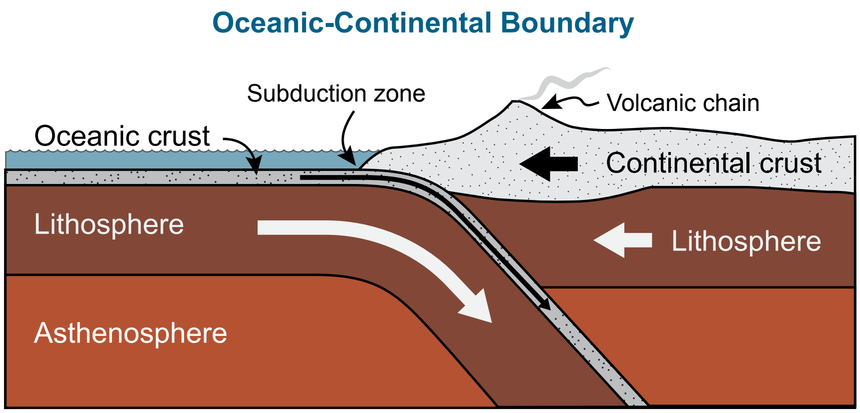
Along an oceanic-oceanic boundary, both plates are made from similar types of rock, but one of the plates will be denser than the other and will therefore undergo **subduction**, which means it sinks below the less dense plate. The subducting plate melts to form **magma**. Magma is less dense than the solid rock, so it rises to the surface forming chains of volcanic islands called volcanic island arcs, such as the Hawai'ian Islands. Deep oceanic trenches, long, narrow steep-sided depressions across the ocean floor, like the Mariana Trench, can also form along convergent oceanic-oceanic boundaries.



Convergent oceanic-oceanic boundaries: When one plate is denser than the other, it sinks and is pulled down by the force of gravity below the other plate. The Mariana Trench is an example of a convergent oceanic-oceanic boundary.

Convergent Oceanic-Continental Boundaries

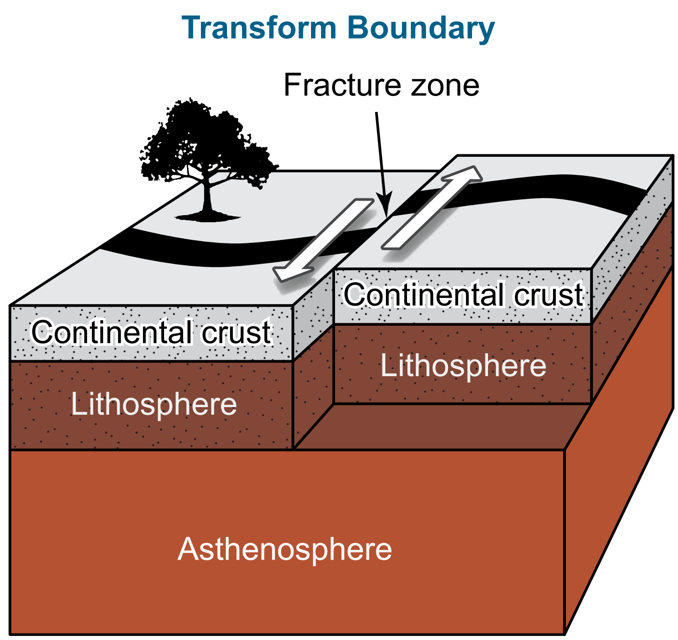
At an oceanic-continental boundary, the thinner and denser oceanic crust is subducted under the thicker and less dense continental crust. The boundary where subduction is happening is called the **subduction zone**. Chains of volcanoes form along this type of boundary. Earthquakes are also more common along this type of boundary. The Andes Mountains, in western South America, is an example of an oceanic-continental boundary.



Convergent oceanic-continental boundaries: The oceanic crust is denser than the continental crust. This results in the oceanic crust being subducted beneath the continental crust. Volcanic mountains are common along this type of boundary and can be found in places like the Andes Mountains.

Transform Boundaries

At a **transform boundary**, plates slide past each other. Plates are huge and made from rough rocks! As they slide, they scrape against each other, causing earthquakes. Transform boundaries have **fracture zones** with long cracks in the Earth's crust. These are called faults, and an example is the San Andreas Fault in California.



Transform boundaries: Plates slide past each other, causing earthquakes. One of the most famous examples is the San Andreas Fault in California.

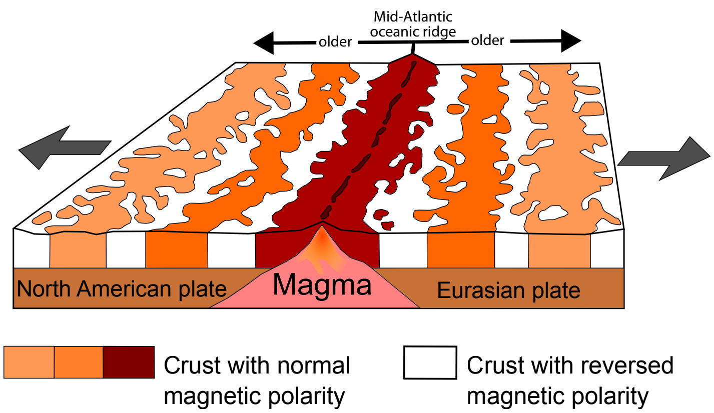
The Evidence for the Theory of Plate Tectonics

The theory of plate tectonics states that the lithosphere is broken into humongous, constantly moving slabs of rock, called tectonic plates. The theory describes how and why tectonic plates move, and how that movement shapes Earth's surface. Scientists have made many observations that support this theory.

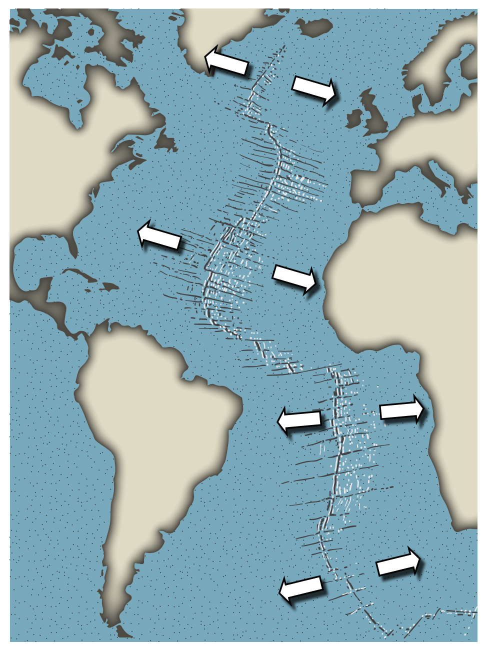
Magnetism and Seafloor Spreading

Earth has a **magnetic field** that surrounds the planet. If you have ever used a compass, you have observed the compass aligning with Earth's magnetic field. Earth's magnetic field has reversed many times, with the North Pole becoming the South Pole and vice versa.

In the 1950s, scientists began using the magnetic properties of magnetite to map the ocean floor. The iron-containing mineral magnetite behaves like a compass. Starting at the center of a mid-ocean ridge and going away from it, scientists were surprised to discover bands of rock alternating in **magnetism** between north-facing and south-facing, back and forth, row after row, in a pattern called magnetic striping. This gave exciting evidence that the seafloor was spreading apart along these ridges.

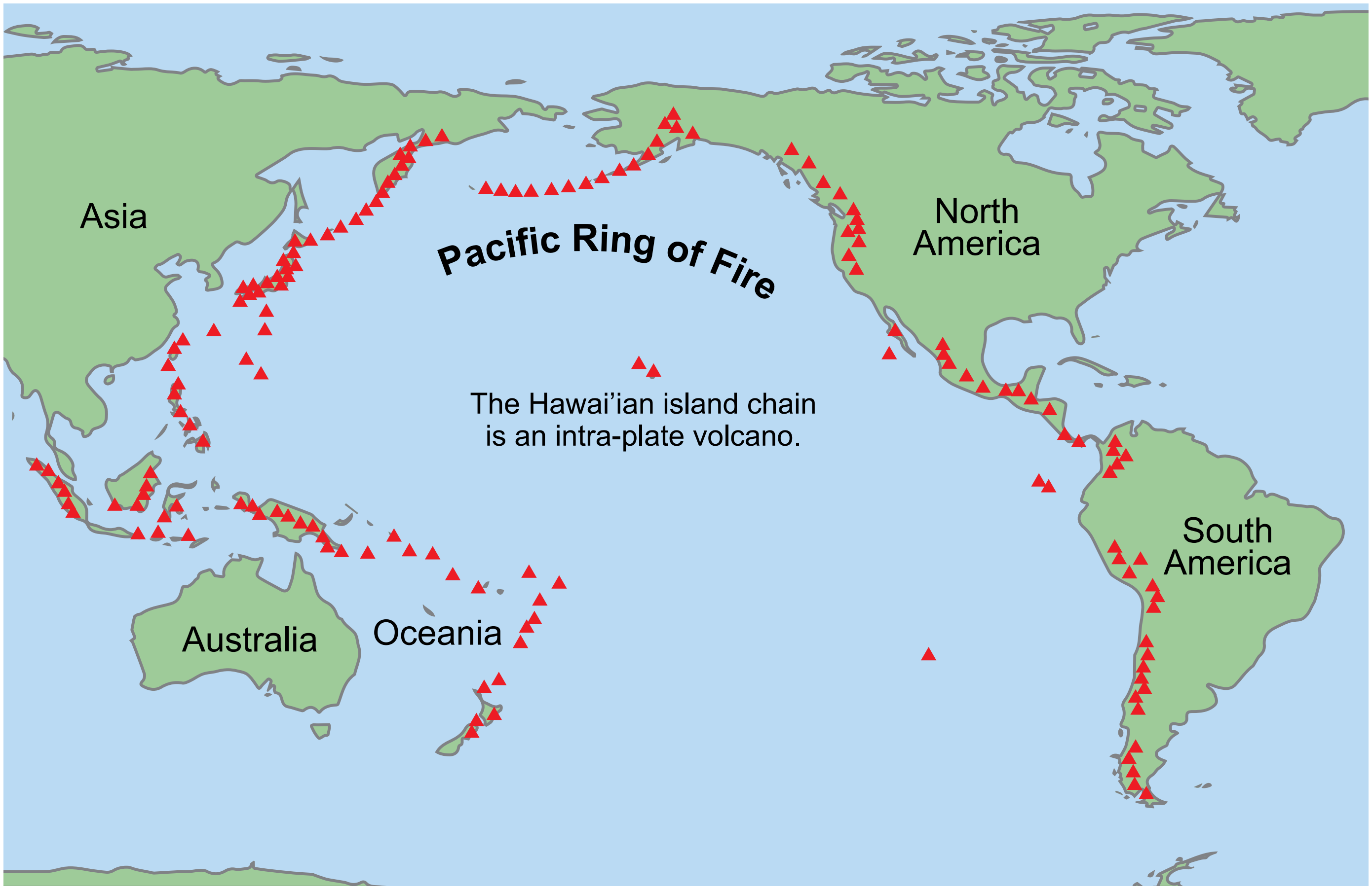


Earth's magnetic field determines the magnetization of lava as it cools to form oceanic crust on either side of the Mid-Atlantic Ridge.



Age and Thickness of Sediment Layers

In 1947, scientists were puzzled to observe that the sediment layer covering the ocean floor was much thinner than expected. It had been assumed that sediments had been piling up on the ocean floor for billions of years. Instead, they observed that whereas continental crust is as much as 20 km (20,000 m) thick, oceanic crust is usually only a few hundred meters. Then scientists discovered that the farther away the sediment was from mid-ocean ridges, the older and thicker the sediment layers were. They also learned that even old oceanic crust is young when compared to continental crust. Scientists hypothesized that the change in depth of sediments and age of the rocks is because oceanic crust is being subducted, made, and recycled to form new rock.



This map shows an area called the Ring of Fire, a region where subduction zones drive volcanic activity and earthquakes, showing the power of moving tectonic plates.

Earthquakes and Volcanoes

Earthquakes and volcanoes are more likely to occur along plate boundaries because of the movement of tectonic plates.

GPS Technology

More recent evidence has come from satellites. Using modern technology, scientists have directly observed the speed and direction of movement of tectonic plates with GPS technology.

Unit III

Earth & Environment LEVEL 2

Earth-Shaping Forces

Chapter 11: Lava You, Lava You Not: Volcanoes

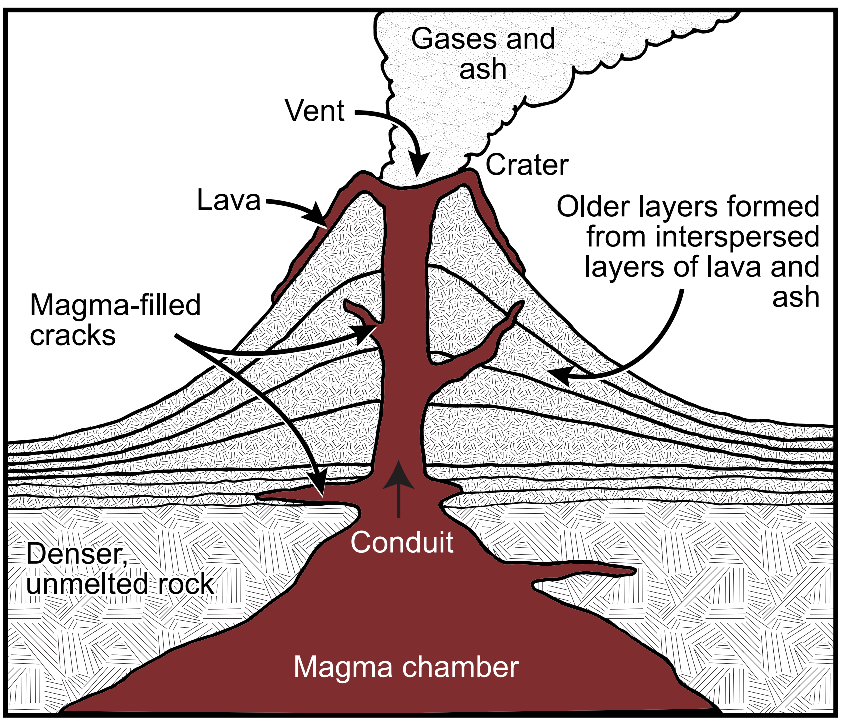
Lesson: Volcanoes

Read

More than 80 percent of Earth's surface is of volcanic origin. That means when you hike, you are likely walking on volcanic rocks! Volcanic activity has played a major role in shaping our planet over billions of years. Countless eruptions have spewed lava, ash, and gases, built mountains and large flat areas called **plateaus**, and even formed ocean floors.

A **volcano** is a site on Earth's crust where molten rock, ash, and gas escape. Magma is less dense than the surrounding material, because of this it rises toward Earth's surface. If magma reaches the surface, it oozes to form a volcano or erupts out of an existing volcano.

Inside Earth, molten rock is called magma. Molten rock at Earth's surface is called lava.



Volcanologists, scientists who study volcanoes, define volcanoes as active, dormant, or extinct based on how likely the volcano is to erupt. An **active volcano** has erupted in the past 10,000 years. A **dormant volcano** has not erupted in the past 10,000 years but is expected to erupt again. An **extinct volcano** is not expected to erupt ever again.

Grímsvötn is a volcano located under the Vatnajökull glacier in southeastern Iceland. It most recently erupted in 2011.

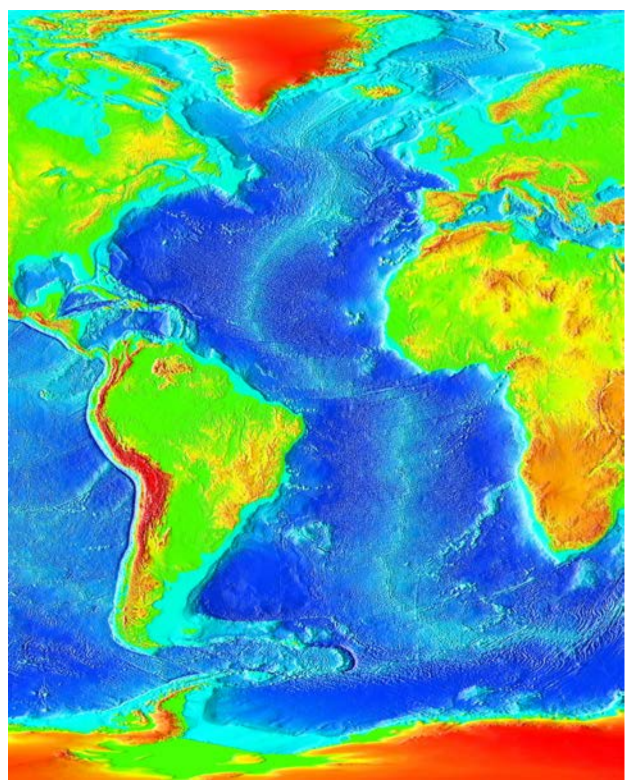
Locations of Volcanoes

Divergent Plate Boundaries

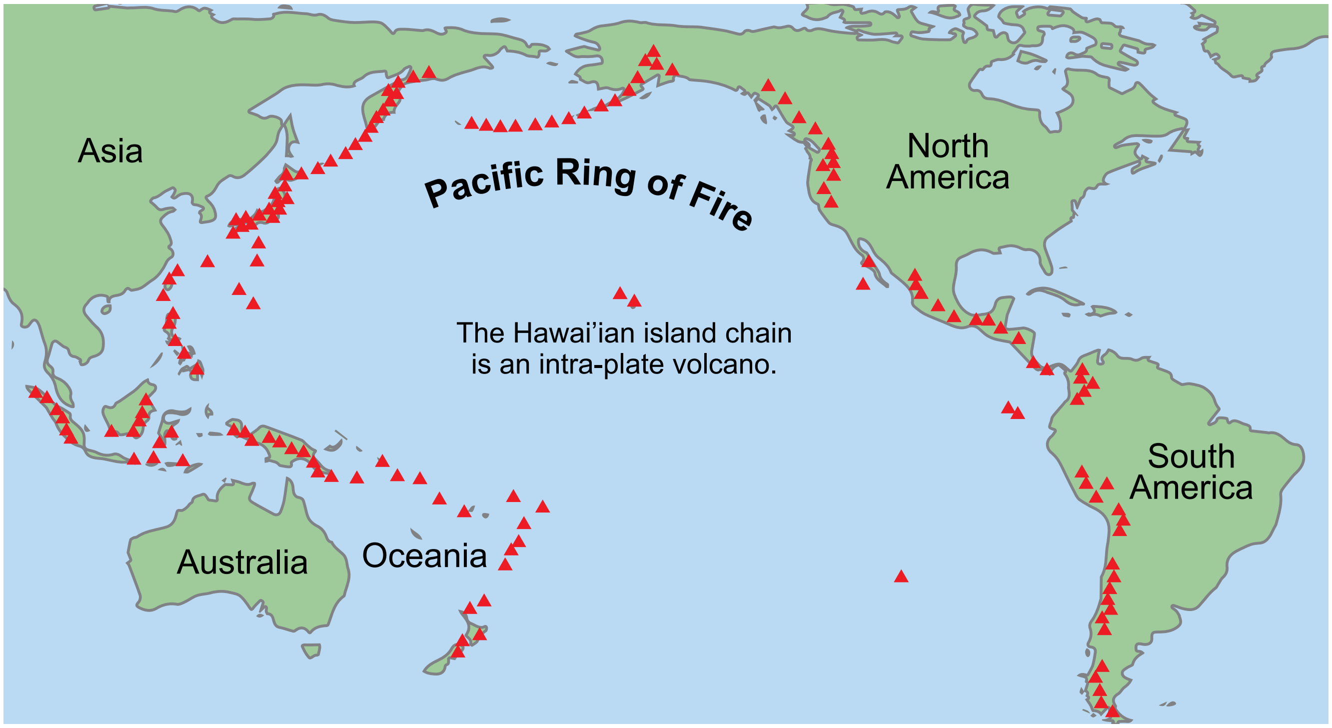
It is easy to understand how volcanoes form at the boundaries between two divergent plates. The plates move apart and the molten rock underneath oozes up. Mid-ocean ridges, like the Mid-Atlantic Ridge, are long underwater mountain chains that formed from volcanic activity at divergent boundaries.

Convergent Plate Boundaries

However, 75 percent of Earth's active and dormant volcanoes, which number about 452, sit along the Pacific Ring of Fire. They are at a subduction zone on the boundaries of two convergent plates, not at divergent boundaries.



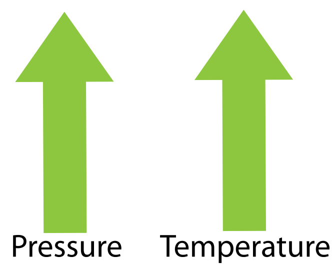
The Mid-Atlantic Ridge formed from volcanic activity.



There are about 452 active and dormant volcanoes that run along the 40,000-km (24,900-mi.) length of the Pacific Ring of Fire.

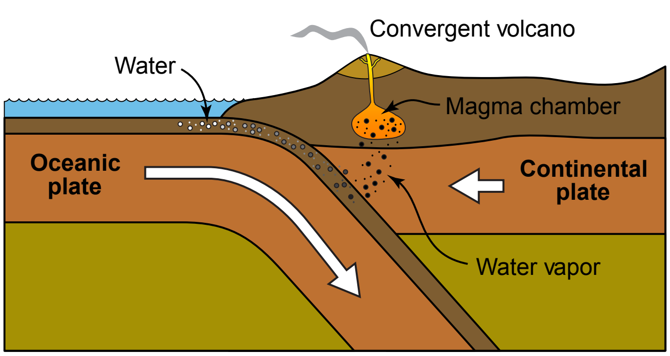
It is not as easy to understand why most of the world's active and dormant volcanoes are in subduction zones. At most convergent boundaries, tectonic plates are colliding with each other and subducting one beneath the other. As the two plates slide and squeeze together, the pressure increases, which increases the temperature between the two plates.

When an oceanic plate is subducted, it takes sediments and water with it. Water is important for magma formation. Water has a lower **melting point** and **boiling point** than rock does. When water is present in the **magma chamber**, the rock melts at a lower temperature. When the rock melts, it is trapped between the two plates, forming a chamber filled with explosive, gas-rich magma that needs to escape, which it does when it erupts along convergent boundaries.



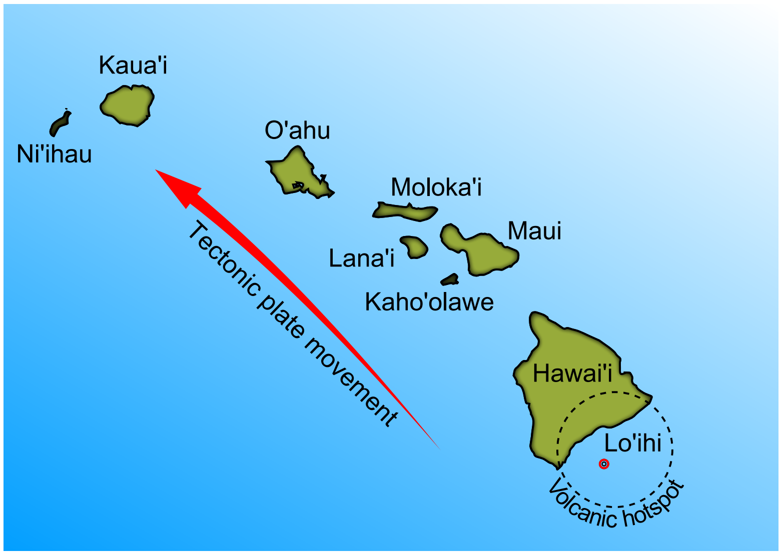
Pressure and temperature have a directly proportional relationship. When one increases or decreases, so does the other.

The melting point is the specific temperature at which a substance melts. The boiling point is the specific temperature at which a substance boils.



Intra-Plate Hotspots

Most, but not all, of Earth's volcanoes are along plate boundaries. Sometimes magma needs to escape from inside a plate boundary. Active volcanoes in the center of plates are called **intra-plate volcanoes** or **hotspots**. The Hawai'ian Islands are intra-plate volcanoes.



The tectonic plate moves away from the hotspot, taking the oldest volcanic islands like Kaua'i the farthest from the hotspot, while the big island Hawai'i and the undersea volcano Lo'ihi are closest to the hotspot.

Intra-plate volcanoes give important evidence about the movement of tectonic plates. If a volcanic mountain forms on top of a plate, it moves with the plate. The magma chamber that supplied the lava to form the mountain does not move with the plate. As the plate moves over the magma chamber, magma comes up at a new location on the surface, and a new volcano forms. This results in a line of volcanoes forming, with the youngest volcano sitting over the magma chamber. The older volcanoes become dormant or extinct as they move farther from the magma chamber.

Modeling Intra-Plate Volcanoes

All you need are your two hands to model this.

1. Point your right pointer finger toward the ceiling and hold it steady; this represents the hot spot of the intra-plate volcano.
2. Hold your left hand horizontally.
3. Slide your left hand across your right pointer finger from wrist to fingers. You can see that if your pointer finger were spewing lava, the first place it spewed out was at your wrist and the last place it spewed would be at your fingers. This shows that while the source material for the volcanoes stayed at the same place, the place it erupted onto the surface did not.

Not All Magma Is the Same

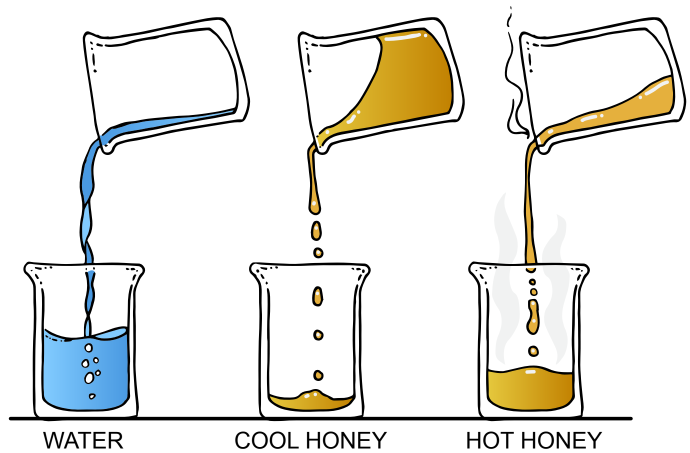
Some magma explodes and some oozes to the surface. The two things determining whether magma explodes or oozes onto Earth's surface are the magma's viscosity (thickness) and the amount of dissolved gas in it.

Viscosity

Viscosity is the ability to resist flow. For example, honey has a higher viscosity than water. The molecules that make a substance affect its viscosity.

In magma, the amount of silicate (SiO_2) affects its viscosity. Melted silicates are like honey; they have a high viscosity. Magma with a large amount of silica, like continental crust, is viscous; it is thick and slow flowing. Magma with low silica content, like oceanic crust, is much less viscous; it flows more easily.

Temperature also affects viscosity. The hotter magma is, the less viscous it is.



Honey has a higher viscosity than water does. There is water in honey, but there are other molecules that make it flow slowly. If honey is heated, it lowers the viscosity of honey, and the honey flows quicker.

Source Material	Silica Content	Viscosity
Oceanic crust	Low	Low
Continental crust	More than 60%	High

Dissolved Gases

Gases, including water vapor, mix with the magma in the magma chamber. The more gas is dissolved in the magma, the more likely the magma is to explode from the volcano. The most explosive volcanoes are those with highly viscous magma and a high content of gas. When the gas becomes trapped in the thick magma, it expands until it explodes through the magma into the air, spewing out magma, ash, gas, and **tephra** (rock fragments made from solidified lava or crust).

When a bottle of soda and a bottle of water are shaken, the soda explodes out because it has more dissolved gas in it than the water does.

Case Study: Mount St. Helens versus Mauna Loa

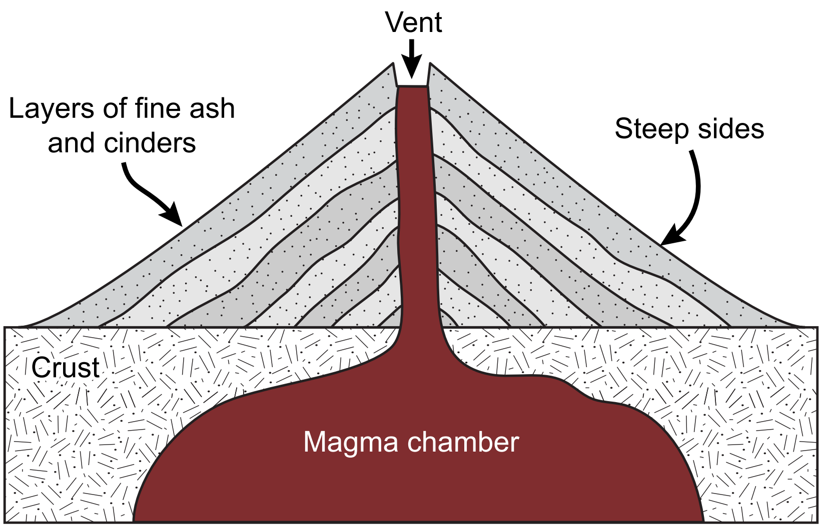
Volcano Name	Mount St. Helens	Mauna Loa
Location	Washington State	Big Island of Hawai'i
Viscosity of Magma	High viscosity due to its high silica concentration	Lower viscosity due to its low silica concentration
Gas Content of Magma	Gas-rich	Gas-rich; however, at a lower concentration than the magma at Mount St. Helens.
Explosiveness	The high viscosity makes it difficult for gas bubbles to escape the magma, leading to pressure buildup and potentially explosive eruptions.	The low viscosity allows gas bubbles to easily rise and escape, resulting in less explosive eruptions that produce gentle lava flows.
Type of Eruption	 **When Mount St. Helens erupted in 1980, viscous magma with a high gas concentration led to an explosive situation that caused widespread damage.**	 **The 2022 Mauna Loa eruption was gentler than it would have been if the magma were highly viscous.**

Types of Volcanoes

There are three major types of volcanoes: cinder cones (also called scoria cones), shield volcanoes, and composite cone volcanoes (also called stratovolcanoes).

Cinder Cones

Cinder cones (**scoria cones**) are the most common type of volcano and form from a single eruption event over 1 to 12 months. The magma chamber is small, so the volcano that forms is small. The volcano starts with an explosive eruption that ejects tephra into the air. The viscosity of the lava depends on where it forms. Cinder cones are often found on the sides of shield and composite cone volcanoes. Examples include Parícutin in Mexico and Crater Lake in the U.S.

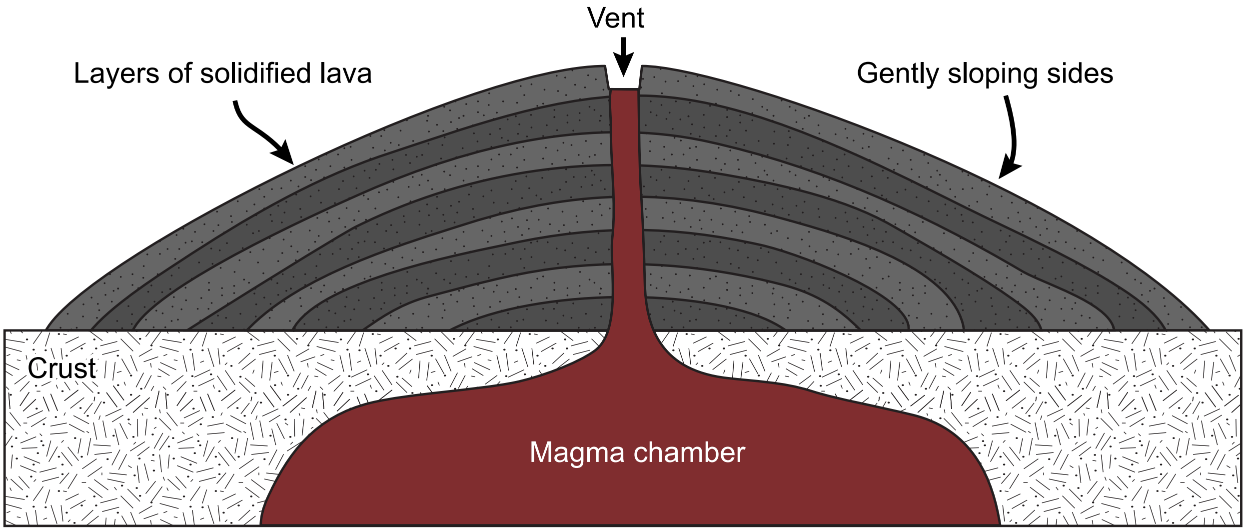


Cinder cone volcano

Wizard Island, in the center of Crater Lake, is a cinder cone volcano.

Shield Volcanoes

Shield volcanoes look like shields turned on their sides. They are large and the sides slope gently. They do not erupt violently because of the low viscosity of the magma and the release of gas from the lava as it flows. Because of the low viscosity, the lava travels faster and spreads out thinly. Shield volcanoes are common at intra-plate hotspots and divergent boundaries. Examples include Hawai'i, the Mid-Atlantic Ridge, and Iceland.

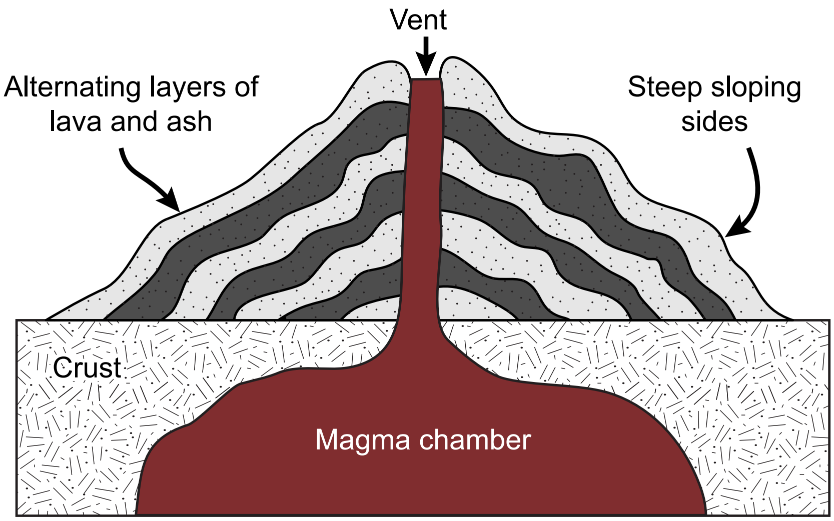


Shield volcano

Mauna Kea is a large shield mountain. This view was taken from the northern slope of Mauna Loa, itself one of the most active shield volcanoes on Earth.

Composite Cone Volcanoes

Composite cone volcanoes (**stratovolcanoes**) erupt explosively because of viscous magma and the higher concentration of dissolved gases. Because the lava is viscous, it spreads slowly. This results in volcanoes that are large with sides that slope steeply. The lava hardens at the top and makes a conical shape built from layers of lava, ash, and rock. Composite cone volcanoes are common at convergent plate boundaries. Examples include Mount St. Helens in the U.S. and Mount Fuji in Japan.



Composite cone volcano

Mount Fuji is a dormant composite cone volcano.

Type of Volcano	Appearance	Description
Cinder Cone (Scoria Cone)	Small	Forms from a single explosive eruption Most common type
Shield Volcano	Large Sides slope gently	No violent eruptions Common at intra-plate hotspots and at divergent boundaries
Composite Cone Volcano (Stratovolcano)	Large Sides slope steeply Conical shape	Explosive eruptions Common at convergent plate boundaries

Environmental and Health Hazards

When a volcano erupts, a lot of various substances are ejected, including gases, magma (which becomes lava), lahars, pyroclastic flows, tephra, and ash.

Outgassing

Outgassing is the release of gas trapped in solids and liquids that have been heated up. Some of the gases released by volcanoes, like water vapor, are harmless. Others, like hydrogen sulfide (H_2S), carbon dioxide (CO_2), and sulfur dioxide (SO_2) are not. Hydrogen sulfide interferes with the body's ability to use oxygen. It can be harmful or fatal even at low concentrations. In high enough concentrations, carbon dioxide can cause serious health problems. Carbon dioxide is heavier than air, and it can displace the air in low-lying areas, killing plants and animals, including humans. Sulfur dioxide causes acid rain, which kills vegetation and is harmful to amphibians and fish.

Lava and Lahars

When magma erupts to the surface as lava, it can cause a lot of damage. Lava can cause fires that burn structures and vegetation. It can melt snow and ice, causing flash flooding and **lahars**, which are fast-moving mudslides that occur on the side of volcanoes. Lahars can bury structures and organisms in their path.

This lahar occurred during the 1982 eruption of the Galunggung volcano on the island of Java in Indonesia.

Pyroclastic Flows

Pyroclastic flows are fast-moving avalanches of hot ash, rock fragments, and gas that hurtle down the slopes of a volcano. They can travel at speeds of up to 700 km/h (about 435 mph) and reach temperatures of 1,000°C (1,800°F) or more. Pyroclastic flows are incredibly destructive, burning and burying what is in their path.

This pyroclastic flow is from the January 2014 eruption of Mount Sinabung on the island of Sumatra in Indonesia.

Tephra and Ash

Rock fragments called tephra along with ash can be ejected into the atmosphere and carried for many kilometers. The tephra are electrically charged and can produce lightning. The ash can interfere with sunlight, reflecting more of it back to space and less of it to Earth's surface. This can lower temperatures, globally affecting the climate.

In 1783, Benjamin Franklin observed there was an unusually cold summer in Europe and the United States. Scientists have determined the reason was ash thrown into the atmosphere from the Laki volcano in Iceland. It erupted over an eight-month period from June 1783 to February 1784. The gases killed livestock and damaged crops, causing a famine in Iceland. The clouds of ash traveled around the world, reflecting sunlight back into space that would normally reach Earth's surface.

The Laki volcano in Iceland erupted continuously from June 1783 to February 1784.

Many scientists think volcanoes at the Deccan Traps in India contributed to the extinction of the dinosaurs. The Deccan Traps is one of the largest volcanic provinces in the world, covering 500,000 km^2 (about the size of California). It is a shield volcano with numerous layers that are more than 2,000 m (6,600 ft.) thick. There is evidence that the Deccan Traps erupted over a 200,000-year period about 65 million years ago, spewing enough ash into the atmosphere to block sunlight from reaching Earth.

The Deccan Traps is a large volcanic province in India, whose eruption 65 million years ago may have contributed to the extinction of the dinosaurs.

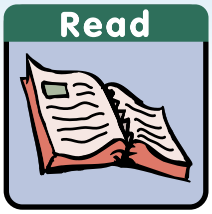
Unit IV

Earth & Environment LEVEL 2

The Hydrosphere

Chapter 18: Just Keep Swimming: Water Pollution and Some Solutions

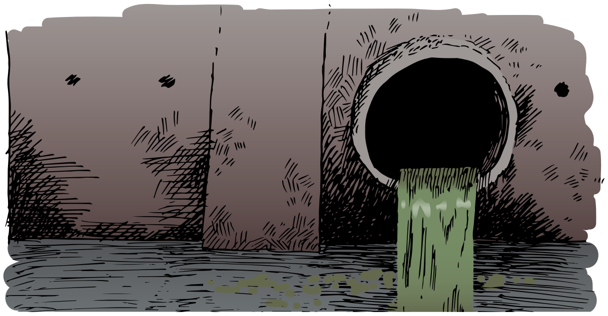
Lesson: Water Pollution and Some Solutions



To determine if water is polluted, scientists look at **water quality**. Water quality describes the chemical, physical, and biological characteristics of water, including its appearance and smell. Clean, unpolluted water has good water quality. Polluted water has bad water quality. Water of good quality supports healthy ecosystems.

The specific requirements for good water quality depend on the intended use and water source. For example, ocean water with good water quality has different chemical, physical, and biological characteristics than fresh water. Water becomes polluted when changes to the water quality harm organisms.

If the water quality needs to be improved, the source of the pollutant must be located. Sources of pollution are classified as point sources or nonpoint sources.



A **point source** of pollution is a source you can point to. The pollution is coming from a specific location. Examples of point source pollution are:

- a pipe that is dumping wastewater into the ocean,
- a leaky gas tank at a gas station where the water table is close to the site of the leaking gas, and
- a uranium mine built near or on a river.

A **nonpoint source** of pollution is a source where pollution is generated over a widespread area. Nonpoint sources of pollution are harder to deal with, because they come from many different sources. Examples of nonpoint source pollution are litter and carbon dioxide emissions, which come from many different people and locations.

Many of the pollutants in water are there because they dissolve well in water. Chemicals that dissolve in water are called **water soluble**. Water-soluble pollutants make water toxic for organisms. They are especially toxic for aquatic organisms that live in water, causing them to become sick or die.

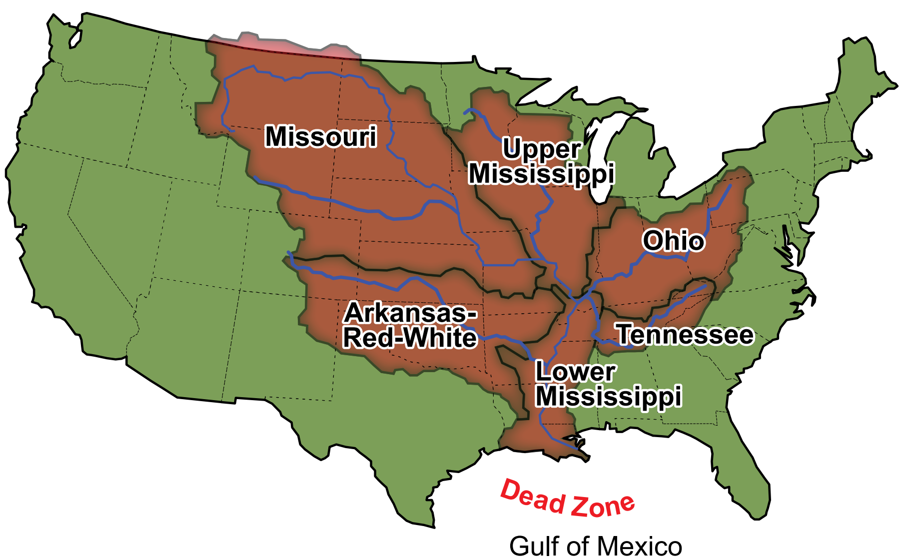
Common Water-Soluble Pollutants

Fertilizers

Fertilizers are a good example of a water-soluble pollutant. People spray fertilizers containing the elements nitrogen and phosphorus to help plants grow better. The problem is that fertilizers do not stay only in the area where they are sprayed. They are carried in water to freshwater and saltwater systems. Nitrogen and phosphorus cause increased plant and bacteria growth in these waters. The increase in plant growth is called **eutrophication**. Eutrophication degrades water quality and harms organisms.

Aquatic plants and algae remove oxygen from water. When plant growth increases, more oxygen is removed. This oxygen is also needed by other organisms. When the plants deplete the oxygen from the water, organisms in the water die from lack of oxygen. Eutrophication in the ocean can lead to "dead zones," where most marine organisms either die or, if they are able, leave the area. A large dead zone forms every spring when farmers fertilize crops in the vast area that is a drainage basin into the Gulf of Mexico. The fertilizer runs off into the gulf, causing eutrophication. Farmers and conservationists are working to capture fertilizers to reduce the runoff of fertilizer-rich water before it enters waterways.

This eutrophication in Sichuan, China, was caused by excessive nutrient runoff.



The largest drainage basin in the U.S. drains into the Gulf of Mexico. The water carries fertilizer, sewage, animal waste, and other dissolved substances, causing an annual dead zone to form during summer and fall. The dead zone can be fixed by using compost as an alternative to fertilizer and by using treatment facilities to clean water.

Sewage and Animal Waste

Everybody poops (and pees), and nobody wants it in their backyard! Most animal waste becomes **sewage**, waste matter that passes through sewers. Poop and pee are water soluble. They also contain bacteria and nitrogen. Bacteria and nitrogen can cause eutrophication.

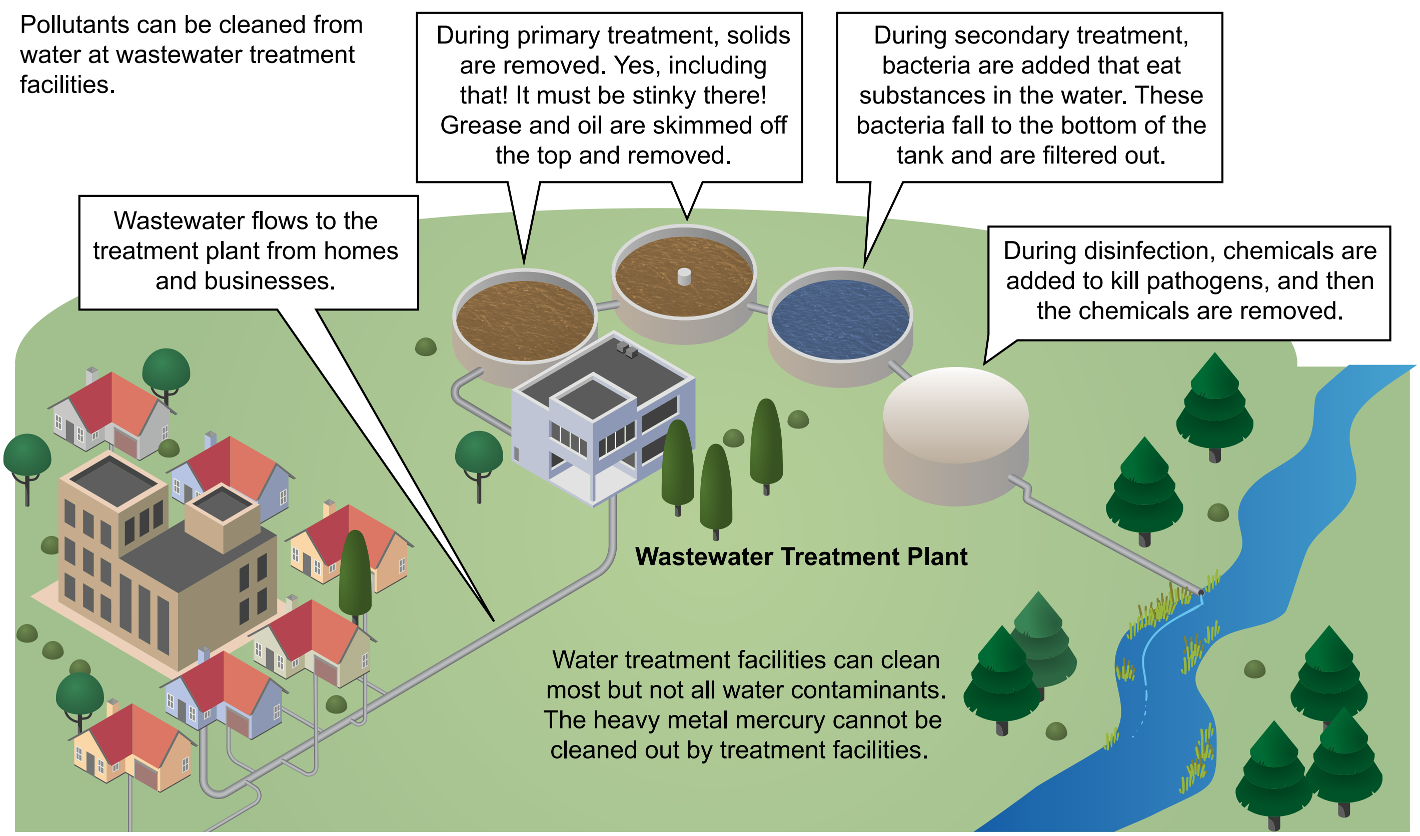
Bacteria can also cause disease. In 1849, London faced a terrible outbreak of a deadly bacterial disease called cholera that caused diarrhea, dehydration, and often death. At that time, people didn't know exactly how cholera was spread. They thought it might be through the air as a form of "bad air" called miasma.

Luckily, a doctor named John Snow had a different hypothesis. He thought cholera was spread through contaminated water. To prove this, he started a scientific investigation into the cases of cholera in a particular area of London. He collected data and made important observations about where the people got their water. Dr. Snow discovered the people with cholera got their water from the same public water pump on Broad Street. He used his data to make detailed maps showing that the closer people lived to this particular pump, the more likely they were to be sick. He reported his conclusion to the local authorities, encouraging them to remove the handle from the Broad Street pump, making it impossible for people to get water from there.

After the pump handle was removed, the number of new cholera cases quickly dropped. This was one of the first times someone used data and mapping to solve a public health problem. John Snow's work didn't just stop the epidemic; it also helped change the way people thought about disease and how it is spread. This event is a major milestone in the field of **epidemiology**, the study of diseases.

Nowadays, wastewater treatment facilities effectively reduce and clean up water to prevent the spread of bacterial diseases such as cholera.

How Wastewater Is Cleaned Up: Wastewater Treatment



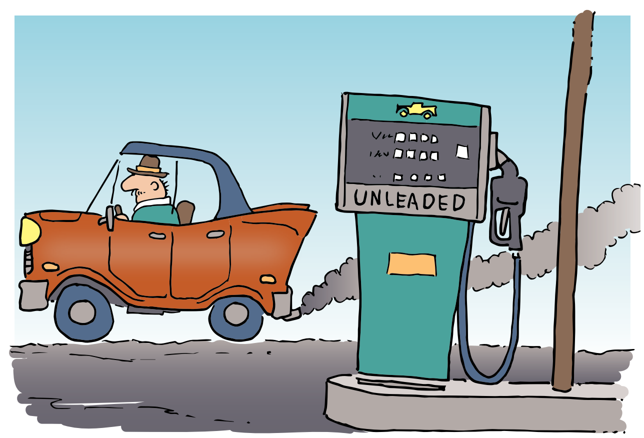
Pesticides and Herbicides

Pesticides are water-soluble chemicals used to kill the insects that eat plants. Herbicides are chemicals used to kill unwanted plants. The problem with pesticides and herbicides is that they do not just kill unwanted insects and plants. They kill other insects and plants as well, including those that live in water. One solution to minimize pesticide and herbicide use is organic farming.

On organic farms, vegetables and fruits are grown without the use of harmful pesticides and herbicides.

Heavy Metals

Some water-soluble metallic elements, such as mercury and lead, are toxic to organisms. Heavy metals are a problem in areas of intensive industry and along roadways where there is runoff. Solutions to minimize these pollutants have been to eliminate them from some commonly used materials, such as taking lead out of gasoline and paint.



Acidification

Acidification means to make something more acidic, which reduces its pH. Most organisms are very sensitive to the pH of their environment. Acidification can harm aquatic organisms. In fresh water, the main cause of acidification is acid rain. Acid rain is caused by the secondary pollutants nitric and sulfuric acid. The acids precipitate back to the ground. The acidification of lakes and rivers occurs when acid precipitation falls into lakes or rivers or in acidic runoff.

Ocean acidification occurs through a series of chemical reactions that start when carbon dioxide is dissolved in seawater. The product carbonic acid lowers the pH of the water, making it more acidic. Reducing emissions of atmospheric pollutants is the solution to the acidification of aqueous systems, both fresh water and salt water.

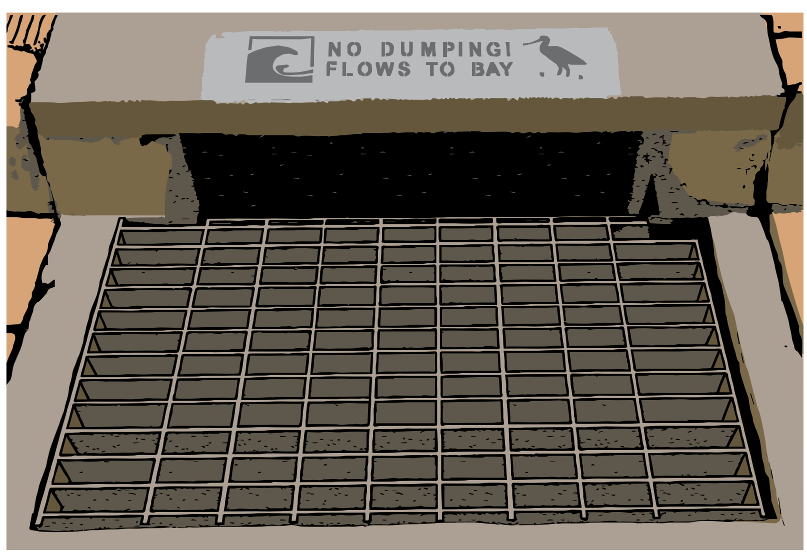
This startling series of images show the dissolution of this organism's calcium carbonate shell due to ocean acidification.

Not Everything Is Water-Soluble

How Oils Pollute Water

Oil and gas in rivers, lakes, and streams come from many different sources. They contain chemicals that are harmful to organisms. Oil spills from tankers carrying oil and at platforms pumping oil are the best-known sources of oil and gas pollutants.

Other lesser-known sources release even more oil and gas pollutants. It is estimated that people dump 240 million gallons of used motor oil every year into storm drains. Leaky gas tanks below filling stations release gasoline into soil that often leaches into the water table.

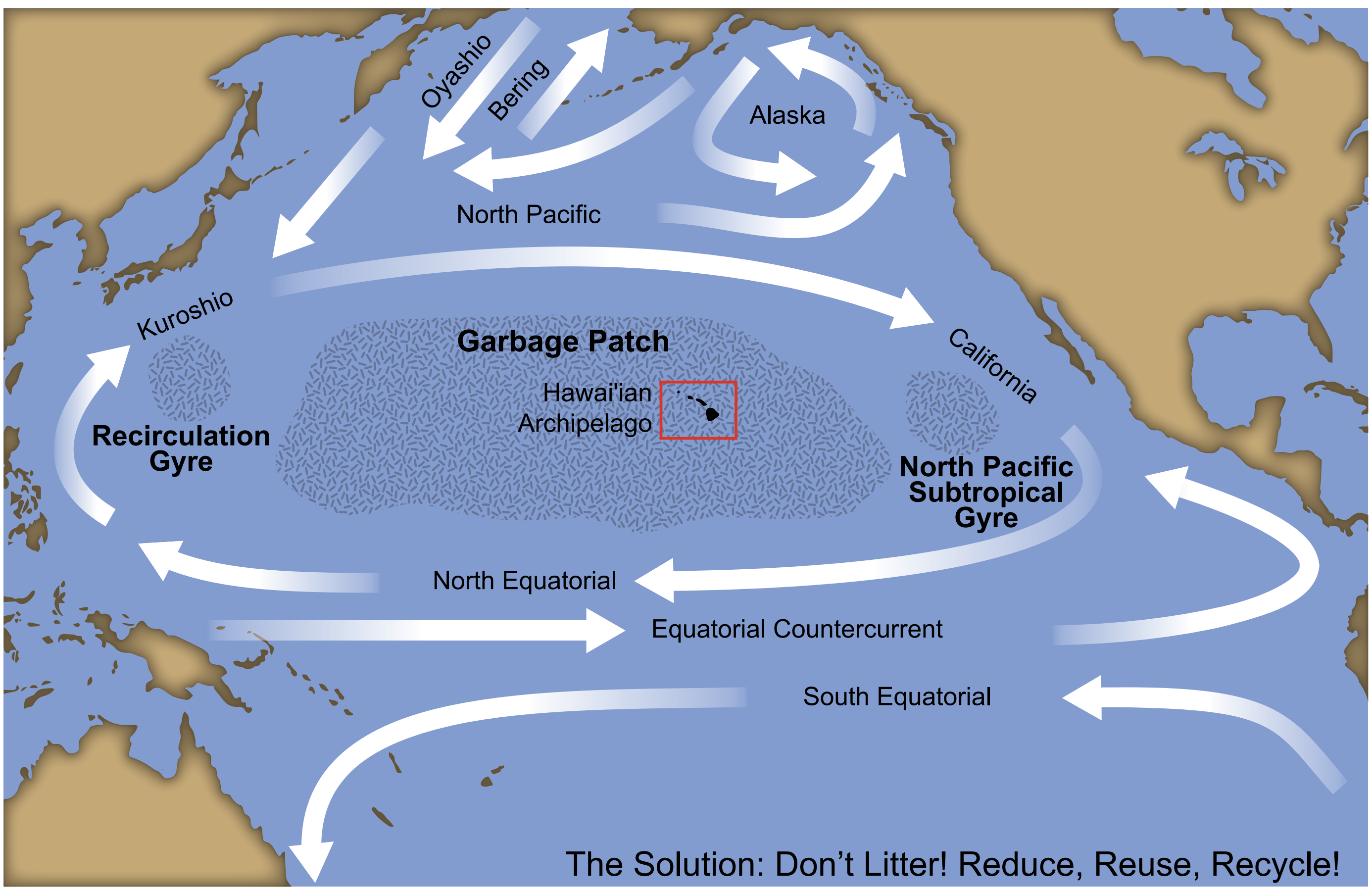


Oil and gasoline are not water-soluble, but they are fluids, so clean-up can be difficult. They cannot just be skimmed off the top of the water. Chemicals can be used to break up the oil, but the chemicals are toxic to wildlife, often doing more harm than good. The best solution is to reduce the global dependence on oil and gasoline. If less gasoline and oil is being transported and used, there will be fewer spills and less dumping. People should also dispose of used motor oil appropriately.

Trash and the Great Pacific Garbage Patch

People make things, they use them, and then they throw them away. Sometimes they throw them away responsibly, and other times they don't. Unfortunately, once this nonpoint pollution reaches lakes, rivers, or the ocean, it generally stays there. Some of it dissolves, some breaks into little pieces, and some sinks to the bottom.

Fishing lines and nets can be a problem when they break off or are disposed of in the water. Animals get caught up in fishing nets and die. Litter is also a problem for animals that mistake litter for food and eat it. Some of the trash contains chemicals that make the water toxic. Too often, this litter makes its way to one of the "garbage patches" that form in gyres. Much of this litter in these garbage patches is so small it can only be seen with scientific instruments. In addition, there are organisms in these areas. The miniscule size of much of the garbage and the presence of organisms has made it challenging to come in and just scoop up the trash.



What Can Be Done?

Pollution is a problem for the atmosphere, land, fresh water, and oceans. While these problems might seem overwhelming, even small actions can make a difference. The first step is understanding the science behind the issues, and you are doing that!

Next, you can do what scientists and inventors do and that is to think about how to solve the problem. Making a scientific model is a good place to start. If you make a scientific model of how the area or ecosystem is being polluted, you might be able to figure out how to either clean up the pollution or stop it from occurring.

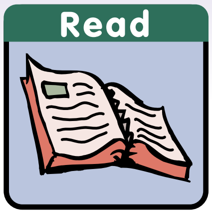
In 2015, teenager Boyan Slat invented a system that removes plastic waste from the Great Pacific Garbage Patch. His innovative solution involves a large, floating barrier that passively collects plastic as it drifts on the ocean currents. The design of the system uses the natural movement of the ocean to its advantage, allowing the ocean currents to push plastics towards the barrier. The barrier then captures and concentrates the plastic, making it easier to gather and remove from the water. This floating barrier is designed to be efficient, cost-effective, and safe for marine life. Slat's work shows how innovation, no matter how old you are, can play a role in addressing environmental challenges, highlighting the potential for creative solutions to combat pollution in our oceans.

Plastic catch on board a support vessel, and Boyan Slat showing sorted plastic that will be recycled.

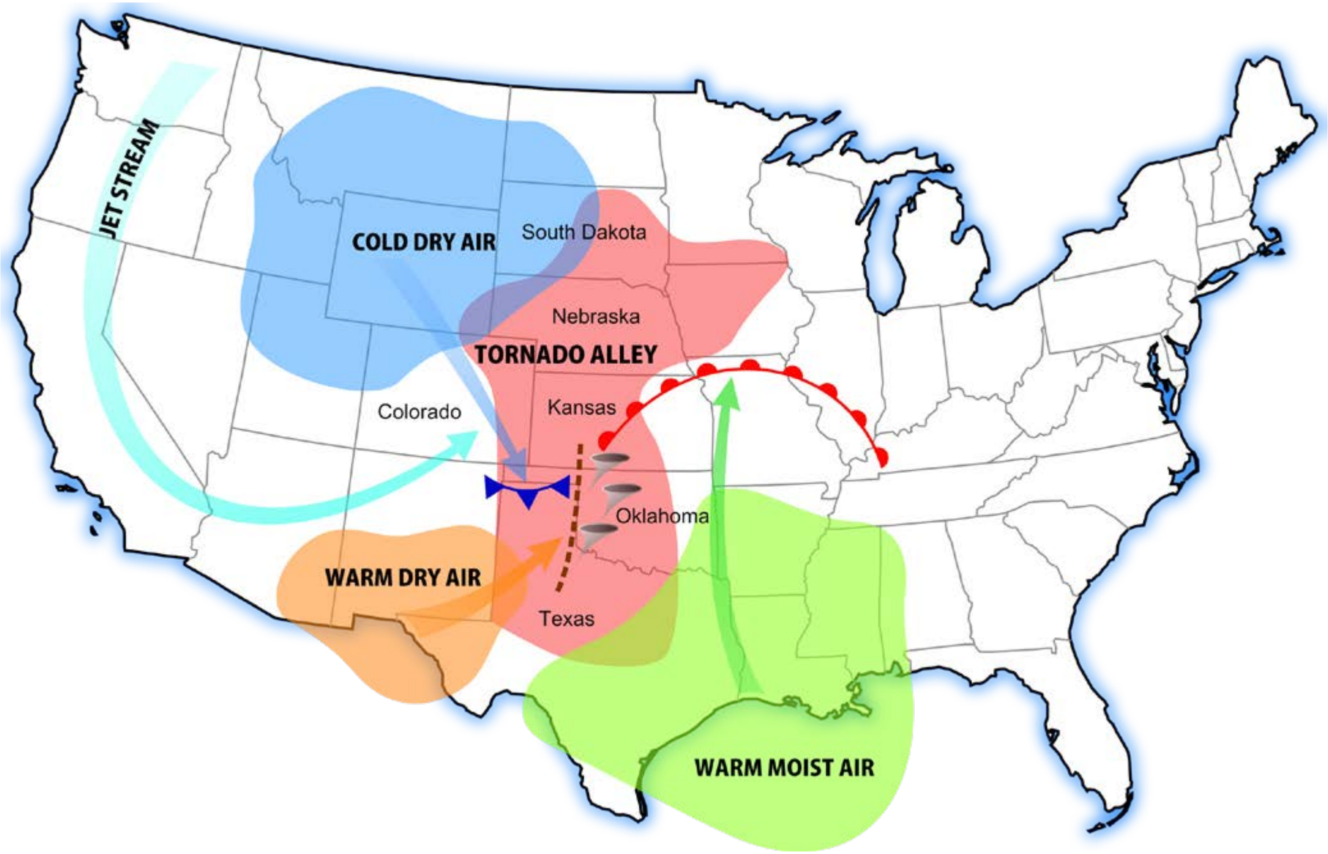
The Atmosphere

Chapter 21: What a Whirlwind: Storms

Lesson: Storms



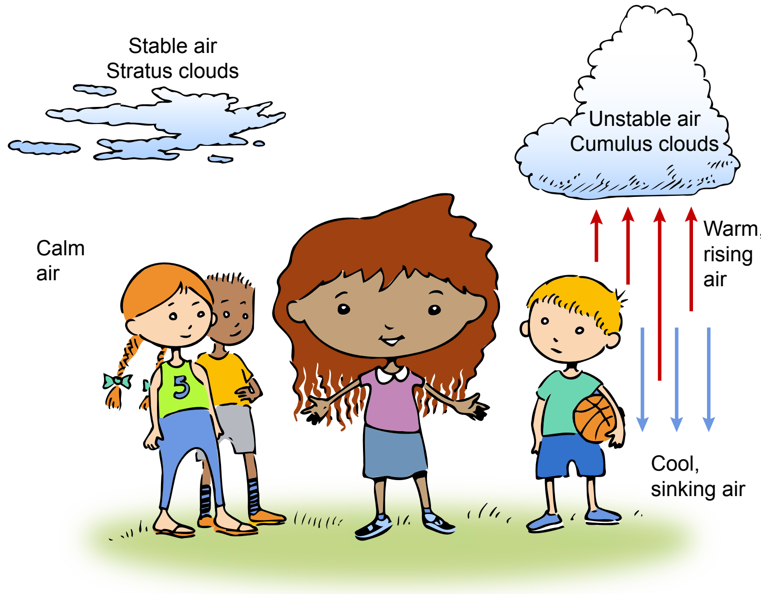
The summer when I was 10, we drove from New York State to California. My clearest memory of the trip is the tornado we saw while driving through what is known as Tornado Alley. The land all around was flat, and in the distance, we could see a perfectly coiled twister. We were a safe distance from it. Even so, my sister and I were nervous. We had seen *The Wizard of Oz*, and neither of us was ready to meet the Wicked Witch of the West. Do you have a memory of a storm? Were you scared? Storms can be destructive, but they are also fascinating.



Air Masses and Storms

Air masses are an important part of storm formation. Air masses are huge. They cover a large amount of surface area along the ground, and they extend up into the atmosphere. As you learned in the previous chapter, the temperature and humidity (the concentration of water vapor) affect the density of air masses. Less dense air rises and denser air sinks. This movement results from convection along the fronts that form between air masses.

This convection at fronts can cause **storms**. Different types of storms occur because of differences in the air masses that cause them. Storms have wind, precipitation, or both. Thunderstorms, tornadoes, and hurricanes have both; snowstorms have precipitation and can have wind; and windstorms have wind.



Stable air stays where it is, resulting in calm air (left). Unstable air is more humid, warmer, or both, making it less dense. It rises while surrounding cool air sinks (right).

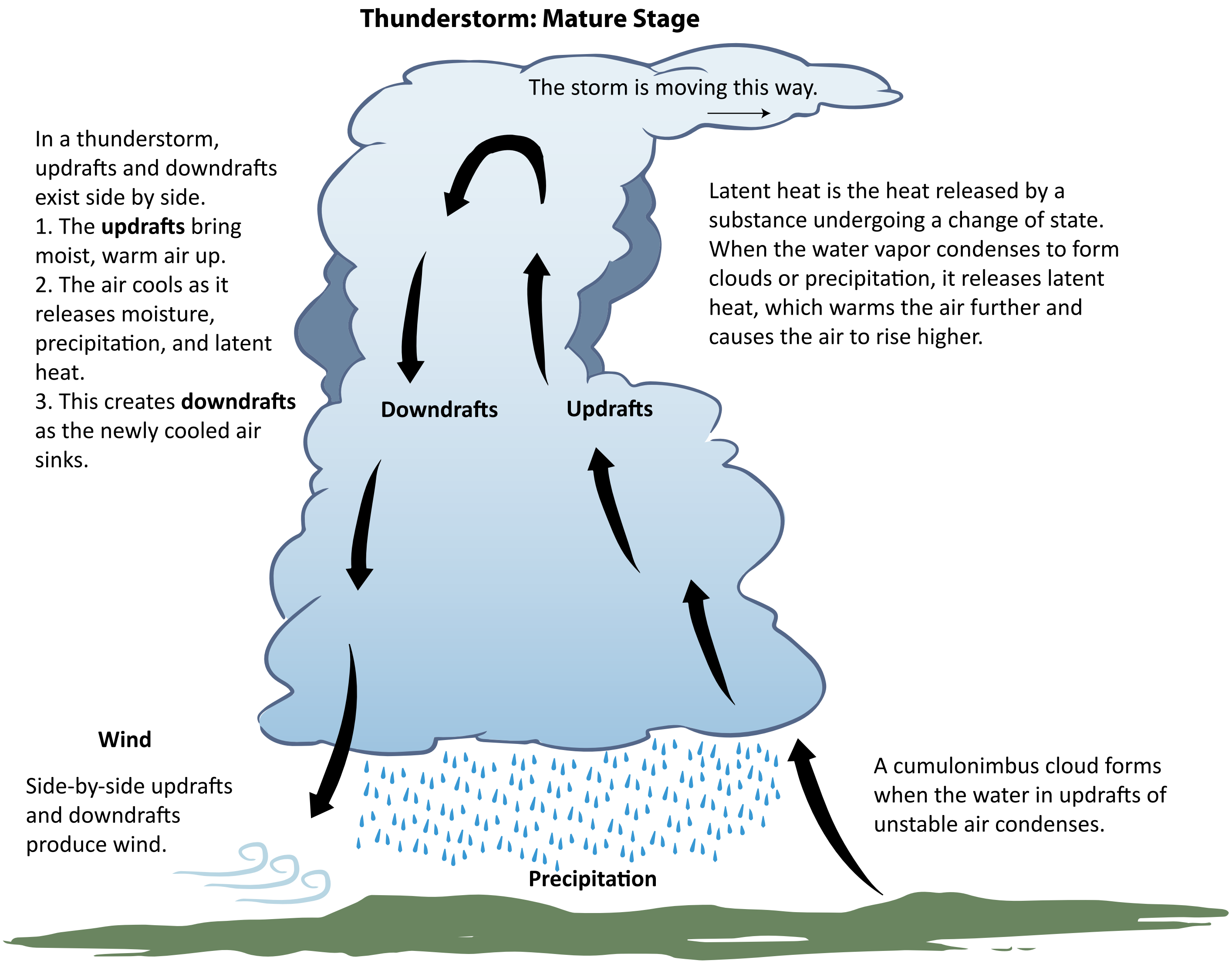
For a storm to form, the rising air needs to be unstable. When unstable air rises, weather can change quickly. Clouds form and precipitation can fall. There are three ways air can become unstable:

1. At the front between a cold air mass and a warm air mass, the densities of the two masses will be different. The mass with the lower density rises and can become an unstable air mass.
2. When a warm air mass collides with a mountain and is forced up because of orographic lifting, the lifting air mass can become unstable.
3. **Surface heating** happens when the ground heats and transfers some of that heat to the surface air above. This makes the packet of air at the surface warmer, causing it to be less dense than the surrounding air. This less dense air packet rises. The rising hot air causes cold air to sink, creating a convection cycle of unstable air.

Unstable air, cloud formation, and precipitation are related. Precipitation starts to form when warm, wet air becomes unstable and rises. As the air goes up in the atmosphere, it cools and the water in the air condenses. The condensing water forms clouds and can result in precipitation. When water vapor condenses to form clouds or precipitation, it releases **latent heat**, which is heat released by a substance undergoing a change of state. This release of latent heat warms the air further and causes the air to rise higher.

Thunderstorms

Thunderstorms form from moist, unstable air. Thunderstorms are defined as storms with lightning and thunder. They also often have high winds and rain or hail. **Hail** is a type of frozen precipitation that forms when a fast updraft is strong enough to carry water drops to an altitude above the freezing level, where the water drops freeze and then fall to the ground. The stronger the updraft, the larger the hail is.



When updrafts and downdrafts rub against each other, an electrical connection is made between charged molecules in the bottom of the cloud and on the land below. When there is enough charge at the bottom of the cloud, a discharge of energy in the form of lightning is emitted. Heat from the lightning causes the air along its path to expand rapidly. Thunder is the sound of the rapidly expanding air.

Development of Thunderstorms

Thunderstorms go through several stages during their life cycle. The first stage is called the **developing stage**. During the developing stage, unstable air begins to rise, creating updrafts and transporting water vapor into the atmosphere. The water vapor condenses and releases latent heat as it forms the liquid water drops that make cumulonimbus clouds.

The second stage is called the **mature stage**. The illustration above shows this stage. During the mature stage, updrafts and downdrafts exist side by side, and precipitation falls.

The third stage of thunderstorm development is called the **dissipation stage**. During this stage, the supply of warm, moist air begins to dissipate, disappear, and the storm ends.

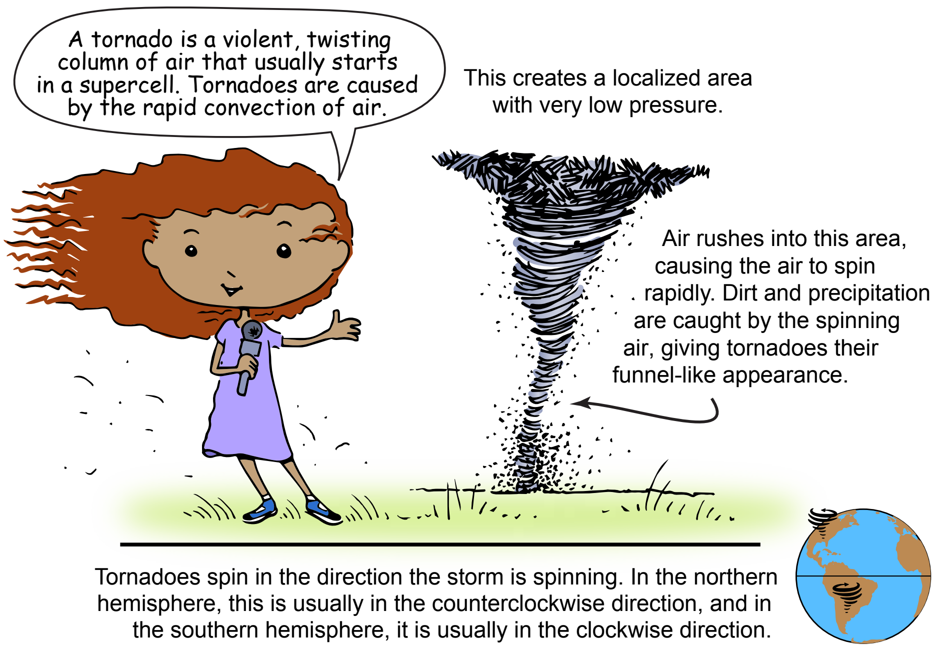
A **supercell** is a thunderstorm where the updrafts and downdrafts are the same strength. Supercells can last for hours before getting to the dissipation stage. This can cause flooding.

If you have ever witnessed a thunderstorm, you know the sight of **lightning** reaches you before the sound of **thunder**. That is because lightning travels at the speed of light (300,000,000 meters per second) and thunder travels at the speed of sound (340 meters per second). That's right—light travels almost a million times faster than sound! The rapid expansion and contraction of air due to the intense heating during a lightning strike produces the sound we hear as thunder.

You can use the speed of sound to determine how far away thunder and lightning are. When you see lightning, count the number of seconds until you hear thunder. Divide the number of seconds by 3 to get an estimate of the distance in kilometers. Divide the number of seconds by 5 to get an estimate of the distance in miles.

Tornadoes

Tornadoes form inside thunderstorms when warm humid air rises while cool air falls. These air currents can start to spin horizontally. As rising air spins, it gets drawn inward by the falling air. This creates a vortex. With enough pressure, the spinning vortex can touch the ground. The more powerful the thunderstorm, the more likely it is that tornadoes will form. Supercells can produce powerful, damaging tornadoes.

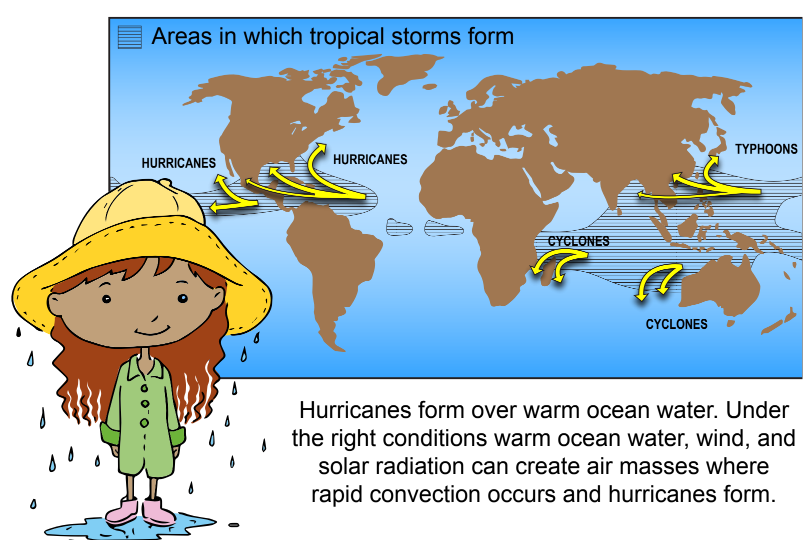


Tornadoes spin in the direction the storm is spinning. In the northern hemisphere, this is usually in the counterclockwise direction, and in the southern hemisphere, it is usually in the clockwise direction.

Hurricanes

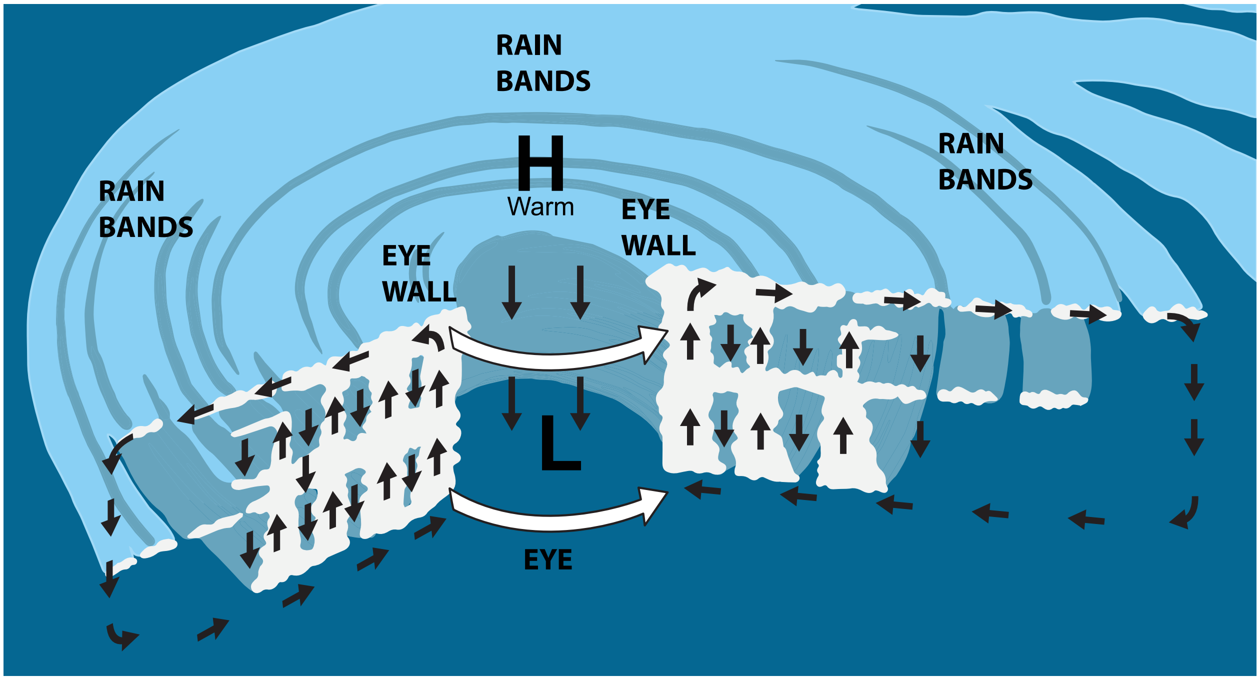
Hurricanes occur during the summer and fall when oceans along the equator are warmest. They start as a group of thunderstorms forming over the ocean when a continental air mass blows off the continent and converges with a warm, wet maritime air mass over warm ocean water.

The warm, wet air mass becomes unstable and rises rapidly, creating a low-pressure system where thunderstorms are common. As the air rises, a high-pressure



Hurricanes form over warm ocean water. Under the right conditions warm ocean water, wind, and solar radiation can create air masses where rapid convection occurs and hurricanes form.

layer forms over the low-pressure layer. The pressure gradient causes the air to begin circulating around the center and wind speeds to increase.



If the storm remains over the ocean, there is continued convection of warm, moist air. When conditions are favorable, such as over the ocean, wind speeds will continue to increase, clouds will expand, and the thunderstorm will become larger. Once the system reaches speeds of 119 km/h (74 mph), it is classified as a hurricane. Hurricanes are an average of 201 km (125 mi.) across. If the hurricane travels over land, the updraft of warm, wet air stops, and the hurricane loses strength. Flooding is common when this happens.

A National Oceanic and Atmospheric Administration (NOAA) satellite captured an image of Hurricane Humberto on September 15, 2019.

The main parts of a hurricane are the **eye**, the **eye wall**, and the **spiral rainbands**. The center of the hurricane is called the eye. In the eye, skies are clear and winds light. These range between 8 and 48 km (about 5 to 30 mi.) in diameter. The eye wall is the ring of cumulonimbus clouds swirling around the hurricane's eye. The worst precipitation and winds are in this area. Spiral rainbands are bands of rain showers that spiral inward around the hurricane's eye.

Other Types of Storms

Snowstorms

A blizzard is a severe snowstorm with high winds.

Snowstorms typically form within areas of low pressure where warm air meets cold air. They do not start as a part of a thunderstorm. The process begins with the formation of a cold front when a mass of cold, dense air moves into an area previously occupied by warmer air. As the warm air is forced to rise over the colder air mass, it cools and condenses. If moisture is present, clouds form.

Within these clouds, water vapor condenses onto tiny particles, such as dust, forming ice crystals. These ice crystals then collide and stick together, forming snowflakes. If the atmosphere is cold enough from the surface up through the clouds, the snowflakes remain frozen as they fall to the ground.

If the air temperature remains at or below 0°C (32°F) between the cloud and the ground, the precipitation falls as snow. If the air near the ground is above freezing, the precipitation melts into rain or freezing rain.

Windstorms

A **windstorm** is a storm with strong winds. These storms typically form in regions where there is a significant contrast in temperature and pressure between two air masses. This contrast sets up a pressure gradient, with air moving from areas of high pressure to low pressure. As air rushes to equalize these pressure differences, it generates strong winds. While windstorms are primarily defined by their wind intensity, they can sometimes involve precipitation, such as rain or snow. The occurrence of precipitation in a windstorm depends on various factors, including the moisture content of the air masses involved.

Dust storms are a type of windstorm. They occur over dry areas where there are significant amounts of dust.