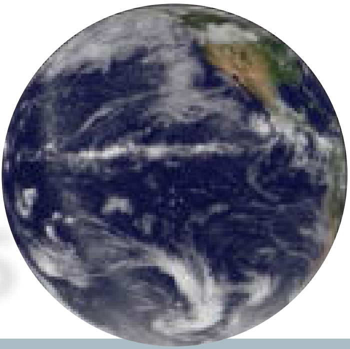
Core Knowledge® Science

Modeling Earth's Systems

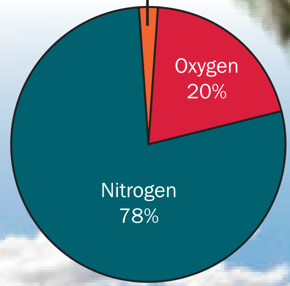


Hydrosphere

Reader

Geosphere

Biosphere



Interaction of Earth's systems

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Modeling Earth's Systems

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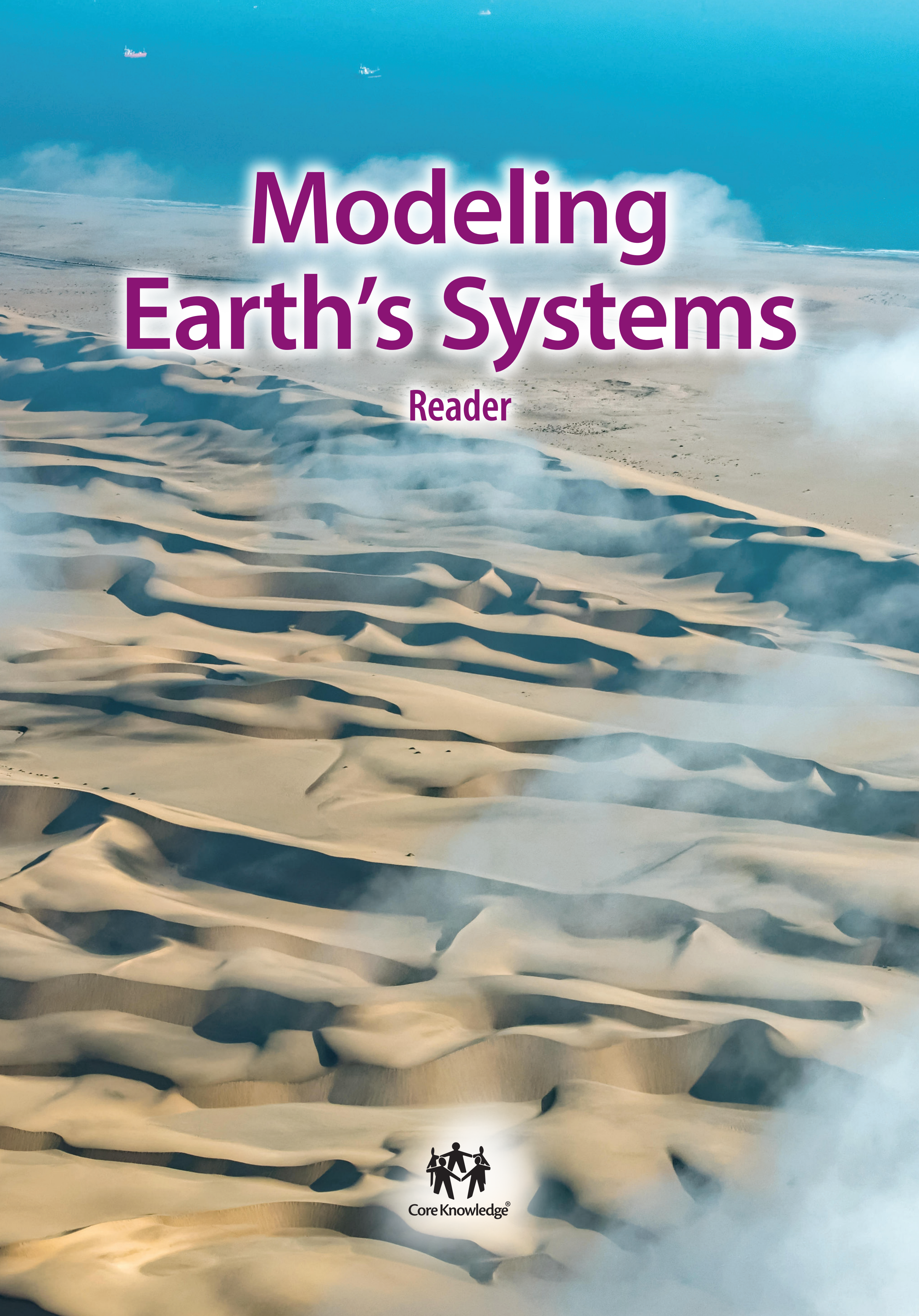

Core Knowledge®

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Modeling Earth's Systems

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The Hydrosphere

Chapter 1

If you look at Earth from space, directly above the center of the Pacific Ocean, you would barely see any land at all. About seven-tenths of Earth's surface is covered by water. Most of the water is found in Earth's oceans. Water is also found in streams, rivers, ponds, and lakes. Cracks and spaces in underground rocks and soil contain water, too. So does the air.

Most of Earth's water is liquid. However, some of Earth's water is solid, frozen in ice caps and other glaciers. Some of Earth's water is an invisible gas, called *water vapor*, in the atmosphere. Altogether, all the water on Earth makes up a system called the **hydrosphere**.

Big Question

What is the hydrosphere?

Vocabulary

hydrosphere, n. the Earth system that contains all of the water on Earth

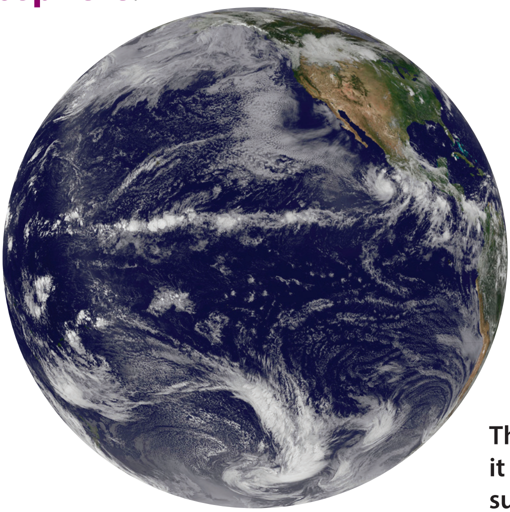
Word Part

The word part *hydro-* means "water."

Words to Know

A *system* consists of parts that *interact*.

To *interact* means to have an effect on something else.

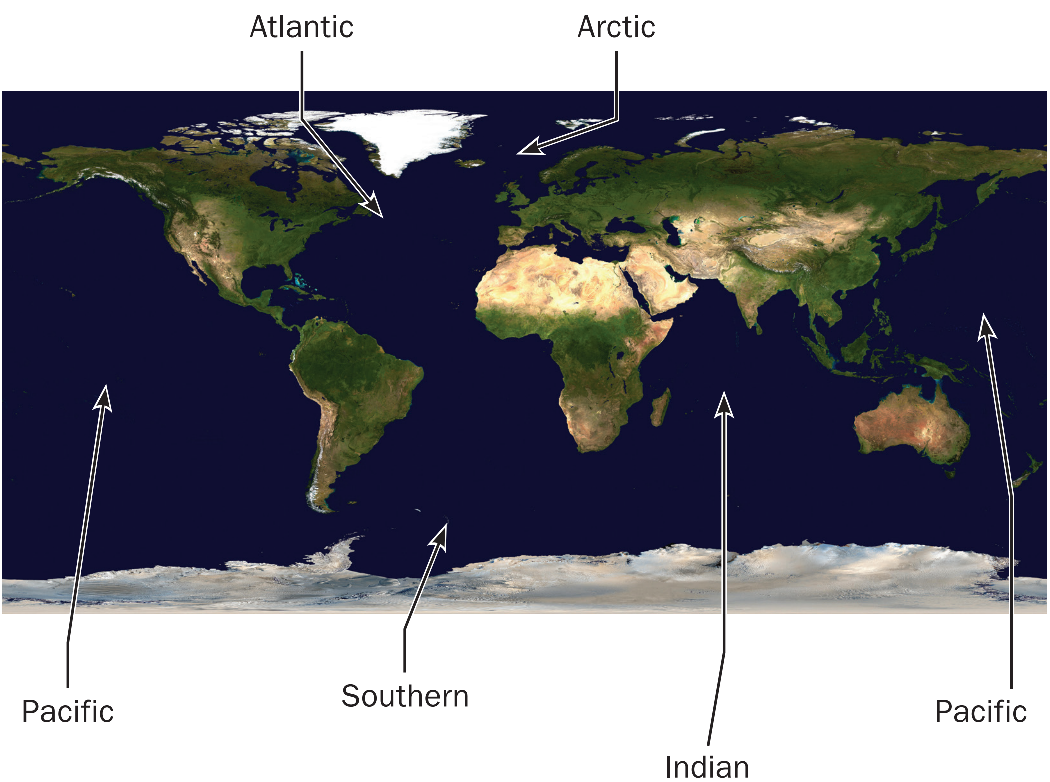


The view from space makes it clear that most of Earth's surface is covered with water.

Earth's Hydrosphere Contains Salt Water

All the surface ocean water on Earth is interconnected and forms one giant world ocean. But people have named ocean regions with their own names.

The largest ocean region is the Pacific Ocean. It covers approximately one-third of Earth's surface. This is where Earth's ocean is deepest. The average depth of the Pacific Ocean is about 13,000 feet (4,000 meters). At its deepest point in a far western area, the ocean floor is about 36,000 feet (11,000 meters) below the surface. That is almost seven miles! This section of the ocean is called the Challenger Deep. Because it is so deep, it is mostly unexplored by scientists.



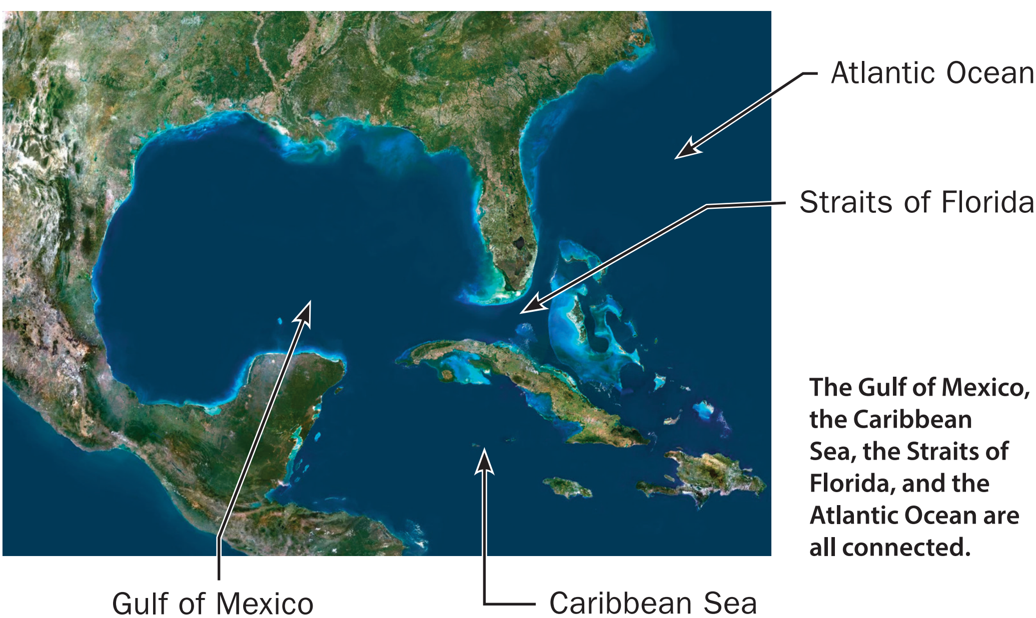
Different regions of Earth's ocean have different names. But they are all connected in one huge body of water.

Specific regions of oceans can be called seas or gulfs. These regions are defined by land that borders or partially surrounds them. Larger regions of ocean water are connected by narrow bodies or water between landmasses. These narrower waterways are called straits.

Oceans, seas, and gulfs all contain salt water. **Salt water** is simply water that contains salt. Most of the salt, the chemical sodium chloride, is the same as table salt! Some bodies of water are saltier than others. The salt comes from rocks on Earth's land surfaces. It is picked up by streams and rivers as they flow toward the ocean. As water evaporates from the ocean into the air, the salt is left behind. Over very long periods of time, this process has made the oceans salty.

Vocabulary

salt water, n.
water that contains dissolved salt



The Gulf of Mexico, the Caribbean Sea, the Straits of Florida, and the Atlantic Ocean are all connected.

Earth's Hydrosphere Contains Fresh Water

Oceans are only one part of the hydrosphere. Water also occurs in streams, rivers, ponds, and lakes. These bodies of water lie on Earth's land surfaces. There is also water beneath Earth's surface in the spaces between rocky material. This water is called **groundwater**. Places where water collects, in all its states, are called **reservoirs**.

Earth's main water reservoir is the ocean, which contains salt water. But most of Earth's inland water reservoirs contain fresh water. **Fresh water** is any water that has low amounts of salt in it. Rivers, streams, and wetlands all contain fresh water.

Vocabulary

groundwater, n. water stored in the spaces between materials beneath Earth's surface

reservoir, n. a place where water collects

fresh water, n. naturally occurring water that contains little or no salt

Some groundwater and water in lakes are salt water instead of fresh water. The Great Salt Lake in Utah is one example. It formed when water carrying salts from rocks flowed into the lake. The lake has nowhere for the water to flow out. When water in the lake evaporates, salt is left behind. Over time, the salt accumulated, making the water very salty.

Part of the Great Salt Lake is a pinkish color. The concentration of salt in the Great Salt Lake is much higher than that found in the world's oceans.

Some of the fresh water on Earth is liquid, but most fresh water is frozen in glaciers. The ice caps at the North and South Poles are two very large glaciers. Much of this water is permanently frozen. However, some polar ice thaws and refreezes with the seasons. When this freshwater polar ice melts, it can make the ocean water around it less salty. Because of recent warming of Earth's climate, more polar ice melts each year than refreezes.

Fresh water from rivers flows into larger bodies of water. Rivers flow into lakes, oceans, gulfs, and seas. Where ocean water backs up into freshwater streams and rivers, the water becomes brackish. Brackish water has more salt than fresh water but not as much salt as ocean water.

This photo shows where the Mississippi River empties into the Gulf of Mexico. The water found here is brackish.

Water Has Physical Properties

Water can be found in nature as a solid, a liquid, or a gas. This is because water's physical properties cause it to evaporate, condense, freeze, and melt within a relatively close range of temperatures.

The temperature at which water boils is 212°F (100°C). The temperature at which it freezes is 32°F (0°C). Water evaporates, or changes to a gas, very quickly at the boiling point. But it can evaporate at lower temperatures when heat energy is present. Water can even evaporate when it is frozen.

Condensation occurs when water changes from a gas (water vapor) back to a liquid. Water vapor condenses when it cools. This can also happen at different temperatures. Condensation on the outside of a glass of ice water happens when water vapor in the air contacts the cold glass.

Water vapor, water as a gas, is invisible. But it is present here, along with solid and liquid water.

Earth's atmosphere contains water that enters the air as water vapor. As the water vapor rises into the air, it encounters cooler temperatures. This may cause the water vapor to condense into liquid water. Clouds are tightly packed droplets of liquid water. Eventually, these droplets of water fall back to Earth as precipitation. Precipitation can occur as rain, snow, sleet, freezing rain, or hail. The form that precipitation takes usually depends on the temperature of the air near Earth's surface.

Because wind pushes the clouds around, water is deposited in new places on Earth when it falls. The water that you see in a lake or river was once water vapor in the atmosphere. The water that falls to Earth continuously replenishes Earth's ocean, lake, and groundwater reservoirs. And water evaporates from surface reservoirs to become water vapor again.

The sun provides heat energy that causes water from a lake's surface to evaporate into the atmosphere.

The Water Cycle

The hydrosphere is constantly moving and changing. Evaporation, wind, and precipitation move water from one water reservoir to another. Gravity also moves water. Its pull causes water to flow downward. Currents in Earth's oceans continuously move the water, too.

The dynamic movement of water on, below, and above Earth's surface is called the **water cycle**. As water moves, the hydrosphere interacts with Earth's land, air, and living things. In addition to changing position, water in the water cycle is constantly changing states.

Word to Know

Dynamic means constantly changing. It comes from the Greek word *dynamikos*, which means "powerful."

The sun is the energy source for state changes in the water cycle. It provides heat that causes water to evaporate. Water vapor rises, cools, and condenses into cloud droplets. Then liquid water falls back to Earth as precipitation somewhere else. This process happens over and over, in cycles.

Vocabulary

water cycle, n. the dynamic movement of water on, below, and above Earth's surface

The Geosphere

Chapter 2

Although Earth's surface is mostly covered with water, the planet itself is made almost entirely of solid, rocky material. There are different layers of this material, and each layer has different properties. Taken together, all the rocky material that makes up Earth is called the **geosphere**. The geosphere includes all of Earth's visible **geologic** features, such as mountains, as well as the inner rocky layers that you cannot see. It includes all of Earth's rocks and minerals. The bits of rock in soil are also part of the geosphere.

Big Question

What is the geosphere?

Vocabulary

geosphere, n. the Earth system that contains all the rocky layers of Earth

geologic, adj. relating to Earth's rocky inner and outer features

Like the hydrosphere, the geosphere is dynamic. It is constantly changing because of different Earth processes. Many of these changes to the geosphere occur over a very long time, so they are difficult to directly observe.

Word Parts

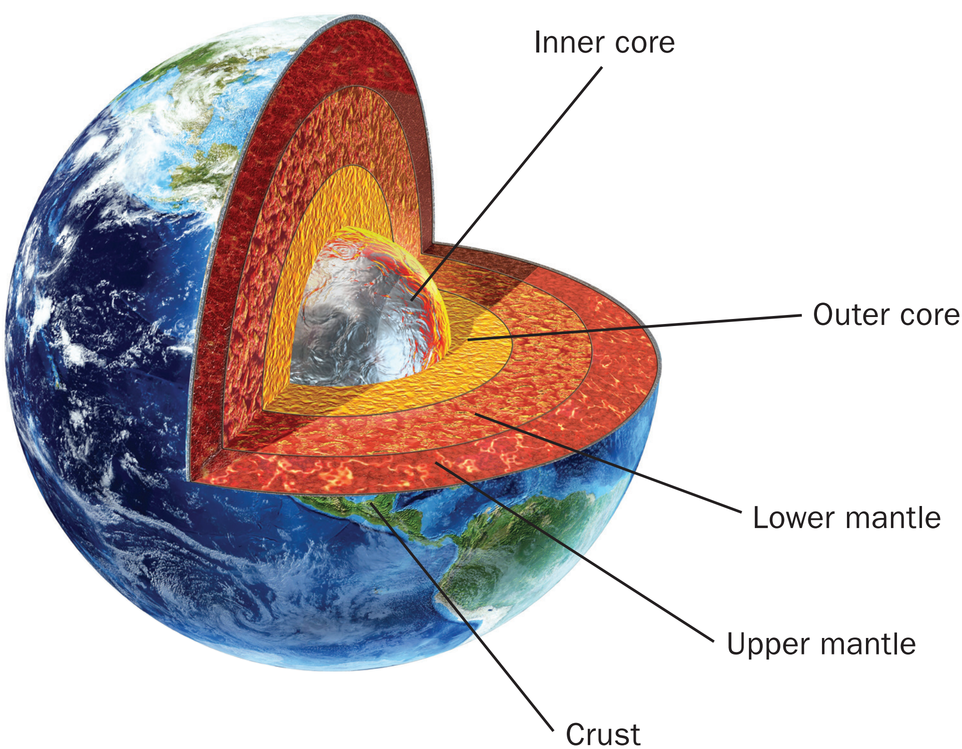
The word part *geo-* means "earth," as in ground or soil.

Mountains are just one part of Earth's geosphere.

The Geosphere Has Layers

Earth's internal structure is made up of different layers of material. It is composed of five layers: the inner core, the outer core, the lower mantle, the upper mantle, and the crust. The inner core is a ball of solid metal that contains mostly iron and is about three-quarters of the size of Earth's moon. Scientists estimate that the temperature of Earth's inner core is approximately 8,000–10,800°F (4,400–6,000°C). They made this estimate based on their knowledge of the melting point of iron. The iron in Earth's inner core is under so much pressure that it is unable to melt!

The outer core is approximately 1,400 miles thick. It is made up mostly of the metals iron and nickel. The metals in the outer core are not solid like the iron in the inner core; instead, they behave like a soft plastic and are described as "liquid" or "fluid."



The layers just outside of the outer core are called the lower and upper mantle. Together, these mantle layers make up most of Earth. Most of these rocks are solid, but there are parts of the mantle where the rock is fluid, almost like a plastic. It is able to move slowly over millions of years. Movement and energy deep in Earth's mantle contribute to the occurrence of earthquakes, volcanic activity, and the formation of mountains on Earth's surface.

The uppermost layer of the geosphere is called the crust. We live on Earth's crust. The crust is broken into plates that rest on the fluid part of the upper mantle. Over geologic time, these plates move atop the soft rock below them. New crust forms when liquid rock moves up through the cracks and then cools.

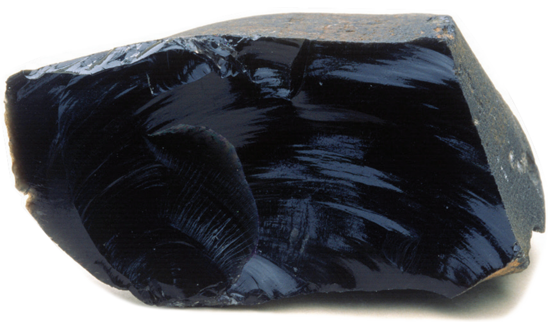
In one part of Iceland, you can see where two plates in Earth's crust are pulling away from each other.

Earth's Crust Contains Different Kinds of Rock

Earth's crust contains three different kinds of rock: igneous rock, metamorphic rock, and sedimentary rock. Rocks are classified as belonging to one of these groups based on how they form.

Hot, molten, liquid rock called *magma* can flow up through cracks in Earth's crust and emerge at the surface as lava. The lava cools quickly on the surface and hardens into solid rock that can have a smooth, glassy texture.

Igneous rock can form at Earth's surface and below it. Magma trapped below Earth's surface can take thousands or even millions of years to cool. Igneous rocks formed underground this way have a rough, coarse texture when compared to those that form at Earth's surface.



Obsidian's glassy texture is a sign that it formed from magma that cooled quickly.

Grainy crystals in granite are a sign that it cooled more slowly.

Sedimentary rock can form in a few different ways. Wind and water can wear down exposed rock on Earth's surface into sediments, or rock material that has been broken down into tiny pieces. These sediments are deposited and buried under later layers of sediments. The layers become pressed together over time. Another kind of sedimentary rock forms when a large number of living things die and become stuck together after they decompose. One example of this kind of sedimentary rock is coal, which forms from dead plant material. A third kind of sedimentary rock forms from minerals that have been dissolved and moved by running water. These dissolved minerals eventually separate from the water and become solid again when conditions change in the environment.

Sedimentary rock often has visible layers.

Word to Know

Sediments are rock material that has been broken down into tiny pieces.

Metamorphic rock forms when intense heat and pressure below Earth's surface cause physical and chemical changes to rock that has already formed. Sometimes these rocks are igneous or sedimentary rocks. Sometimes they are other types of metamorphic rock. This heat and pressure causes changes to the mineral makeup of the rocks.

The Movement of Earth's Crust Causes Changes

Movement of crust plates causes both slow and sudden changes. Pressure from two plates moving in relation to one another produces cracks and breaks. Sometimes plates rub against each other. Sometimes they pull apart. (The photo on page 11 shows an example of a valley that is forming between two plates that are moving away from each other.) Plates can also move up and down. Sometimes one plate will slide underneath the other. Long-term plate pressure causes the buckling or sliding of crust that forces up some types of mountain ranges.

As plates move slowly against each other, pressure builds. Eventually underground rocks break from the pressure. Cracks and breaks between zones of rock are called faults. When the rock breaks, energy is released in the form of seismic waves. These seismic waves cause the ground to shake in an earthquake. The strength of an earthquake depends on the amount of energy that is released.

Word to Know

A *seismic wave* is a transfer of energy through rock at and below Earth's surface. Earthquakes occur when the disturbance of matter from seismic waves causes the ground to shake.

This photo shows a major fault in California called the San Andreas Fault.

While most changes to the geosphere happen over very, very long periods of time, some changes happen rapidly. An example of a rapid change to the geosphere is a volcanic eruption.

Volcanoes are openings in the crust through which magma emerges as lava. Volcanic eruptions occur commonly along plate boundaries. After many eruptions, lava piles up and can form entire mountain ranges.

When volcanic eruptions happen along cracks in the ocean floor, the buildup of crust can form underwater mountains. Their peaks can rise to emerge above the water's surface and create islands, such as the Hawaiian Islands.

Some volcanic eruptions can be sudden and explosive, causing lava and ash to shoot into the air. Other eruptions are slower and more continuous, with ribbons of lava slowly flowing from the opening.

The Geosphere Is a Dynamic System

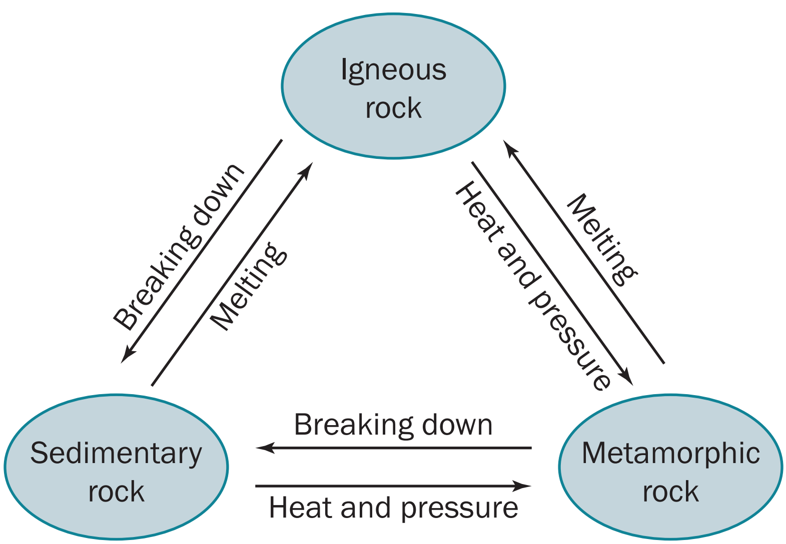
Like the hydrosphere, the geosphere is a dynamic system. Earth's rock changes over time. The **rock cycle** is the continuous process in which rock changes form.

Vocabulary

rock cycle, n. the process through which rock changes form through igneous, sedimentary, and metamorphic types

Igneous, metamorphic, and sedimentary rock on Earth's surface is broken down into tiny pieces and moved to different locations. Over time, the tiny pieces become pressed together and change to sedimentary rock. As sedimentary rock becomes buried, heat and pressure cause it to change to metamorphic rock. Further heat and pressure below Earth's surface can melt the metamorphic rock, changing it to magma.

Magma cools, either at or below Earth's surface, forming new igneous rock. The processes of the rock cycle can happen in any order. There is no beginning or end.



This model of the rock cycle shows some, but not all, of the processes by which three rock types interact.

The Atmosphere

Chapter 3

The **atmosphere** is the layer of mostly gases that surrounds Earth and contains the air that you breathe. It is composed overall of about seventy-eight percent nitrogen and twenty percent oxygen. The remaining two percent of the atmosphere's makeup includes trace gases such as carbon dioxide and water vapor.

Big Question

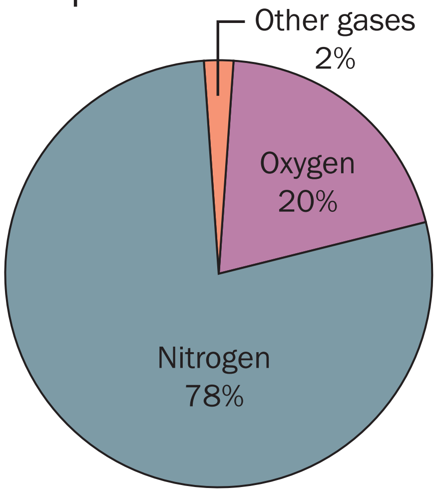
What is the atmosphere?

Vocabulary

atmosphere, n. the Earth system that is composed of all the gases that surround Earth

Word Parts

The word part *atmos-* means "air."



Like the hydrosphere and geosphere, the atmosphere is dynamic, so it is always changing. Some of these changes, such as the movement of particles, occur naturally. Other changes, such as the increase of gases and particles from burning fuels, are caused by human activities.

Organisms are adapted to survive using the types and amounts of gases in Earth's atmosphere. Other planets in our solar system have different atmospheres that cannot support Earth's life-forms. One planet, Mercury, has no atmosphere at all.

The Atmosphere Has Layers

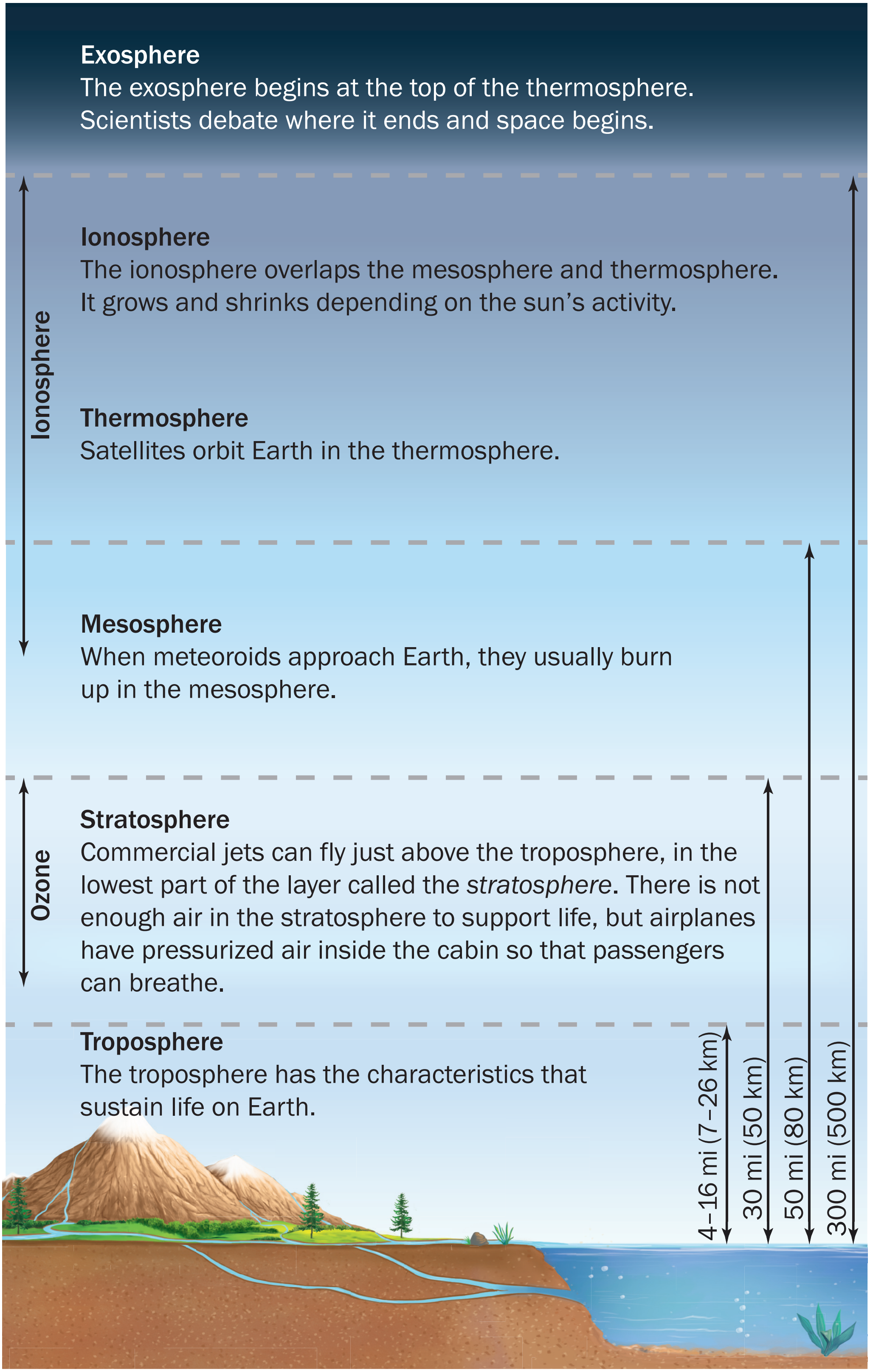
Scientists divide the atmosphere into several layers. Each layer has specific characteristics. The layer closest to Earth's surface is called the *troposphere*. It is the layer that contains most of our air. It is also where almost all weather occurs.

Word to Know

Altitude is the measure of height upward from sea level. Sea level is the average level of the surface of the ocean relative to land.

The amount of air in the atmosphere decreases with altitude. As altitude increases, air particles are more spread out. This makes it harder to survive at high altitudes. People who climb Earth's highest mountain peaks, such as Mount Everest, usually require extra oxygen to breathe.

The peak of Mount Everest does not quite reach the top of the troposphere.



Each layer of Earth's atmosphere has specific characteristics.

Temperature, Air Pressure, and Weather

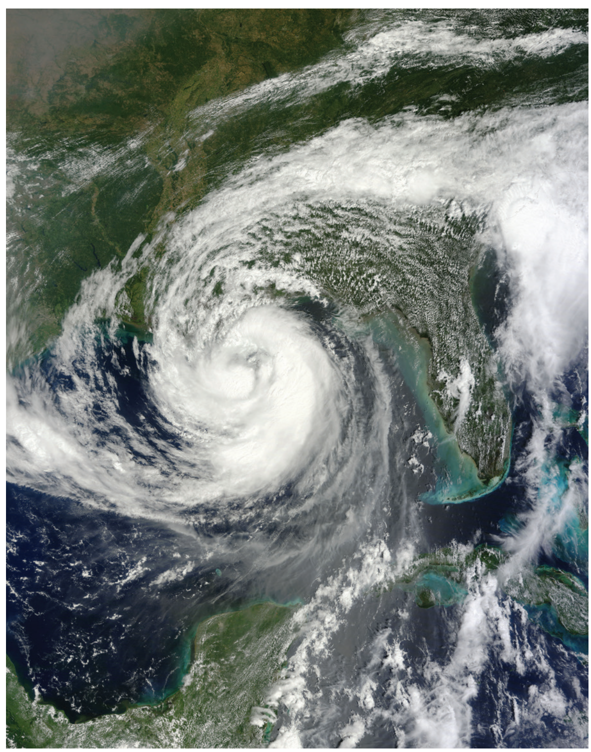
Air temperature in the troposphere decreases as altitude increases. It is very cold above the tree line at the tops of the highest mountains. At the top of Mount Everest, the average high temperature in July is only –2°F (–19°C). In January, the coldest month, the average high temperature is about –33°F (–36°C).

You can't see or hold the air around you, but it is matter, and its weight can be measured. Air, like all matter, is made of tiny particles. The more particles in a certain volume of air, the greater the weight. The weight of air decreases as altitude increases. This is because the particles are farther apart.

Vocabulary

air pressure, n. the weight of air pressing on all things beneath and within it

The weight of air particles also creates pressure. **Air pressure** is the weight of air, pulled down by gravity, pressing on all things beneath and within it. Like air temperature, air pressure also decreases as altitude increases. It is measured with a tool called a barometer.



Combinations of temperature and air pressure can produce strong storms, such as this hurricane.

The heating and cooling of the troposphere drives weather. Earth's surface is warmed by the sun, and in turn, the surface warms this layer of air in the lower atmosphere. Land and water features also transfer heat unevenly to air. Both factors cause **air masses** to heat unevenly. This means that some air masses are warmer than others.

Vocabulary

air mass, n. a large body of air with similar temperature, air pressure, and moisture throughout

Variations in temperature among air masses cause them to move in the atmosphere as warm air rises and cool air sinks. This rising and sinking, along with the pushing of one air mass against another, produces wind. Wind carries air masses with their clouds and precipitation to new places, producing changing weather.

Air pressure also affects weather. Low-pressure weather systems are associated with clouds, wind, and precipitation. High-pressure weather systems generally bring clear skies and calm winds.

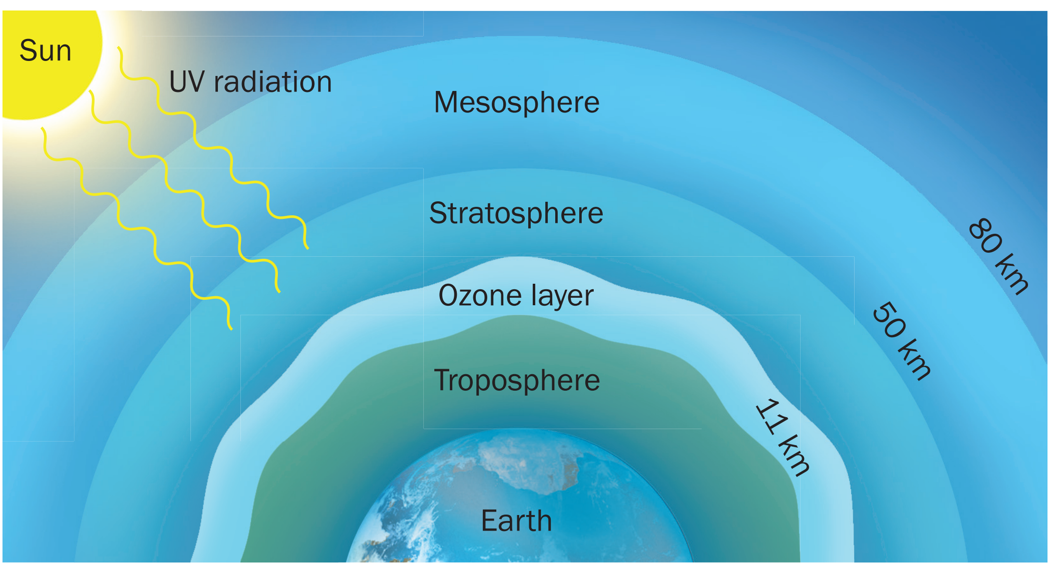
Thunderstorms can form along the boundary between a cold air mass and a warm air mass.

The Atmosphere Supports and Protects Life on Earth

Earth's atmosphere has an important role in supporting and protecting Earth's organisms. It contains levels of oxygen and carbon dioxide that organisms need to survive. All plants and animals that live on land use gases from the air in their body processes.

The atmosphere also plays a major role in maintaining temperatures that allow living things to thrive in their particular environments. Air temperatures vary from day to night and throughout the seasons. But without the atmosphere, Earth's surface would be very hot in the sunlight and very cold in the darkness of night. The extremes would not support the diverse life that Earth has now.

The atmosphere provides a protective layer against harmful radiation from the sun. You may have heard of the ozone layer. The ozone layer exists in the stratosphere.



The ozone layer absorbs the type of ultraviolet light from the sun that is damaging to living things.

The Biosphere

Chapter 4

Millions of species of living things are found in environments all over the world. They look and behave differently, but they all have one thing in common: they are alive. What makes a living thing alive is that it can respond to its environment and it can reproduce. This is true of every organism, no matter how simple or complex. All living things on Earth form a system called the **biosphere**. You, and all other humans, are part of the biosphere.

Organisms of the biosphere interact with each other. They also interact with the nonliving parts of their environments, including sunlight, air, minerals, and water. Living things use energy sources from their environments to support the processes that keep them alive. These life processes occur over a limited time span. Life spans of different kinds of organisms vary, but all organisms eventually die.

Big Question

What is the biosphere?

Vocabulary

biosphere, n. the Earth system that is composed of all the living things on Earth

Word Parts

The word part *bio-* means "life."

The biosphere includes all life on Earth.

Biodiversity and Classification

Life on Earth is incredibly varied. The word for the variety of species is **biodiversity**. A **species** is a group of organisms that share many traits and are capable of producing offspring that also share those traits. Earth supports millions of species.

Living things are very diverse structurally. Individuals of some species exist as a tiny single cell. They are called unicellular. Individuals of other species are made of billions of cells. These organisms have complex systems of structures to carry out their life processes. They are called multicellular.

Because there are so many kinds of living things, scientists have developed systems for classifying them. The branch of science that names and groups organisms is called taxonomy. Taxonomy organizes living things by levels according to how similar they are. The levels of organization are domain, kingdom, phylum, class, order, family, genus, and species. Every known organism on Earth is classified in this way.

Let's take a look at how taxonomists classify the African lion. In taxonomy, names for different classifications are often based in Latin.

Vocabulary

biodiversity, n. the variety of species on Earth or in any one environment on Earth

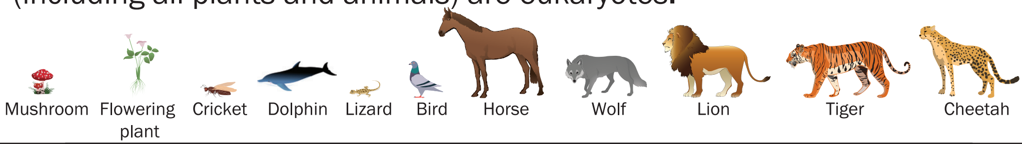
species, n. a group of organisms of the same type that are capable of reproducing together

Word Parts

Taxonomy comes from the Greek word *taxis*, which means "arrangement," and the suffix *-nomia*, which means "distribution."

Domain: Eukarya

At the highest level, living things are classified into three different domains: Archaea, Bacteria, and Eukarya. Organisms with cells that have a nucleus (including all plants and animals) are eukaryotes.

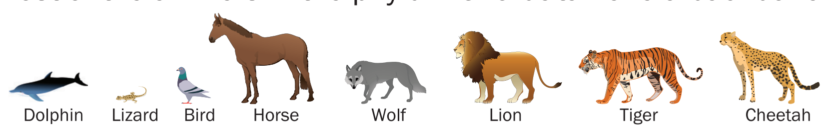


Kingdom: Animalia

Organisms are classified into different kingdoms, including plants, fungi, and bacteria. Animalia is a large kingdom.

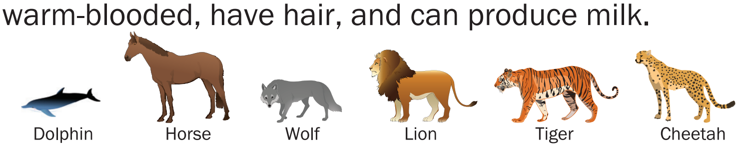
Phylum: Chordata

Most of the animals in the phylum Chordata have a backbone.

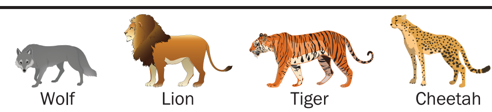


Class: Mammalia

All of the animals in this class are mammals, which means that they give birth to live young, are warm-blooded, have hair, and can produce milk.

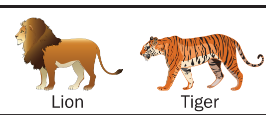


Order: Carnivora



Family: Felidae

Genus: *Panthera*



Species: *Panthera leo*

Dependence on and Response to Environments: Biomes

Organisms are adapted to the environments in which they live. These environments can be very small, such as the moist, decaying area under a fallen log. They can also be very large, such as a forest of pine trees. The one thing environments have in common is that they are places where organisms can obtain energy, find shelter, and reproduce. Environments on Earth vary greatly, and so do the organisms that live in them.

A **biome** is a large region on Earth with a specific climate that is shared by a collection of species. Other factors besides climate influence life in a biome. They include type of soil and amount of water. Biomes can change. Places on Earth that were once warm and rainy can become hot and dry over time.

Vocabulary

biome, n. a large region on Earth with a specific climate that contains certain species

Deserts are one type of biome.

Six major biome types are tundra, forest, ocean, fresh water, grassland, and desert. The tundra has a cold, dry climate where few plants can survive. Polar bears, arctic foxes, and mountain goats are some animals that live in tundra biomes. Plants grow low to the ground, where they are less affected by wind. Trees cannot usually survive in a tundra's harsh climate.

A grassland is a biome that contains mostly grasses and few trees. Rainfall can vary in grasslands depending on the region. Grasslands are home to a variety of animals, including giraffes, antelope, zebras, elephants, and coyotes.

A biome is a large region and can contain many ecosystems. An ecosystem is a group of diverse species and their nonliving environment, including water, soil, and air. Ecosystems can vary greatly in size, from a small pool of water to a huge rain forest. But a biome contains all the ecosystems in a broad climate region.

The tundra biome has a very short summer season when snow melts and wildflowers bloom.

Continuous Change and Extinction

The species that are alive now on Earth are not the same ones that have always been here. When climate patterns change, biome locations shift. Species in the ecosystems within those biomes must respond. Sometimes organisms cannot adapt to changes in their environments and all the members of a species die. When an entire species dies off, it becomes extinct. However, some species gradually change over time and adapt to new conditions. New species arise in this way.

Word to Know

Extinct means a species no longer exists on Earth.

Astonishing numbers of species have thrived and then, throughout Earth's long existence, became extinct. Many more are becoming extinct in recent years because of human activities such as overhunting, poaching, changing climates, and habitat destruction.

There are two colors of tawny owls. Some have gray feathers, and others have brown feathers. Lately, the gray owls are disappearing. Scientists think this may be caused by a warming climate. With less snow on the ground, the gray owls may be easier for predators to see and the brown owls harder to see.

This tawny owl's feathers are more brown than gray.

Hydrosphere Interactions

Chapter 5

A lone raindrop falls on your hand and cools your skin on a warm day. Moments later, as you take shelter, heavy rain starts to pour down. Puddles and flowing streams form. Soil and fallen leaves are picked up and carried by running water. The grassy soil becomes saturated and muddy. Birds swoop down to peck at earthworms that have crawled to the soil's surface. When the rain stops and the sky clears, water vapor rises from the wet land and drifts into the air. You look down and see that the raindrop on your skin has also evaporated. Blades of grass and leaves on trees appear less wilted. The next day, there are new mushrooms and flowers among the grass, and the air buzzes with mosquitoes.

Big Question

How does the hydrosphere interact with Earth's other spheres?

All of these events from the rainfall are examples of Earth's hydrosphere interacting with and affecting its other spheres. The rain interacted with soil, sediment, and other physical parts of Earth's crust—the geosphere. It provided much-needed water to organisms—the biosphere. Some of the water evaporated, cycling it back into the air—the atmosphere.

Rainfall can change Earth's surface and its inhabitants.

The Hydrosphere Interacts with the Geosphere

Rain affects the geosphere through **weathering**. Weathering is the breakdown of rock into smaller pieces. The flow of water in a mountain stream, driven by gravity, can carry rocks. They smash along the streambed and against other rocks, breaking into smaller pieces. Over time, this physical weathering can turn what was once a large boulder into a streambed of small, smooth river rocks. Flowing water and debris can carve a canyon into Earth's crust.

Vocabulary

weathering, n. the process of breaking down rock into smaller pieces

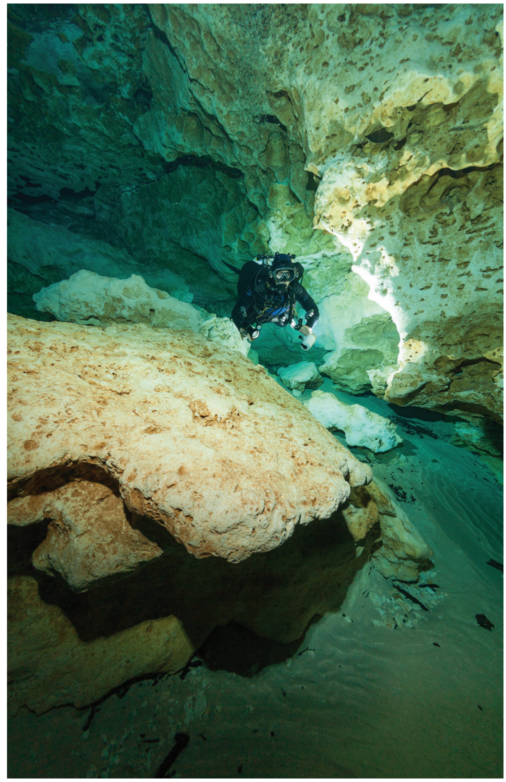
Precipitation can also weather rock through the freeze-thaw cycle. Rainwater or melting snow seeps into cracks in rock and then freezes and expands. The ice acts as a wedge to open up cracks and even cause chunks of rock to break off. When the ice melts, it can sink deeper into the cracks or into new ones. If it freezes again, even more weathering can occur. Over time, this freeze-thaw cycle can dramatically alter a landscape and produce new features.

Bryce Canyon in Utah was partly formed by the freeze-thaw cycle that physically weathered the limestone.

Weathering Happens in Different Ways

Water breaking down a boulder in a freeze-thaw cycle is one kind of physical weathering. The hydrosphere also interacts with the geosphere through chemical weathering. Water can interact with rock in a chemical way that causes the rock to break down. Limestone is a sedimentary rock made of calcium carbonate. If slightly acidic water seeps into cracks in limestone, the acid can react with the carbonate and break it down. Over time, what was once a small crack can become a large cave or cavern.

Acidic water can also chemically weather rocks on Earth's surface. For example, stone structures carved by humans have been weathered by rain in recent centuries because rain has become more acidic. This is called acid rain and results from pollutants that human activities have released into the atmosphere.



The cave in the top photo formed slowly as acidic water weathered the limestone. The carved stone in the bottom photo has been weathered by acid rain.

Erosion Is the Movement of Weathered Rocks

The rock pieces, or sediments, that weathering produces are often carried away by the process of erosion. **Erosion** is the movement of sediment away from its original location. There are different agents of erosion, or things that can help carry sediment away. Water, of course, moves sediment. Wind is an agent of erosion. Animals can also act as agents of erosion. So can the slow movement of a glacier.

Vocabulary

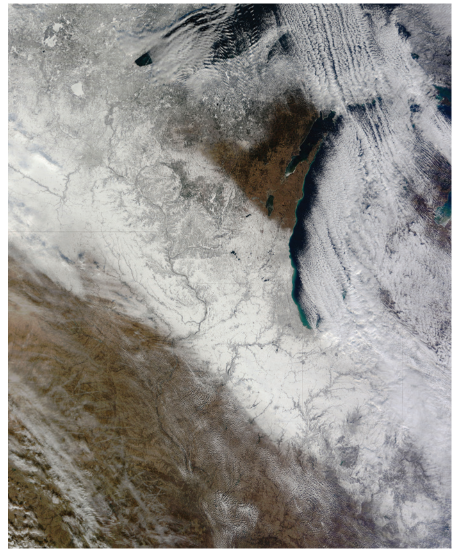
erosion, n. the movement of sediment

Water can erode sediment in different ways. Ocean waves can pick up sand and take it away from the beach. A large ocean storm may move large amounts of sediment out to sea. A dry area of Southern California suddenly getting a tremendous amount of rain could experience landslides as hills become saturated with water.

Other land features are carved slowly by the combined forces of weathering and erosion. The Grand Canyon, for example, has been formed by the flow of the Colorado River over a long period of time.

As the Colorado River carved deeper into the rock, its banks continually collapsed. The river eroded the loosened rock and sediment.

The Hydrosphere Interacts with the Atmosphere



The heat and water vapor rising from the Great Lakes interacts with cold, dry air from the Arctic to produce tremendous snowfall on land near the lakes.

Knowing about the physical characteristics of water helps us understand the interaction between the hydrosphere and the atmosphere. Lake-effect snow is an example. Water takes longer to cool down or warm up than the air. In the winter, this means a lake or area of ocean will remain relatively warm compared to the atmosphere and the land. For example, temperatures above Lake Michigan, one of the Great Lakes, can be well below freezing (0°C, 32°F) for days or weeks in a row. However, the lake may remain considerably warmer and unfrozen. The lake is free to release water vapor and heat, which builds large clouds when cold air from the Arctic moves in. These clouds will release heavy snowfall.

Large bodies of water can also cool coastal areas that would otherwise be warm. Just as water takes longer to cool or freeze compared to land or air, it takes more energy to warm up. While the atmosphere and land heat up quickly in strong sunlight, water is able to absorb much more of that energy without increasing much in temperature. The warm land heats the atmosphere above it, causing the air to rise. This draws in cooler air from the ocean—a sea breeze. This is why the climates of coastal cities can be relatively cool and comfortable compared to areas that are farther inland.

The Hydrosphere Interacts with the Biosphere

The hydrosphere provides water for organisms of the biosphere. All living things depend on water.

Many different substances dissolve in water and are transported from one location to another. For example, nutrients that plants need can dissolve in rainwater and sink down through soil. There, nutrients can be taken up by roots, and plants can use them to grow. Dissolved nutrients are also carried by different kinds of currents in the ocean.

The water cycle can be observed in full in a rain forest biome. The dense forest's trees and other plants release water vapor from their leaves. Vapor can also evaporate from damp soil or from streams. The vapor rises and condenses into clouds in the lower atmosphere, which can condense further and produce rainfall. The rainwater trickles down to the forest floor, where plant roots absorb it. The water is used for photosynthesis. The leaves release water again, and the cycle keeps going.

The water cycle can be observed in a fairly small area in a rain forest biome.

Geosphere Interactions

Chapter 6

Near volcanic islands in the South Pacific, the ocean suddenly begins to boil and froth. Gases explode into the air, along with fragments of lava that have been cooled and hardened by the seawater. For several days, the lava erupts at the sea surface, forming a steaming, lifeless island that looks more like the moon than the other islands of the area. A week later, the eruption is over. Birds leave droppings that contain some seeds from different fruits they ate. The wind and sea carry more seeds to the new island. Rainfall supplies water. Over time, the island develops a layer of soil in which different plants take hold and reproduce.

Big Question

How does the geosphere interact with Earth's other spheres?

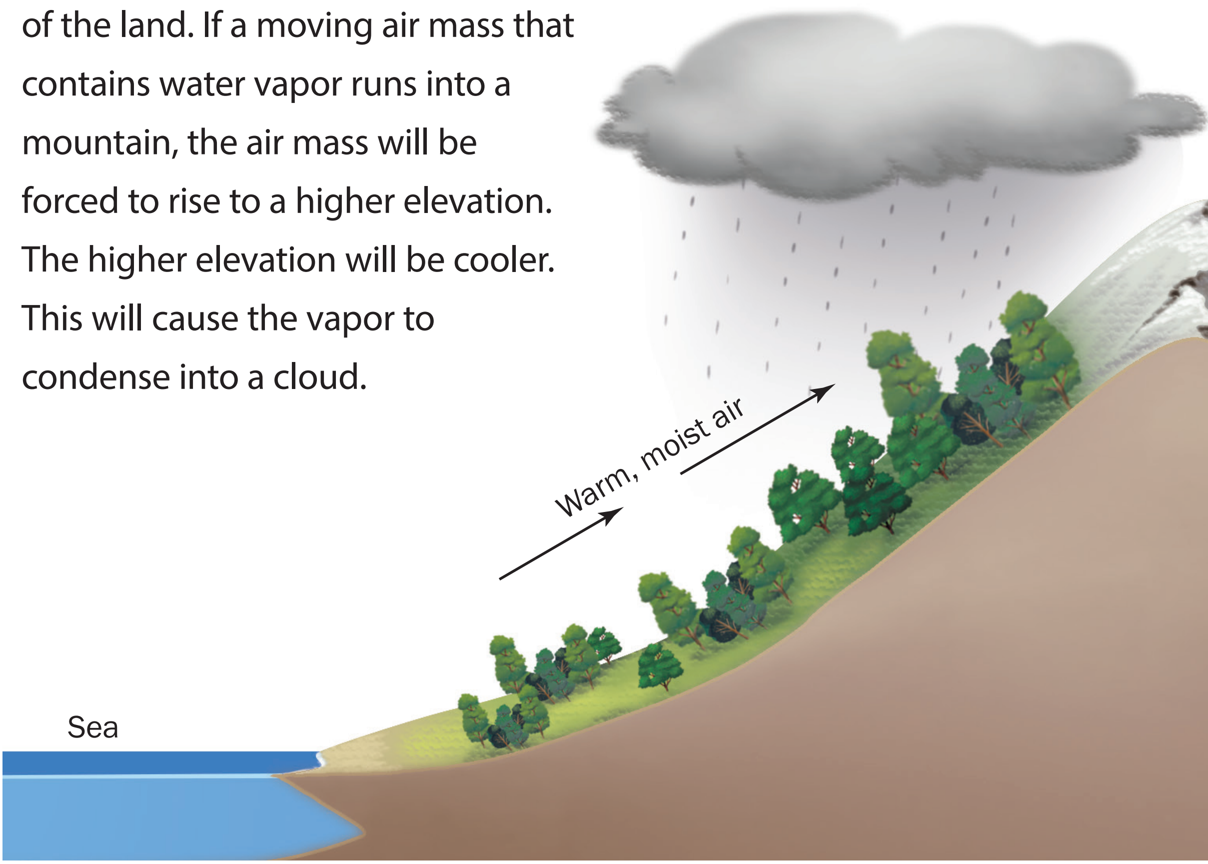
This is one example of how the geosphere can interact with Earth's other spheres and produce a new home for organisms. Like other interactions between spheres, some parts happen quickly. Others happen slowly. The new island formed in a matter of days, but other effects between the geosphere and the island's biosphere may take many years to develop.

A volcano, part of the geosphere, produces new land. Interaction with Earth's other spheres transforms the bare rock into a place supporting life.

The Geosphere Interacts with the Atmosphere

Think of a moving air mass, or wind, blowing across the ocean toward land. The air mass is picking up water vapor from the ocean. What will happen to this moist air mass if it reaches land? Will it continue to move in the same direction? Will it release its water vapor as precipitation? It depends largely on the land itself. If the land is relatively warm, then the air mass could be warmed by heat rising off the land. If the land is cold or the air mass collides with a colder air mass, then the water vapor could condense into fog or a large cloud. If it condenses enough, the cloud could release the water as precipitation.

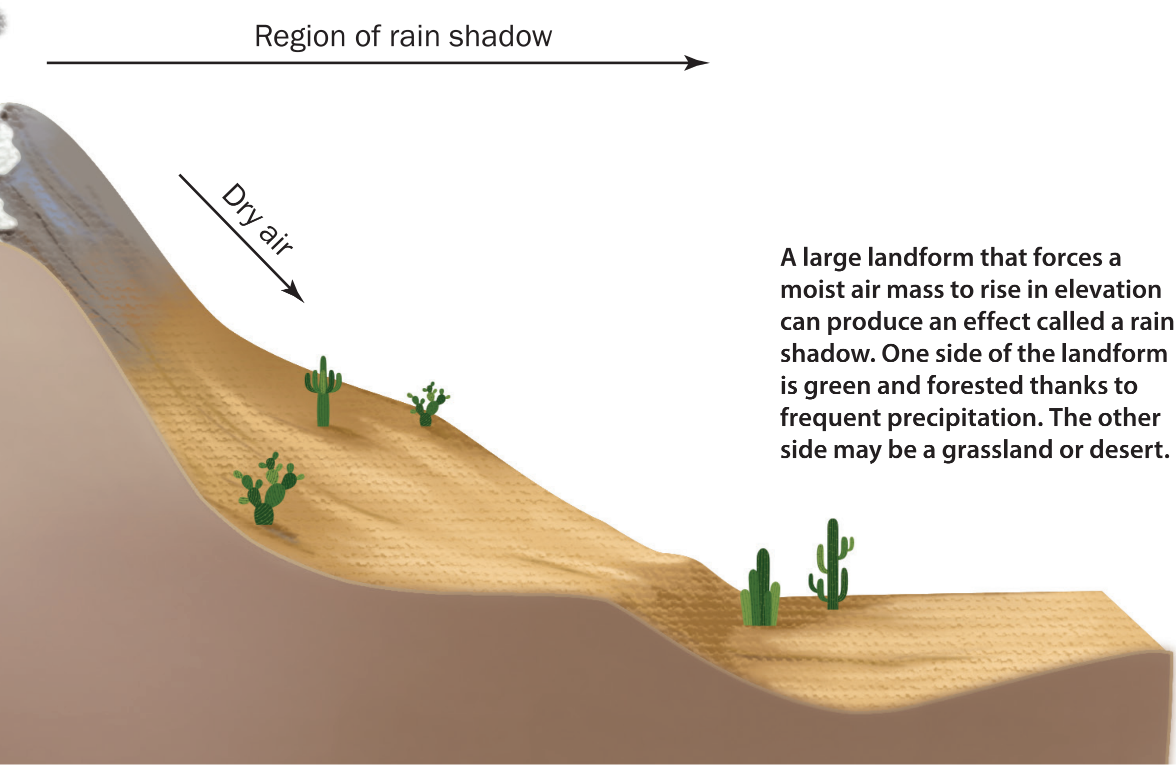
The temperature of the land is one factor that affects the interaction between the geosphere and the atmosphere. Another is the shape of the land. If a moving air mass that contains water vapor runs into a mountain, the air mass will be forced to rise to a higher elevation. The higher elevation will be cooler. This will cause the vapor to condense into a cloud.



As a result of this condensation, the wind-facing, or windward, side of the mountain is much more likely to receive precipitation than the opposite, leeward side of the mountain. Most of the rain in the air mass falls out on the windward side of the mountain. In fact, the leeward side of the mountain is often in what is known as a **rain shadow**. The "shadow" is an area that gets very little precipitation because the atmosphere does not receive much moisture from the other side. Landscapes in rain shadows are often grassland or desert biomes.

Vocabulary

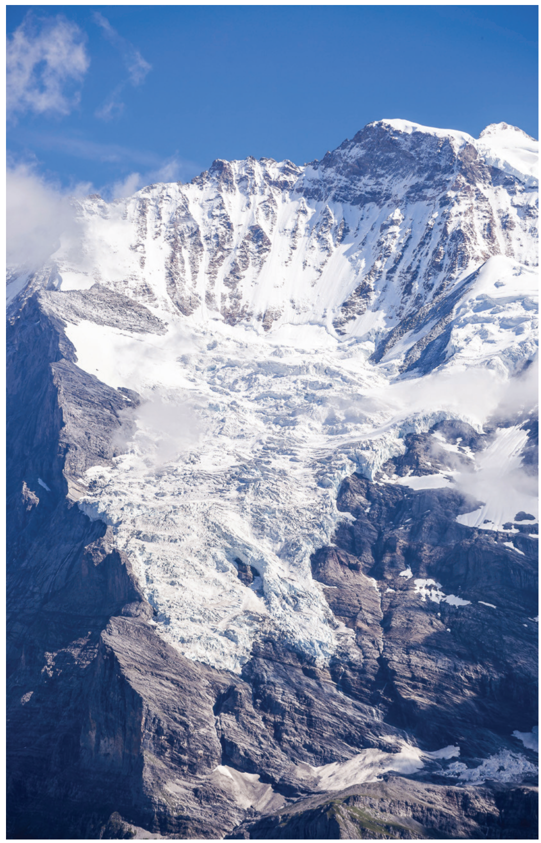
rain shadow, n. a dry region on one side of a mountain that results from precipitation on the other side of the mountain removing moisture from clouds



A large landform that forces a moist air mass to rise in elevation can produce an effect called a rain shadow. One side of the landform is green and forested thanks to frequent precipitation. The other side may be a grassland or desert.

The Geosphere Interacts with the Hydrosphere

The geosphere interacts with the hydrosphere. The shape of land affects where and how water collects. A tall mountain range is likely to have a cold climate near its peaks. Any precipitation that falls there is likely to be snow or ice. That means it could build up and remain frozen for a very long time. If the mountain range is shaped to trap that frozen precipitation, it could remain in place even longer. The overall impact of this can affect the entire hydrosphere at a global scale. If more water accumulates on land as snow or ice, that means less water is available for the ocean, lakes, rivers, and underground. This is what occurs during an ice age. Landmasses accumulate so much snow and ice that the sea level drops. The large volumes of ice that build up are called glaciers.

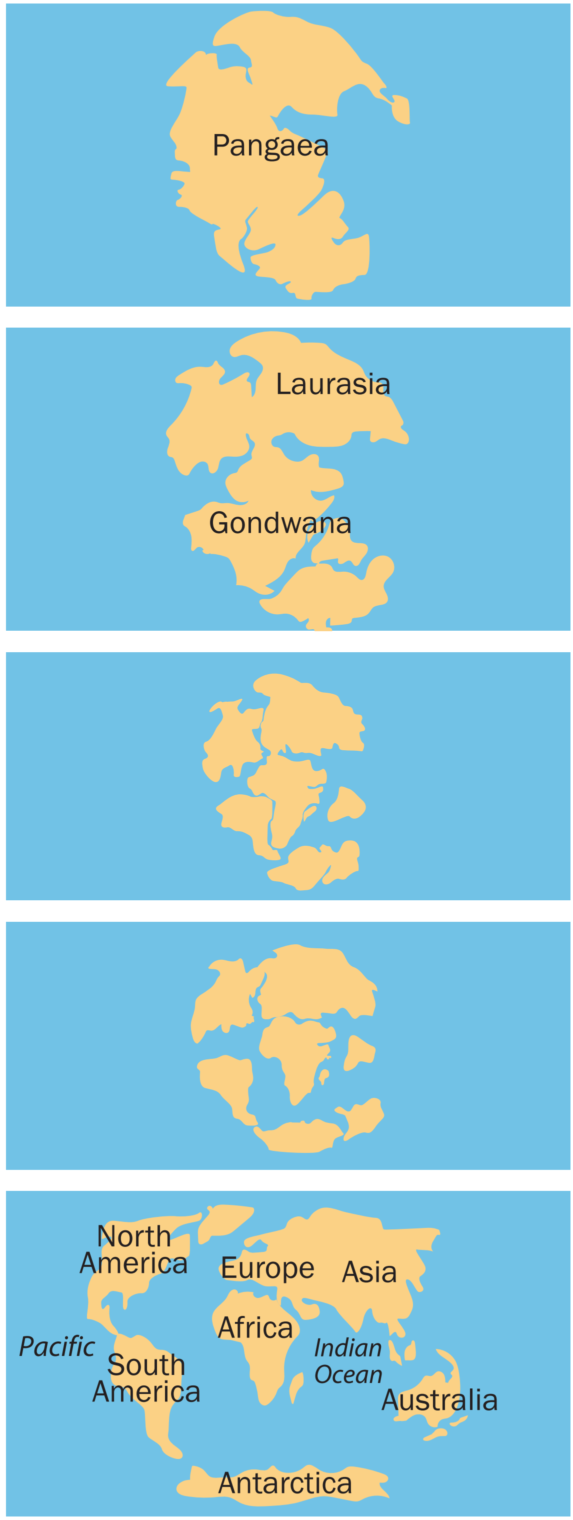


Even in warmer climate zones, glaciers can exist at high land elevations.

When precipitation melts or is already in liquid form, the shape of land affects where it flows. Lakes and ponds form where the water cannot drain away any further. Rivers and streams occur where the geosphere's shape allows for water to gather and flow toward the sea.

The Pacific Ocean is the largest ocean because the continents around it happen to be far apart and the islands in the Pacific Ocean are small. The contours of land affect the path of deep ocean currents.

Meanwhile, the arrangement of the landmasses is constantly changing. The Pacific Ocean is widening by about ten centimeters per year because Earth's crust is broken into plates that move. As the plates slowly drift, over the course of millions of years, the movement of continents determines the changing shape of oceans.



Earth used to have a single, fused landmass that scientists call Pangaea. Over time, the continents have broken up, forming new oceans, seas, and lakes.

Rocks and Aquifers

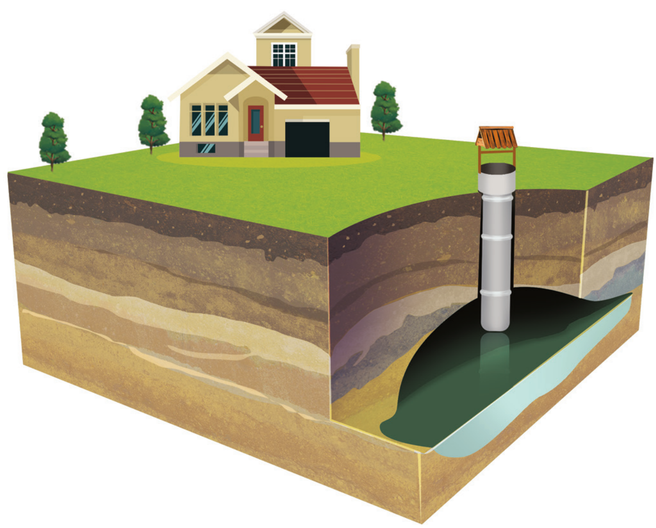
The geosphere also affects the underground portion of the hydrosphere. For example, a sandy landscape will allow rainwater to seep underground. Where underground layers are cracked or porous, the water can sink deeper into the ground. Where a large volume of water collects, an **aquifer** may form. An aquifer is an area of underground material that contains water that can be drawn out through a well. Aquifers are important groundwater resources for humans, especially in areas that do not have large bodies of usable water on the surface.

Vocabulary

aquifer, n.
an underground region of rocky material containing water that can be drawn out through a well

water table, n.
the upper surface or level of groundwater

An aquifer can change over time if water is pulled out of it or a lot of water seeps into it. For example, during a rainy season, an aquifer's surface may rise. This causes the groundwater to get closer to the surface. The **water table** is the upper surface of groundwater, where the earth material is saturated with water. The water table may fall during the summer as groundwater is tapped by wells for drinking water or farming.



Wells are dug into the ground to tap into an aquifer. The well should be deep enough to reach the water table when it falls to its lowest point.

The Geosphere and Soil

The geosphere and biosphere interact in the formation of **soil**. Soil is a dark brown material that often makes up the top layer of Earth's land. It contains a mix of rock particles, clay, and the remains or products of organisms—fallen leaves, dead grass, animal remains, animal waste, seed husks, and so on.

Vocabulary

soil, n. the top layer of Earth's land that often has a mix of organic and inorganic material

Words to Know

Inorganic describes materials that are made from nonliving things, such as rock.

Organic describes materials that come from living things.

Weathering and erosion produce the rock sediments that are the inorganic parts of soil.

Organisms add organic material and nutrients to the ground. For example, birds that land on a new island will leave their droppings, which are rich with nutrients and may even contain seeds that could sprout into plants. When organisms die, their remains decompose and release nutrients that improve the soil. Over time, the accumulation of organic material makes soil richer and better for the survival and growth of plant life and other organisms.

These plants are among the first to sprout in this volcanic landscape. Over time, their remains will combine with weathered volcanic rock particles to form soil in which other organisms will be able to live.

The Geosphere Interacts with the Biosphere

Just as the locations, shapes, and elevations of the geosphere's landmasses affect the hydrosphere, they also affect the biosphere. A new island is a potential new home for land-dwelling organisms. A vast continent with different elevations, climates, soil types, and places where the hydrosphere can provide fresh water has many potential homes for organisms. In some cases the geosphere is, all by itself, a home for organisms. For example, a desert fox can dig a burrow in the sandy soil and take shelter there when the temperature drops. Bats can take shelter in rocky caves. Plants can take root in cracks of boulders and cliffsides. Sea turtles dig nests in sandy beaches and lay their eggs in them.

This female green sea turtle is going to dig a nest where she can lay her eggs. The soft, warm volcanic sand will incubate and shelter her eggs until they hatch.

In addition to providing a physical home for many organisms, the geosphere provides chemicals that organisms need. These chemicals, known as minerals, contain elements that are essential for plants. Examples include phosphorus, iron, magnesium, potassium, sodium, and calcium. These minerals dissolve into water from the surfaces of rocks and sediment. The water can then be absorbed by plant roots, which means chemicals from the minerals can be absorbed as well.

Word to Know

Minerals are solid inorganic substances that occur naturally.

Atmosphere Interactions

Chapter 7

A rock containing iron rusts in the presence of water and oxygen. Hurricane winds reshape sand dunes on a coastal beach. A heat wave dries out a forest, leaving it vulnerable to fire. Elsewhere on Earth, the atmosphere chills a region of the ocean to the point that ice forms. These are all examples of how the atmosphere interacts with Earth's other spheres.

Big Question

How does the atmosphere interact with Earth's other spheres?

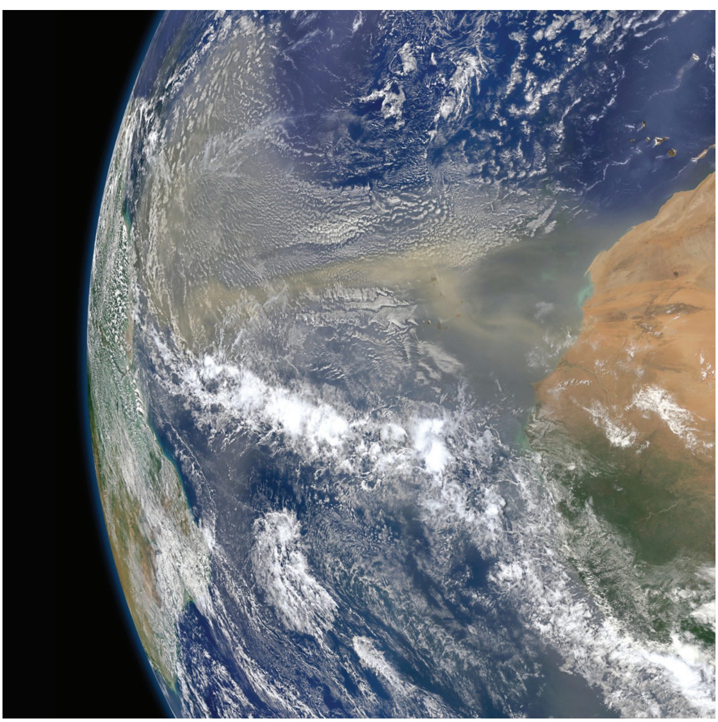
The atmosphere is the first sphere to receive sunlight as it reaches Earth. Like a window, some of the sunlight passes through, and some is reflected. And like a window, the atmosphere acts as insulation to retain some of the heat that would otherwise radiate from Earth out into space. This effect of the atmosphere controls Earth's surface temperatures and regulates how much of the sun's energy reaches the other spheres.

The thin layer of air that surrounds Earth affects its surface.

The Atmosphere Interacts with the Geosphere

Picture a desert full of shifting sand dunes. Like ocean waves moving in slow motion, the dunes change shape and move with the wind. If the wind is strong enough, grains of sand can be picked up and carried great distances. For example, fine sand particles from the Sahara in Africa can blow all the way across the Atlantic Ocean to South America, the Caribbean, and Florida. The plume of Saharan dust brings much-needed nutrients to the Amazonian rain forest.

The heating and cooling of the atmosphere creates wind. When an air mass is heated, its particles are excited and move around more. This causes the air to expand and take up more space. If the air mass is surrounded by cooler air, it will rise because it is less dense than the cooler air mass. A nearby air mass will rush in to fill the void. This produces wind.



Fine particles from the Sahara blow to the west across the Atlantic Ocean.

Physical and Chemical Change

Vocabulary

deposition, n. the dropping of sediment in a new location

Recall how the hydrosphere moves the geosphere by erosion—picking up and carrying away sediment from a given location. The atmosphere also causes erosion. The wind blowing dust from the Sahara out over the Atlantic Ocean is an example of wind erosion. When sediment is dropped, or deposited, at another location, it is called **deposition**. The erosion and deposition of sediment affects the geosphere at scales both small and large and at rates both slow and fast.

For example, a sand dune in Namibia can shift by several centimeters over the course of a few hours. Over a year's time, a dune can move much farther, and a series of dunes might look completely different than it did a year before.

The sand dunes of Namibia's Skeleton Coast are shaped by wind.

Wind erosion can also reshape solid rock. The wind itself can knock particles loose and carry them away, but when the wind is carrying sand, it has even more power to erode.

While wind works on the geosphere through physical erosion, the air itself can chemically react with elements of the geosphere. Oxygen in the air reacts with iron in certain types of rock to produce rust. Other components of the air, such as sulfur, can dissolve in precipitation and chemically weather certain types of rock on Earth's surface. Sulfur can be released into the atmosphere by volcanic eruptions and human activities.

The iron in rock reacts with oxygen in the atmosphere to produce rust.

The Atmosphere Interacts with the Hydrosphere

The atmosphere interacts with the hydrosphere in several important ways. The amounts of sunlight and solar energy that are allowed in by the atmosphere control how much of Earth's surface water is liquid or solid, how much is vaporized, and how warm or cold bodies of water are. The amount of heat that is retained by the atmosphere also regulates the temperatures and states of water in different parts of the hydrosphere.

If the combination of gases in the atmosphere changes, then it can affect the other spheres in different ways. For example, the large increase in carbon dioxide in the atmosphere due to human activities is trapping more heat, possibly causing climate change. A warmer atmosphere means a warmer hydrosphere. As bodies of water warm, they expand. This means the sea level rises. Warmed ice and snow melt, and the meltwater flows into the sea. This also causes sea-level rise.

As large volumes of ice melt from the land or fall into the ocean, the sea level rises.

Large-scale melting of ice caps, sea ice, and glaciers also reduces the amount of sunlight reflected by Earth's surface, which means surface warming is even more likely.

The atmosphere's composition can also change due to other events, such as large-scale volcanic eruptions. Major eruptions in Earth's history have introduced so much ash and sulfur into the atmosphere that the amount of sunlight that could reach and warm Earth's surface was reduced for years at a time. This resulted in global cooling.

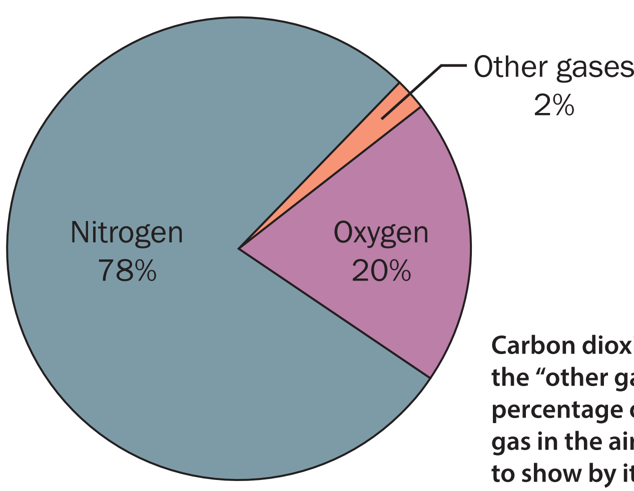
Volcanic activity affects the atmosphere.

The Atmosphere Interacts with the Biosphere

The atmosphere acts as a protective blanket around Earth. The upper part of the atmosphere has a layer of a substance called ozone that blocks some harmful rays from reaching the biosphere. But for the most part, the atmosphere lets sunlight in. This sunlight is the major source of energy for almost every organism. Energy and warmth that organisms need pass through the atmosphere. But at the same time, the atmosphere blocks a great deal of harmful radiation from the sun. The atmosphere's role as an insulator and climate regulator produces air temperature conditions that are suitable for different forms of life, especially on land.

Atmospheric Gases

All living organisms exchange gases with their environments. The gases are used in chemical life processes. The atmosphere contains three gases that are essential for life: carbon dioxide, nitrogen, and oxygen. Plants and animals use these gases in different ways. But living things are adapted to the current proportions of gases in the atmosphere. For example, humans need to breathe oxygen to survive, but we function poorly breathing pure oxygen.

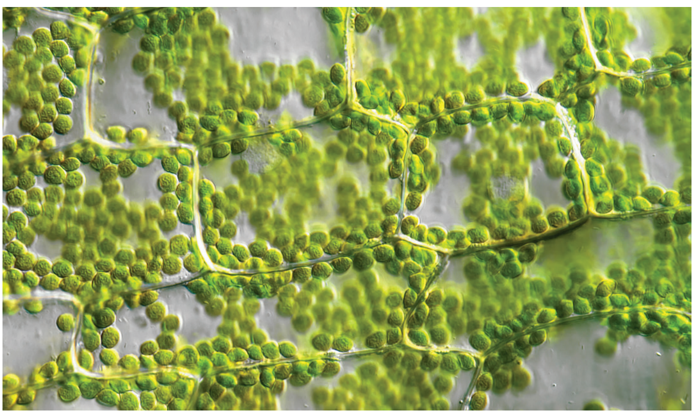


Carbon dioxide makes up just a small portion of the "other gases" that together are still a small percentage of the atmosphere. (The amount of gas in the air that is carbon dioxide is too small to show by itself in the circle graph.)

Carbon dioxide is taken in by organisms that produce their own food during photosynthesis. Oxygen is used by organisms in cellular respiration, which is the process that releases energy from food. Nitrogen is important to plants. Nitrogen compounds that become fixed in soil are taken up by plant roots and used for producing chlorophyll, a green pigment that helps convert sunlight to food.

Words to Know

Respiration is the exchange of gases with the environment, breathing. *Cellular respiration*, which occurs inside cells, is the chemical process that releases energy from food.



Plant cells use nitrogen to make the green pigment chlorophyll. The chlorophyll helps the plant convert carbon dioxide and water into food and oxygen through photosynthesis.

All organisms use oxygen, but organisms that undergo photosynthesis also produce oxygen. Respiration releases carbon dioxide, but photosynthetic organisms use it for photosynthesis. Nitrogen cycles back into the atmosphere when plants die and decompose.

Human activities can alter the composition of the atmosphere. Burning fossil fuels such as coal and oil and burning carbon-rich forests mean more carbon dioxide is released into the atmosphere. So far, the absorption of carbon by the biosphere has not been able to keep pace with the amount that we are adding.

Biosphere Interactions

Chapter 8

The biosphere makes up a relatively tiny fraction of Earth's mass, but it affects the atmosphere, hydrosphere, and geosphere. When you inhale, your body takes in oxygen from the atmosphere. When you exhale, your body releases carbon dioxide, a waste product of cellular respiration. When you can see your "breath" on a cold day, you are seeing condensation of water vapor that you have released into the air. In this simple way, you—a member of the biosphere—interact chemically with the atmosphere and hydrosphere with every breath.

Big Question

How does the biosphere interact with Earth's other spheres?

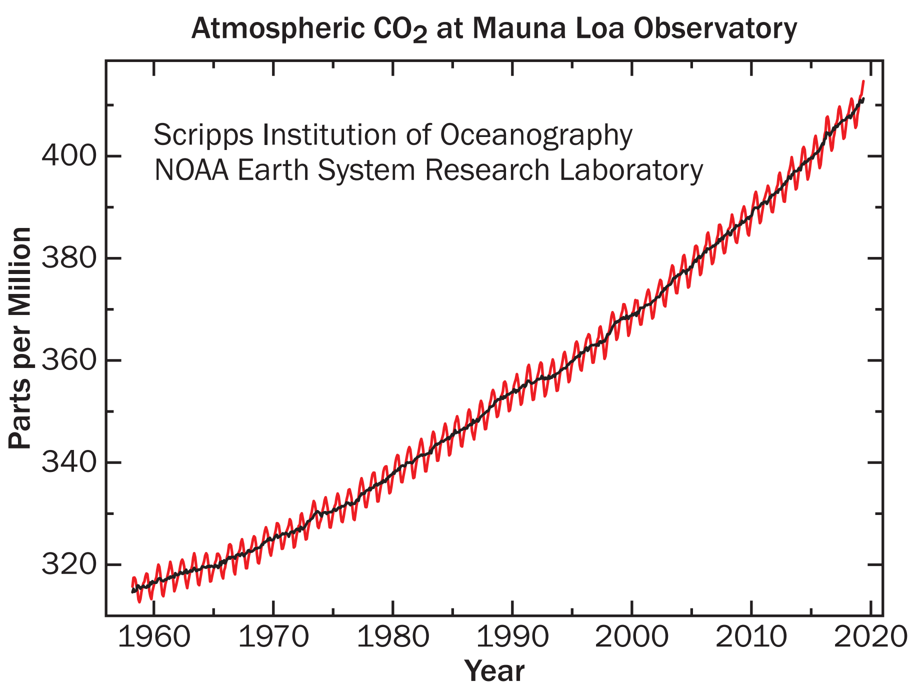
Organisms also affect Earth's other spheres in physical ways. A tree's roots grow into a crack in a boulder and widen the crack little by little. The remains of plankton sink to the ocean floor and form new layers of rock. Humans drill tunnels through the rock. A coral reef builds up over time, forming the foundation for islands. These are all examples of the biosphere physically interacting with and shaping Earth's other spheres.

Coral reefs are made of the skeletons of corals, small marine animals. Reefs can grow large enough that they accumulate sand and become islands.

The Biosphere Interacts with the Atmosphere

As an animal, you interact with the atmosphere by exchanging gases. You take in oxygen and release carbon dioxide and water vapor. Organisms that undergo photosynthesis take up carbon dioxide and release oxygen. Overall, there is balance between the oxygen-producing plants and the oxygen-using organisms and their effects on the atmosphere. Likewise, there is balance between organisms that use carbon dioxide from the atmosphere and those that produce it.

Over the last two centuries, human activity has caused a surge in the amount of carbon dioxide in the atmosphere. The seasonal up-and-down pattern of carbon dioxide continues, but the overall trend is toward much more carbon dioxide in the atmosphere. This is another example of how the biosphere interacts with the atmosphere.

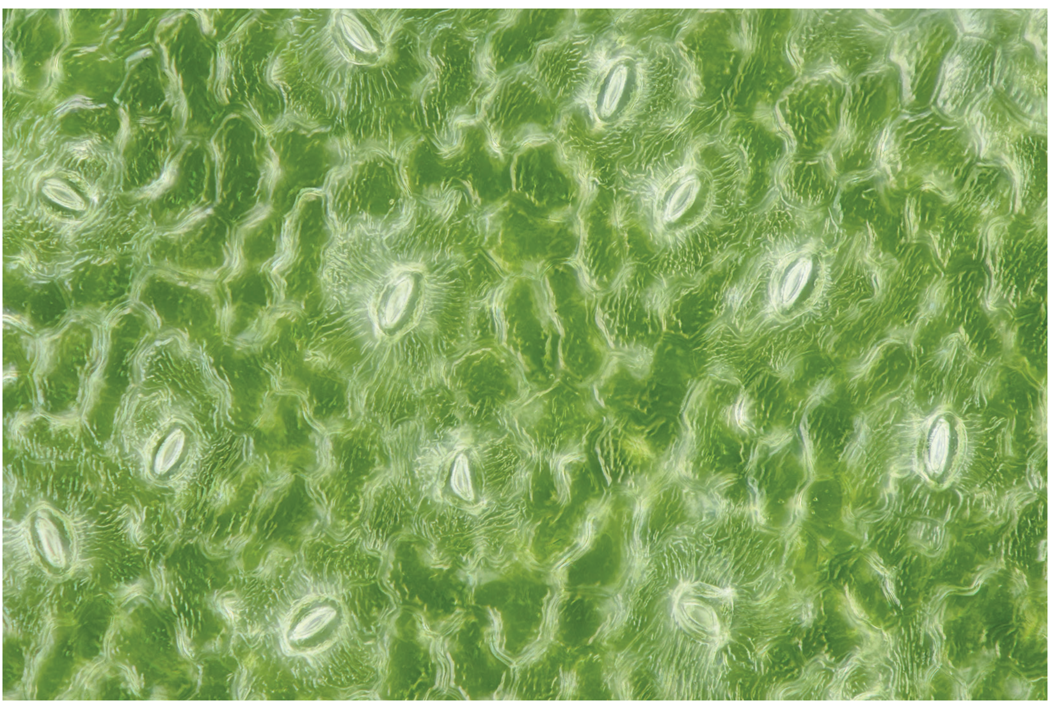


This graph shows the change in atmospheric carbon dioxide since 1960. Overall, CO_2 in the atmosphere has increased steadily. Each red peak marks the winter high. During winter in the Northern Hemisphere, many plants are are dormant. Less photosynthesis occurs. During summer in the Northern Hemisphere, plants remove more carbon dioxide (CO_2) from the atmosphere.

Photosynthesis requires sunlight, carbon dioxide, and water. Plants release water back into the atmosphere as well. Plant leaves have pores called stomata that open and close to exchange gases with the atmosphere. When plants are taking in more water than they need through their roots, the stomata open and release water vapor. This process, called transpiration, is part of the water cycle. Like evaporation from bodies of water, transpiration cycles water back into the atmosphere. There, the water is carried by wind to other locations, condenses into clouds, and falls back to Earth's surface as precipitation.

Word to Know

The release of water vapor from the leaves of plants is called *transpiration*.



This is a microscope close-up of a leaf. The oval-shaped features are stomata, which open and close to release water vapor and take in carbon dioxide.

Nitrogen is another gas in the atmosphere. Organisms need it, but they usually cannot absorb it directly from the air. Bacteria in soil, however, can take nitrogen from the air and fix it, meaning combine it with hydrogen or oxygen into forms that plants can absorb through their roots. Nitrogen then becomes part of plant structures that are eaten by animals. Waste products from animals and the decomposition of organisms' remains cycle the nitrogen back into soil and the atmosphere.

Nitrogen fixed in soil becomes useful to plants.

Methane is a gas made of carbon and hydrogen. Some methane is produced by decomposing organisms, especially in wetlands. It is also produced by the digestive systems of animals. Methane is a powerful greenhouse gas that helps trap heat near Earth's surface.

Livestock such as cows are a source of methane in the atmosphere.

The Biosphere Interacts with the Hydrosphere

Just as the biosphere exchanges gases with the atmosphere, it exchanges water with the hydrosphere. Organisms need water, and they take it in from sources such as lakes, rivers, the ocean, and aquifers. A deer that sips water from a stream recycles that water by exhaling and excreting waste. A fish takes in water from the ocean and excretes water back out.

The biosphere can alter parts of the hydrosphere chemically. For example, if algae in a pond become very abundant, they will turn the pond green and make it very murky. The algae alter the amount of oxygen dissolved in the pond water. This can lead to the deaths of fish and other organisms that depend on dissolved oxygen.

Microorganisms can also release toxins that kill other organisms. In warm coastal areas, such as the Gulf Coast of the United States, blooms of too many microorganisms produce toxins that can kill fish, turtles, birds, and marine mammals. These harmful blooms can also occur in lakes and rivers.

Word to Know

A *toxin* is a substance that is harmful or fatal to an organism.

The biosphere can alter the hydrosphere by introducing substances that dissolve in water and then are absorbed or ingested by other parts of the biosphere. A red tide, caused by a toxic bloom of microorganisms, can result in a massive fish kill, such as the one shown here.

The Biosphere Interacts with the Geosphere

The biosphere plays an important role in making the geosphere more livable. The organisms that first arrive on a new volcanic island, for example, do the first work to make the island suitable for life. Animals can physically weather and erode the landscape. They can also excrete wastes containing nitrogen and other chemicals that help turn the ash and rock into soil. Plant seeds in animal waste or carried by wind or waves can take root and, over time, improve the soil by the decomposition of their remains.

People often collect decaying leaves, grass clippings, scraps of food, and other organic material to use as compost to improve or fertilize soil. It's a way of recycling the biosphere, and it also alters the geosphere.

The earth beneath your feet is part of the geosphere. But soil layers are built up by the biosphere.

The geosphere is both broken down and built up by the biosphere. As microscopic organisms in the ocean live and die, their remains accumulate on the ocean floor. Over time, the layers of remains are compacted until they form sedimentary rock. Through activity of Earth's crustal plates, these layers of rock can be thrust above the ocean and become landforms.

Plant roots can grow into cracks in rocks and break them apart. Animals can weather and erode rock as well, often by burrowing to make dens or tunnels.

These parrotfish feed on hard corals. They eventually excrete the broken-up pieces of coral as sand. This sand can build up as an island over time.

Decomposers

Decomposers recycle nutrients and other matter back into the geosphere, hydrosphere, and atmosphere so the nutrients can be used by plants. Some bacteria are decomposers. Mushrooms are also decomposers. If you observe a fallen tree after it dies, you will probably see the wood break apart and grow soft as mushrooms pop up from it. The mushrooms release chemicals that break down wood so the nutrients can be absorbed. The mushrooms survive this way, and they also cycle matter back to the geosphere, atmosphere, and hydrosphere.

Ecosystems need for organisms to decompose. For example, the forests of the Pacific Northwest and Alaska depend on the decomposition of salmon. Salmon swim upstream from the Pacific Ocean to reproduce, and then they naturally die. The millions of dead salmon that drift along the bottoms of rivers slowly decompose. Nitrogen and other elements dissolve in the water. The nutrient-rich water seeps out through the riverbed and surrounding soil to the roots of the forest's plants.

The death of this salmon after it reproduces brings much-needed nutrients to the surrounding forest ecosystem. Bacteria and other organisms decompose the salmon.

The Search for Earth II

Chapter 9

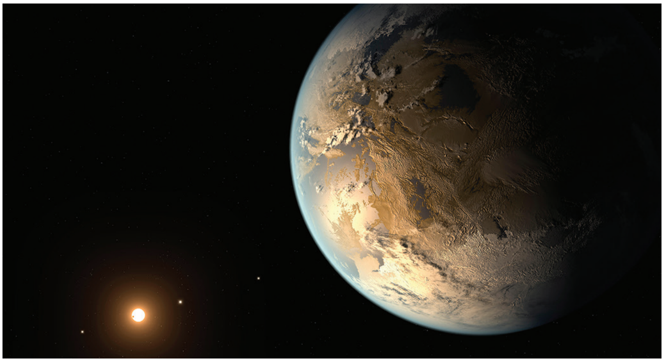
You have read about the four Earth spheres and how they interact. Could similar systems exist on other planets?

Big Question

Is it possible that there is another planet somewhere that has the right combination of features to support life?

NASA, the National Aeronautics and Space Administration, has been looking into space for signs of planets that could have the right conditions for life. Such a planet would need a source of energy, so it would most likely orbit a star like the sun. Planets that orbit stars outside our own solar system are called exoplanets.

NASA has been seriously looking for exoplanets since 1995. The space agency approved a mission called Kepler to look for systems where planets are in the habitable zone around a star. The habitable zone is close enough to the star for the exoplanet's temperature to allow liquid water to pool on the surface and, potentially, support life. The Kepler mission ended in 2018, having discovered thousands of planets within habitable zones of stars and with rocky composition (a geosphere). Could one of them support life similar to the way Earth does?



This is an artist's illustration of what the exoplanet Kepler 186f might look like.

Ingredient #1 of Earth II: Geosphere

Scientists have to figure out what it would take to make a distant exoplanet a kind of second Earth, or Earth II. They start by applying what we know of Earth's spheres. Scientists also ask: Could humans live on an exoplanet?

One thing a planet would need to sustain life as we know it is a geosphere with enough of a rocky, hard surface to support living things. Some planets, such as Neptune, have solid cores like Earth but have a surface that is slushy and barely separate from the thick, icy atmosphere. An icy, slushy surface would not work for humans.

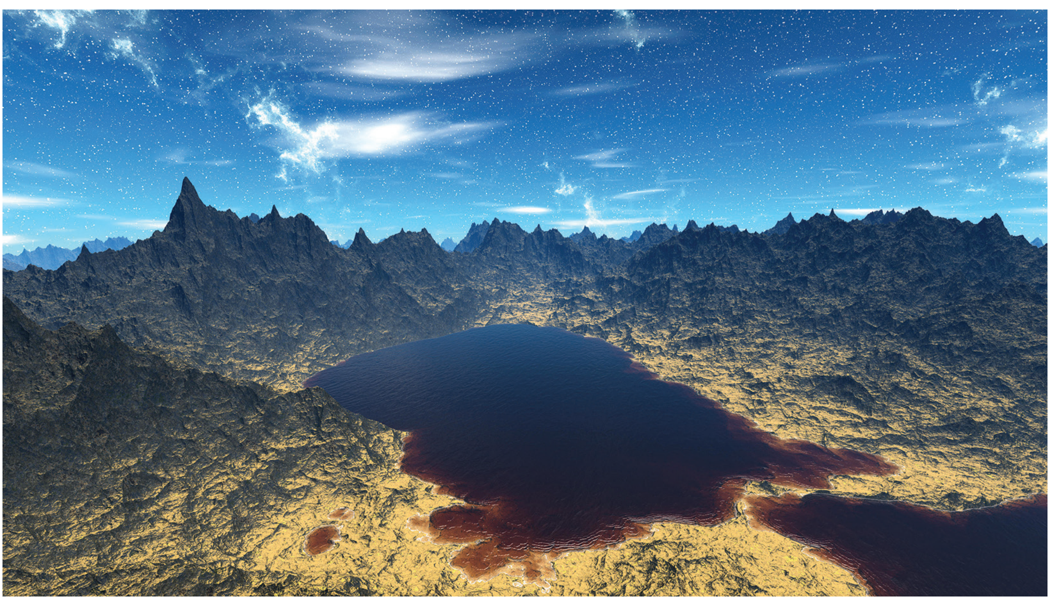
The solid materials shown here, which are becoming part of a building or are necessary to move the parts into place, are all mined from the geosphere.

On Earth we rely on the geosphere for soil to grow crops that we eat and trees that we use for lumber to build homes. We dig marble, granite, limestone, and other types of rock from the ground to make buildings. We use a mix of rock and oil to make asphalt for roadways. We mine metals such as iron and nickel to make strong alloys such as steel, which we need for beams, nails, and screws. An Earth II would need similar materials for inhabitants to extract.

Ingredient #2 of Earth II: Hydrosphere

A planet that sustains or supports life needs to provide liquid water. A planet that is too close to its star is likely to be too warm to have any liquid water. A planet too far from its star could be too cold to have anything but solid water, or ice.

Scientists who have analyzed the data from the Kepler mission think many of the exoplanets that Kepler found are water-rich planets. But the liquid water itself is likely very different from what we have on Earth. It is likely much hotter or colder or mixed with other substances. Even if we traveled to an exoplanet that has a lot of liquid water, it would not be of much use to us if it were all boiling hot or mixed with ammonia, as on Neptune. We need a hydrosphere with temperature and chemical characteristics similar to what we have on Earth.

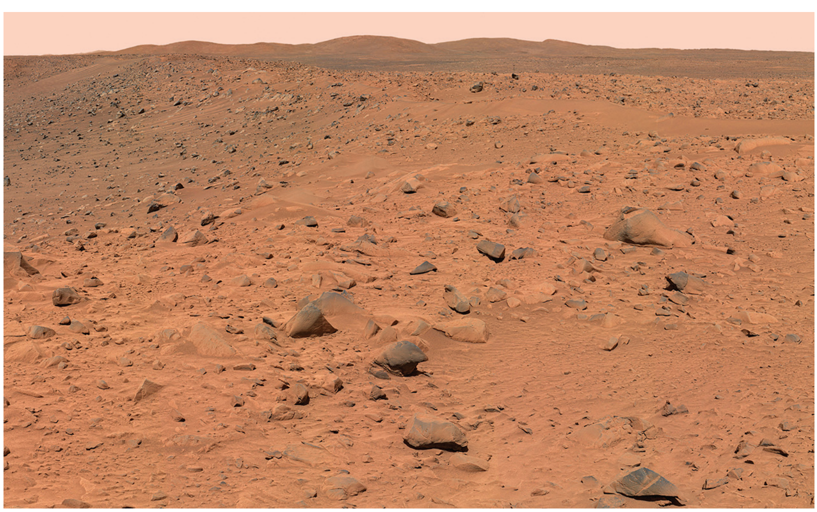


This artist's illustration shows what a body of water could look like on a distant planet. The liquid water contains some chemicals that make it different from Earth's surface water. This pool of surface water may resemble a pond on Earth, but it could be much hotter or mixed with poisonous substances. Life as we know it requires not only a hydrosphere, but a hydrosphere similar to Earth's.

Ingredient #3 of Earth II: Atmosphere

Some exoplanets may have had liquid surface water at some point. An exoplanet similar to Mars could have a very thin atmosphere, and lack of water may be due to solar winds that stripped away the atmosphere over time. Solar winds are streams of charged particles from the sun that radiate out to the solar system. Without a thicker atmosphere to protect the surface, liquid water vaporizes. If an atmosphere is too thin, it will not have pressure similar to Earth's, and it will be too hot or cold.

Even if an exoplanet had an atmosphere with the right thickness, pressure, and temperature, that still would not necessarily make it livable for humans or other forms of life as we know it. The atmosphere's mix of gases would need to be like Earth's. The combination must be relatively low in carbon dioxide, high in oxygen, and free of poisonous gases. If the atmosphere isn't breathable, then the best we could do is live and breathe in sealed environments with artificial atmospheres. We would have to wear special suits when venturing outside of such environments.



The atmosphere on Mars is too thin, which means the planet is much too cold for life as we know it to survive there.

Ingredient #4 of Earth II: Biosphere

The interactions of Earth's atmosphere, geosphere, and hydrosphere allowed for life to develop and created the biosphere over millions of years. The organisms that inhabit Earth today are adapted for the mix of gases in today's atmosphere. That includes us. We only survive because the biosphere has made the atmosphere oxygen-rich with low carbon dioxide.

Of course, we also rely on the biosphere for food and other resources that are made from living things or their remains. Without the ability to grow plants or hunt animals on a colony elsewhere in the galaxy, we would not last long there. It is not possible to transport years' worth of food via space travel. We would also be without materials that are used for clothing, medicine, furniture, homes, and so much else that we depend on.

Forests and other parts of the biosphere provide us with materials we need for survival, including some of the oxygen that is in the atmosphere.

Biosphere 2

Biosphere 2 in Arizona is an example of an experimental self-contained environment that may help prepare us to live on other planets. In 1991, a crew of eight scientists sealed themselves in the three-acre glass-and-steel structure in the Arizona desert. Biosphere 2 had a rain forest, a savanna, a small farm, a desert, and even a small ocean. For two years, the crew lived off food they grew or gathered, drank water that was recycled through the habitats, and recycled their own wastes. They conducted experiments in addition to being subjects of an experiment. In early 1993, the level of carbon dioxide in Biosphere 2's atmosphere was twelve times what it is in Earth's atmosphere, and the level of oxygen was low, similar to what mountain climbers experience at high altitude. With many plants thriving inside, it was surprising that there was such an imbalance. It turned out that the developers of Biosphere 2 had loaded the soil with too much compost. The bacteria in the soil sucked up too much oxygen and released too much carbon dioxide, throwing off the balance among Biosphere 2's systems. The complex interactions among Earth's spheres is not easy to duplicate.

Biosphere 2 was a closed system. The only thing that entered from outside was sunlight.

Glossary

A

air mass, n. a large body of air with similar temperature, air pressure, and moisture throughout (21)

air pressure, n. the weight of air pressing on all things beneath and within it (20)

aquifer, n. an underground region of rocky material containing water that can be drawn out through a well (40)

atmosphere, n. the Earth system that is composed of all the gases that surround Earth (17)

B

biodiversity, n. the variety of species on Earth or in any one environment on Earth (24)

biome, n. a large region on Earth with a specific climate that contains certain species (26)

biosphere, n. the Earth system that is composed of all the living things on Earth (23)

D

deposition, n. the dropping of sediment in a new location (45)

E

erosion, n. the movement of sediment (32)

F

fresh water, n. naturally occurring water that contains little or no salt (4)

G

geologic, adj. relating to Earth's rocky inner and outer features (9)

geosphere, n. the Earth system that contains all the rocky layers of Earth (9)

groundwater, n. water stored in the spaces between materials beneath Earth's surface (4)

H

hydrosphere, n. the Earth system that contains all of the water on Earth (1)

R

rain shadow, n. a dry region on one side of a mountain that results from precipitation on the other side of the mountain removing moisture from clouds (37)

reservoir, n. a place where water collects (4)

rock cycle, n. the process through which rock changes form through igneous, sedimentary, and metamorphic types (16)

S

salt water, n. water that contains dissolved salt (3)

soil, n. the top layer of Earth's land that often has a mix of organic and inorganic material (41)

species, n. a group of organisms of the same type that are capable of reproducing together (24)

W

water cycle, n. the dynamic movement of water on, below, and above Earth's surface (8)

water table, n. the upper surface or level of groundwater (40)

weathering, n. the process of breaking down rock into smaller pieces (30)

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