3

Earth's Interdependent Systems

In this chapter, we will discuss planet Earth's structure and its resources. This review will act as a foundation for many of the chapters that come after it, so pay close attention! According to ETS, about 10–15 percent of the test will be on the material that's contained in this chapter, so consult your textbook for more information about subjects that don't look familiar.

In this chapter, we will begin by discussing the components of the solid Earth—what it's made up of, how long it has existed, why we have earthquakes and volcanoes, and things like that. This will be followed by a discussion of soil—how it is formed, what it's composed of, and why it's important to humans. We'll move on to discuss the atmosphere; its structure and how it produces the weather we experience. The atmosphere, hydrosphere, and biosphere are all intricately related, and can almost not be discussed separately. However, we've broken them down into neat sections for review, and we'll go through everything you'll need to know about these systems for test day.

We'll end this chapter by reviewing oceans and freshwater bodies; we'll refresh your memory about certain environmental issues that pertain to Earth's water supply, too.

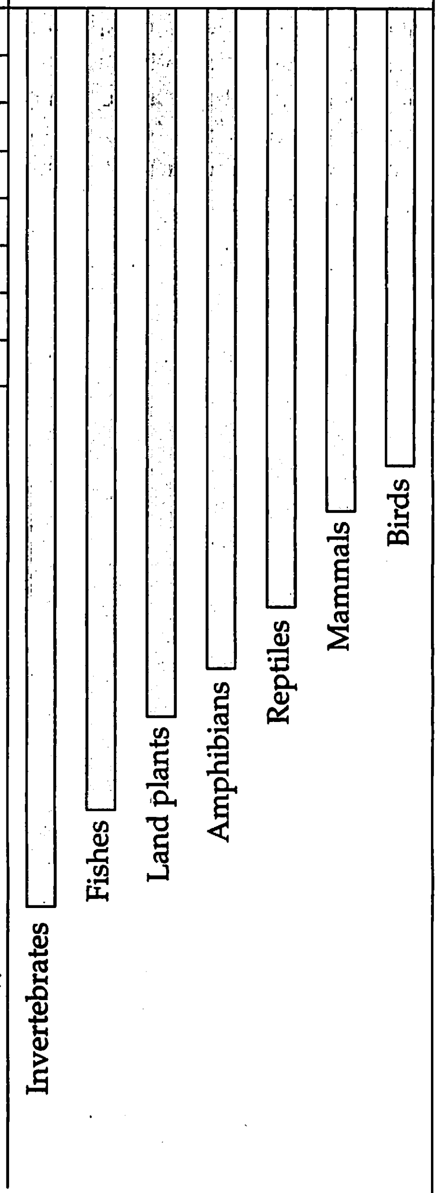
WELCOME TO PLANET EARTH

The first thing you should know about Earth is its history. Earth is thought to be between 4.5 and 4.8 billion years old. That amount of time is pretty inconceivable to humans, but the **geologic time scale** on the following page will help you get a sense of the vast amount of time that has gone by since Earth was formed. You will not be responsible for memorizing all of the eons, eras, periods, and epochs for this exam, but you should be familiar with the major ones; they will come in handy.

TIME UNITS OF THE GEOLOGIC TIME SCALE (Numbers are absolute dates in millions of years before the present.)

Eon	Era	Period		Epoch	
Phanerozoic Eon	Cenozoic Era	Quaternary		Holocene	
				Pleistocene	2
		Tertiary	Neogene	Pliocene	5
				Miocene	24
			Paleogene	Oligocene	37
				Eocene	58
			66	Paleocene	
	Mesozoic Era	Cretaceous	144		
		Jurassic	208		
		Triassic	245		
	Paleozoic Era	Permian	286		
		Pennsylvanian	320		
		Mississippian	360		
		Devonian	408		
		Silurian	438		
		Ordovician	505		
		Cambrian	570		
Proterozoic Eon	Late		900	Precambrian comprises about 87% of the geologic time scale	
	Middle		1,600		
	Early		2,500		
Archeon Eon	Late		3,000		
	Middle		3,400		
	Early		3,800		
Hadean	No record			Origin of Earth about 4.6 billion years ago	

TIME RANGE OF SEVERAL GROUPS OF PLANTS AND ANIMALS



Where Is Earth in the Solar System?

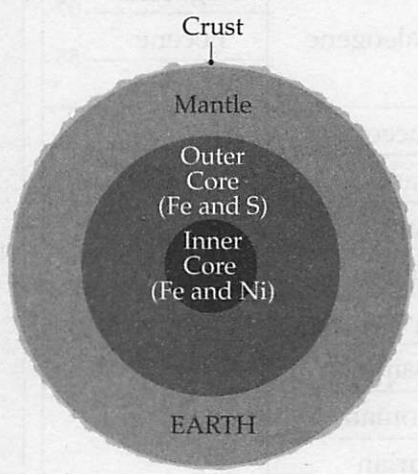
Earth is the third planet from the sun in our solar system, which contains a total of eight planets. From the sun outward, the planets are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

You probably already know that Earth and the other planets orbit the sun in an elliptical pattern. And, of course, it takes Earth about 365 $\frac{1}{4}$ days, or 1 year, to complete its orbit of the sun.

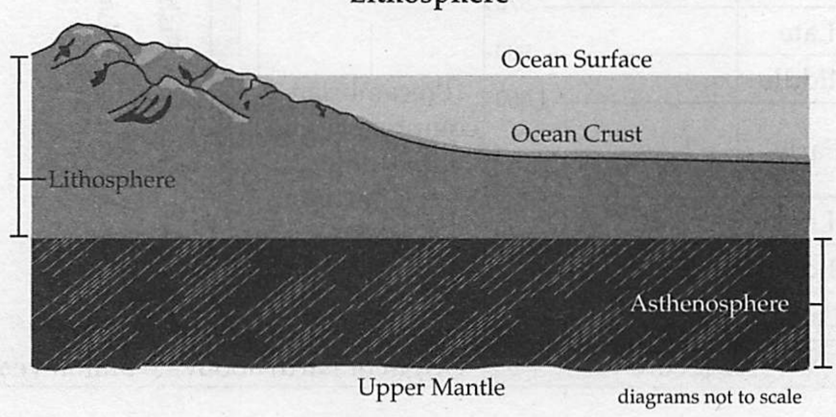
What Is Earth Made Of?

Planet Earth is made up of three concentric zones of rocks that are either solid or liquid (molten). The innermost zone is the **core**. The core has two parts: a solid inner core and molten outer core. The inner core is composed mostly of nickel and iron, and is solid due to tremendous pressures. The outer core is composed mostly of iron and sulfur, and is semi-solid due to lower pressures. Surrounding the outer core is the **mantle,** which is made mostly of solid rock. The mantle has an area, called the asthenosphere, which is slowly flowing rock. The **lithosphere,** a thin, rigid layer of rock, is the outermost layer of the earth. The lithosphere contains the rigid upper mantle and the **crust**, our solid surface of the earth.

Earth's Layers



Lithosphere

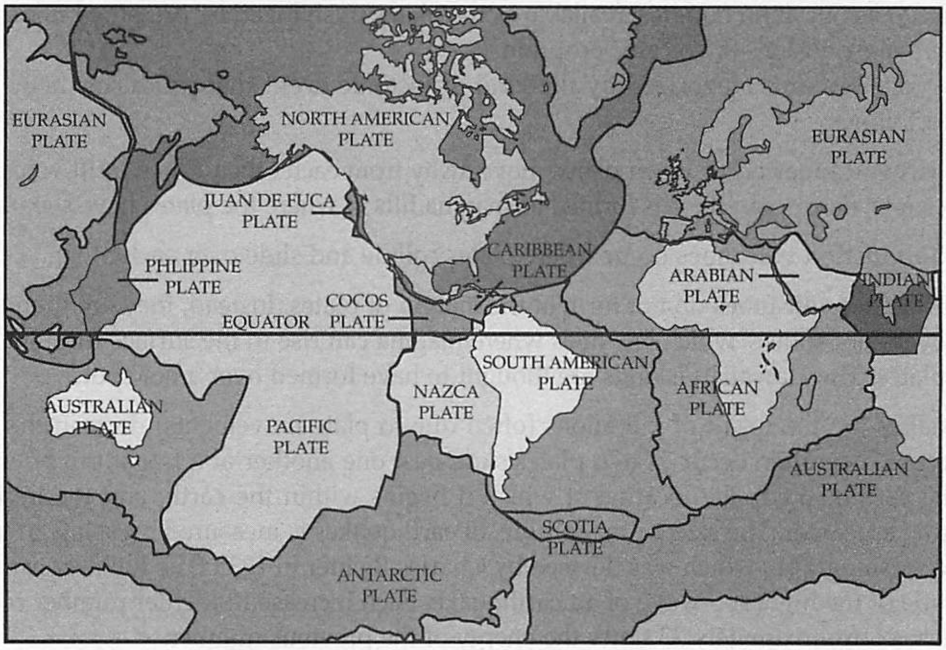


Tectonic Plates

Because the lithosphere floats atop the asthenosphere like a cracker on a layer of pudding, it can move and break into large pieces or **tectonic plates.** There are a total of a dozen or so tectonic plates in the lithosphere that move independently of one another. The plates are made up of both mantle and crust. The majority of the land on Earth sits above six giant plates; the remainder of the plates lie under the ocean as well as the continents.

Some plates consist only of ocean floor, such as the Nazca plate, which lies off the west coast of South America, while others contain both continental and oceanic material. One example of the latter is the North American plate, where the United States is located; this plate extends out to the mid-Atlantic ridge. There is even a plate that is located exclusively within the Asian continent; its boundaries nearly coincide with those of Turkey. The largest plate is the Pacific plate—it primarily consists of ocean floor, but also includes Mexico's Baja Peninsula and southwestern California. The major plates of Earth are shown on the map below.

Earth's Plates



The edges of the plates are called **plate boundaries** and the places where two plates abut each other is where events like sea floor spreading and most volcanoes and earthquakes occur. There are three types of plate boundary interactions.

- **Convergent boundary**: Two plates are pushed toward each other. One of the plates will be pushed deep into the mantle.
- **Divergent boundary**: Two plates are moving away from each other. This causes a gap that can be filled with magma (molten rock), and when it cools new crust is formed.
- **Transform fault boundary**: Two plates slide from side to side relative to each other—like when you rub your hands back and forth. These are also called transform boundaries.

So, what happens when plates collide? It depends on what types of plates collide, and where. Converging ocean-ocean and converging ocean-continent boundaries often result in **subduction,** in which a heavy ocean plate is pushed below the other plate and melts as it encounters the hot mantle. Converging continent-continent boundaries result in the uplifting of plates to form large mountain chains, like the Himalayas (which were created by a collision between the plate carrying India and the Asian plate), the Urals, the Alps, and the Appalachian Mountains.

One important result of plate movement is the creation of volcanoes and earthquakes. Let's examine those next.

Volcanoes and Earthquakes

Volcanoes are mountains formed by magma from the earth's interior. **Active volcanoes** are those that are currently erupting or have erupted within recorded history, while **dormant volcanoes** have not been known to erupt. It's thought that **extinct volcanoes** will never erupt again.

Volcanoes form where tectonic plates meet. At these junctures, breaks occur in the earth's crust and magma flows out. If no outlet is available as the plates push together, pressure builds up until it is relieved in an explosion—a volcanic eruption.

Active volcanoes are categorized by the kind of tectonic event that produces them. The three types are as follows:

- **Rift volcanoes** occur when plates move away from each other. When a rift volcano erupts, new ocean floor is formed as magma fills in where the plates have separated.
- **Subduction volcanoes** occur where plates collide and slide over each other.
- **Hot spot volcanoes** do not form at the margin of plates. Instead, they are found over "hot spots," which are areas where magma can rise to the surface through the plates. The Hawaiian Islands are thought to have formed over a hot spot.

Earthquakes are the result of vibrations (often due to plate movements) deep in the earth that release energy. They often occur as two plates slide past one another at a transform boundary. The **focus** of the earthquake is the location at which it begins within the earth, and the initial surface location is the **epicenter.** The size, or magnitude, of earthquakes is measured by using an instrument known as a **seismograph,** which was devised by Charles Richter in 1935. The Richter scale measures the amplitude of the highest S-wave of an earthquake. Each increase in Richter number corresponds to an increase of approximately 33 times the energy of the previous number.

In January 2010, an earthquake of magnitude 7.0 struck the nation of Haiti. The center of the quake occurred in the boundary region separating the Caribbean plate and the North American plate. Official estimates from the U.S. Geological Service had 222,570 people killed, 300,000 injured, 1.3 million displaced, 97,294 houses destroyed and 188,383 damaged across the Port-au-Prince area and much of southern Haiti. This includes at least 4 people killed by a local tsunami in the Petit Paradis area near Léogâne. Tsunami waves were also reported at Jacmel, Les Cayes, Petit Goâve, Léogâne, Luly, and Anse à Galets.

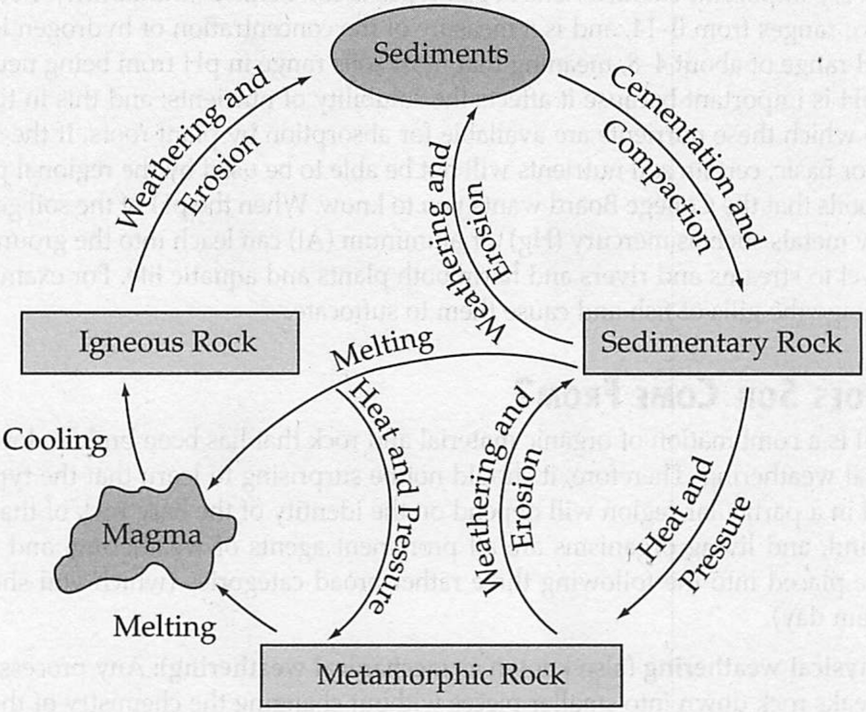
The Rock Cycle

Rocks are all around us, in the soil, our buildings, and the ore used in industry. So, where do all those rocks come from? The answer is: other rocks. The oldest rocks on Earth are 3.8 billion years old, while others are only a few million years old. This means that rocks have to be recycled. The process that does this is the **rock cycle**. In the rock cycle, time, pressure, and the earth's heat interact to create three basic types of rocks.

- **Sedimentary**—these rocks are formed as sediment (eroded rocks and the remains of plants and animals) builds up and is compressed. One place this can occur is at a subduction zone where ocean sediments are pushed deep into the earth and compressed by the weight of rock above it. An example of a sedimentary rock is limestone.
- **Metamorphic**—this type of rock is formed as a great deal of pressure and heat is applied to rock. This can happen as sedimentary rocks sink deeper into the earth and are heated by the high temperatures found in the earth's mantle. An example of a metamorphic rock is slate.
- **Igneous**—this type of rock results when rock is melted (by heat and pressure below the crust) into a liquid and then resolidifies. The molten rock (**magma**) comes to the surface of the earth, and when it emerges it is called lava; solid lava is igneous rock. An example of an igneous rock is basalt.

The diagram below illustrates the rock cycle. Make sure you are familiar with it before the exam!

The Rock Cycle



SOIL

One very important but often underappreciated player in Earth's interdependent systems is soil. Soil plays a huge and crucial role in the lives of the plants, animals, and other organisms that live in the biosphere, and acts as a crucial link between the **abiotic** (the nonliving components of the world) and the **biotic** (that's right, the living components of the world). As we'll see in the next chapter, soil also plays an active role in the cycling of nutrients. Let's take a moment to review the major characteristics of soil that you'll be expected to know for the test.

Soil Is More than Just Dirt

Although we may be tempted to think of soil as simply "dirt," soil is actually a complex, ancient material teeming with living organisms. Some soil is hundreds of years old! In just one gram of soil, there may be as many 50,000 protozoa, as well as bacteria, algae, fungi, and larger organisms such as earthworms and nematodes. About one half of the volume of soil is made up of mineral materials, and about 5 percent is organic matter (both living and dead). The pores between the grains of minerals in soil are filled with air or water and, as a rule, the size of the particles that make up the soil determines the size of the pores between the soil particles.

Soils can be categorized based on numerous physical and chemical features including color and texture. The United States Department of Agriculture (USDA) divides soil textures into three large groups: The category with the smallest particles is **clay**, which has particles that are less than 0.002 mm in diameter. The next largest is **silt**, with particles 0.002–0.05 mm in diameter, and **sand** is the coarsest soil, with particles 0.05–2.0 mm in diameter. Sand particles are too large to easily stick together, and sandy soils have larger pores; which means that they can hold more water. Clays easily adhere to each other and there is little room between particles for water; clay soil is extremely compact.

Another very important characteristic of soil types is soil **acidity** or **alkalinity.** Recall that the pH of a substance ranges from 0–14, and is a measure of the concentration of hydrogen ions. Most soils fall into a pH range of about 4–8, meaning that most soils range in pH from being neutral to slightly acidic. Soil pH is important because it affects the solubility of nutrients; and this in turn determines the extent to which these nutrients are available for absorption by plant roots. If the soil in a region is too acidic or basic, certain soil nutrients will not be able to be used by the regional plants. One last thing about soils that the College Board wants you to know. When the pH of the soil gets more acidic, ions of heavy metals such as mercury (Hg) or aluminum (Al) can leach into the ground water. These ions can travel to streams and rivers and harm both plants and aquatic life. For example, aluminum ions can damage the gills of fish and cause them to suffocate.

Where Does Soil Come From?

Basically, soil is a combination of organic material and rock that has been broken down by chemical and biological weathering. Therefore, it should not be surprising to learn that the types of minerals found in soil in a particular region will depend on the identity of the base rock of that region.

Water, wind, and living organisms are all prominent agents of weathering, and all weathering processes are placed into the following three rather broad categories (which you should definitely know for exam day).

- **Physical weathering** (also known as **mechanical weathering**): Any process that breaks rock down into smaller pieces without changing the chemistry of the rock. The forces responsible for physical weathering are typically wind and water.
- **Chemical weathering:** Occurs as a result of chemical interactions between water and other atmospheric gases, and the bedrock of a region.

- **Biological weathering:** Weathering that takes place as the result of the activities of living organisms.

Soil is made up of distinct layers with very different characteristics. Let's discuss those next.

Soil Layers

Soil comprises distinct layers known as **horizons,** which vary considerably in content.

- **O horizon:** The O horizon is the uppermost horizon of soil. It is primarily made up of organic material, including waste from organisms; the bodies of decomposing organisms; and live organisms. The dark, crumbly material that results from the decomposition of organic material forms **humus.**
- **A horizon:** The horizon below the O layer is called the A horizon, and this layer is made up of weathered rock and some organic material that has traveled down from the O layer. The A layer is often referred to as **topsoil** and plays an important role in plant growth. This is the zone of **leaching.**
- **B horizon:** This layer lies below the A horizon. The B layer receives all of the minerals that are leached out of the A horizon as well as organic materials that are washed down from the topsoil above. This is the zone of **illuviation.**
- **C horizon:** The bottommost layer of soil is the C horizon. The C horizon is composed of larger pieces of rock that have not undergone much weathering.
- **R horizon:** The bedrock, which lies below all of the other layers of soil, is referred to as the R horizon.

Soil Problems for (and Caused by) Humans

In order to be able to grow all of the foods that humans consume, we must have enough **arable**—or suitable for plant growth—soil to meet our agricultural needs. Soil fertility refers to soil's ability to provide essential nutrients, like nitrogen (N), potassium (K), and phosphorus (P), to plants. Humus (remember, it's in the O layer!) is also an extremely important component of soil because it is rich in organic matter.

Soils composed of roughly the same amount of all three textures (remember: clay, silt, and sand) are described as being **loamy,** and these types of soil are considered the best for plant growth. Another important characteristic of soil for agricultural purposes is the extent to which it aggregates, or clumps. The most fertile soils are aggregates (look, it's a noun, too!) of soils of different textures bound together with organic material.

Monoculture

Unfortunately, certain agricultural activities can change the texture of soil; for example, repeated plowing tends to break down soil aggregates, leaving "plow pan" or "hard pan," which is hard, unfertile soil.

Whereas communities traditionally planted many different types of crops in a field, in modern agriculture the **monoculture,** or the planting of just one type of crop in a large area, predominates. Over the history of agriculture, a significant decrease in the genetic diversity of crop species has taken place. This creates numerous problems. First of all, a lack of genetic variation makes crops more susceptible to pests and diseases. Secondly, the consistent planting of one crop in an area eventually leaches the soil in that area of the specific nutrients that the plant needs in order to grow. One way of preventing this phenomenon is to practice **crop rotation,** in which different crops are planted in the area in each growing season.

Other problems with modern agriculture include its reliance on large machinery (which can damage soil), and the fact that as an industry, agriculture is a huge consumer of energy. Energy is consumed both in the production of pesticides and fertilizers and in the use of fossil fuels to run farm machinery.

The past 50 years or so have seen a huge increase in worldwide agricultural productivity, and this is largely due to the mechanization of farming that resulted from the Industrial Revolution. The boom in agricultural productivity is known as the **Green Revolution,** and unfortunately it has since had many detrimental environmental effects. For example, the use of chemical pesticides resulted in the emergence of new species of insects that were pesticide-resistant. Recently, the introduction of genetically modified plants has enabled researchers to take steps in solving the problem of pesticide-resistant insect species.

Another drawback to the Green Revolution resulted from the dramatic increase in irrigation worldwide; over-irrigated soils undergo salinization. In **salinization,** the soil becomes water-logged and when it dries out, salt forms a layer on its surface; this eventually leads to **land degradation.** In order to combat this problem, researchers have developed **drip irrigation,** which allots an area only as much water as is necessary and delivers the water directly to the roots.

Soil Erosion

As you learned earlier, the small rock fragments that result from weathering may be moved to new locations in the process of erosion, and bare soil (soil upon which no plants are growing) is more susceptible to erosion than soil that's covered by organic materials.

Because of the constant movement of water and wind on Earth's surface, the **erosion** of soil is a continual and normal process. However, when erosion removes valuable topsoil or deposits soil in undesirable places, it can become a problem for humans. Eroded topsoil usually ends up in bodies of water, posing a problem for both farmers, who need healthy soil for planting, and people who rely on bodies of water to be uncontaminated with soil runoff (soil can contaminate the water with pesticides and other harmful chemicals).

The most significant portion of erosion caused by humans results from logging and slash-and-burn agriculture. The removal of plants in an area makes the soil much more susceptible to the agents of erosion.

Unfortunately, human activities such as the ones we have just discussed—the over-cultivation of agricultural fields, overgrazing, urbanization, and deforestation—have significantly increased the levels of erosion in the upper layers of soil. These processes will continue to create problems for farmers searching for arable land until new techniques that preserve the integrity of soil are introduced and utilized.

Soil Conservation

In order to conserve soil resources, several best management practices have been developed. These practices return organic matter to the soil, slow down the effects of wind, and reduce the amount of damage done to the soil by tillage (plowing). Here are some of the more common methods.

- Use animal waste (manure) and the residue of plants to increase the amount of organic matter in the soil.
- Modify tillage practices to reduce the breakup of soil and to reduce the amount of erosion. These include contour plowing and strip planting.
- Use trees and other wind barriers to reduce the force of the wind.

Soil Laws

The federal government recognized the need to protect this vital resource. Review the two laws below that relate to preserving soil.

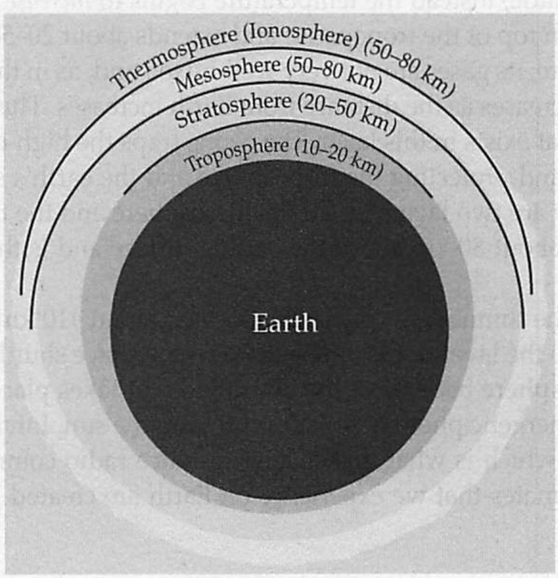
Date	Name of Law	What It Does
1977	Soil and Water Conservation Act	Soil and water conservation programs to aid landowners and users; also sets up conditions to continue evaluating the condition of U.S. soil, water, and related resources.
1985	Food Security Act	Nicknamed the Swampbuster, this act discouraged the conversion of wetlands to nonwetlands. 1990 federal legislation denied federal farm supplements to those who converted wetlands to agriculture, and provided a restoration of benefits to those who unknowingly converted lands to wetlands.

Phew, got it? You're almost at the halfway point of this chapter. If you want, go get a glass of water or a snack to bolster you for the remaining pages!

Next we will turn to a study of what surrounds the earth: the atmosphere.

THE ATMOSPHERE

In the broadest definition, the **atmosphere** is a layer of gases that's held close to the earth by the force of gravity. The layer of gases that lies closest to the earth is the **troposphere;** it extends from the surface of the earth to about 10–20 km (5–10 miles). The troposphere is where all of the weather that we experience takes place; this layer contains the majority of atmospheric water vapor and clouds. Generally the troposphere is vertically well mixed and (with the exception of periods of temperature inversions) it gradually becomes colder with an increase in altitude (by about 6.5°C/km).



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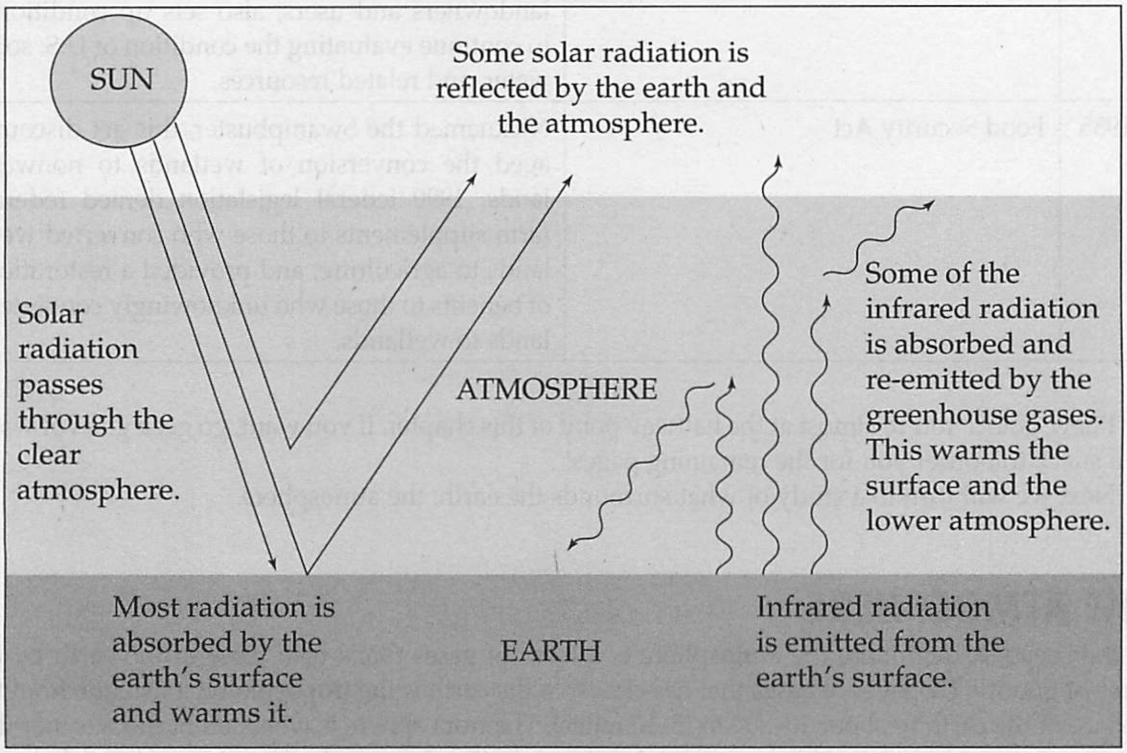
You've probably heard about the troposphere before in the news because of the **greenhouse effect.** The troposphere contains certain gases called "greenhouse" gases, the most important of which are H_2O and CO_2. As the sun's rays strike the earth, some of the solar radiation is reflected back into space; however, greenhouse gases in the troposphere intercept and absorb a lot of this radiation. We'll further investigate the greenhouse effect in Chapter 8, but for now take a look at the following figure.

The Greenhouse Effect



Crowning the troposphere is the **tropopause,** which is a layer that acts as a buffer between the troposphere and next layer up, the stratosphere. In this buffer zone, the atmospheric temperature no longer decreases with altitude; instead the temperature begins to *increase* with altitude.

The **stratosphere** sits on top of the tropopause and extends about 20–50 km above the earth's surface. Unlike the troposphere, its gases are not very well-mixed and, as in the tropopause, the temperature in the stratosphere increases as the distance from Earth increases. This warming effect is due to a thin band of **ozone** (O_3) that exists in this layer. The ozone traps the high-energy radiation of the sun, holding some of the heat and protecting the troposphere and the earth's surface from this radiation.

Above the stratosphere are two layers called the mesosphere and the thermosphere (ionosphere). The **mesosphere** extends about 80 km above the earth's surface and is the area where meteors usually burn up.

The **thermosphere** is the thinnest gas layer; it is located about 110 km above Earth and is where auroras take place. It's also the layer of the atmosphere where space shuttles orbit! The thermosphere is also known as the **ionosphere** because of the ionization that takes place in this region; this region also absorbs most of the energetic photons (solar wind) from the sun. Interestingly, the thermosphere also reflects radio waves, which is what makes long distance radio communication possible. You'll need to know how the climates that we experience on Earth are created by the atmosphere, so let's go into this next.

Climate

The earth's atmosphere has physical features that change day to day as well as patterns that are consistent over a space of many years. The day-to-day properties such as wind speed and direction, temperature, amount of sunlight, pressure, and humidity are referred to as **weather**. The patterns that are constant over many years (30 years or more) are referred to as **climate**. The two most important factors in describing climate are average temperature and average precipitation amounts. **Meteorologists** are scientists who study weather and climate.

The weather and climate of any given area is the result of the sun unequally warming the earth (and the gases above it) as well as the rotation of the earth.

Air Circulation in the Atmosphere

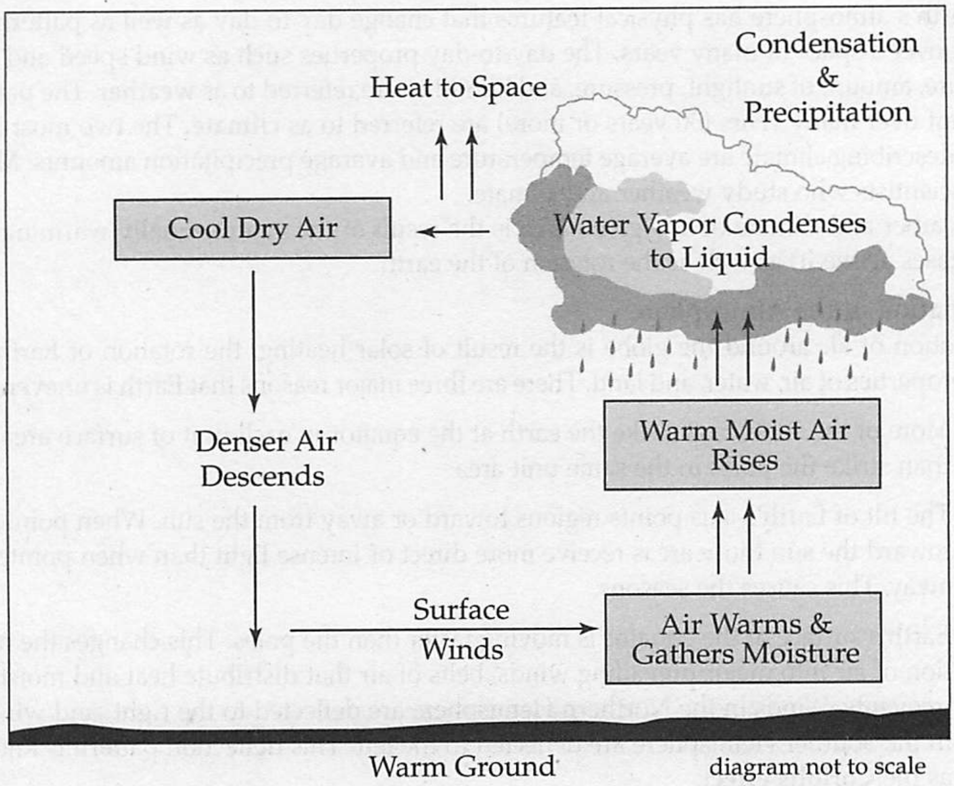
The motion of air around the globe is the result of solar heating, the rotation of Earth, and the physical properties of air, water, and land. There are three major reasons that Earth is unevenly heated.

- More of the sun's rays strike the earth at the equator in each unit of surface area than strike the poles in the same unit area.
- The tilt of Earth's axis points regions toward or away from the sun. When pointed toward the sun those areas receive more direct or intense light than when pointed away. This causes the seasons.
- Earth's surface at the equator is moving faster than the poles. This changes the motion of air into major prevailing winds, belts of air that distribute heat and moisture unevenly. Winds in the Northern Hemisphere are deflected to the right, and winds in the Souther Hemisphere are deflected to the left. This deflection pattern is known as the **Coriolis effect.**

Solar energy warms Earth's surface. The heat is transferred to the atmosphere by radiation heating. The warmed gases expand, become less dense, and rise creating vertical currents called **convection currents**. The warm currents can also hold a lot of moisture compared to the surrounding air. As these large masses of warm moist air rise, cool air flows along Earth's surface into the area where the warm air was located. This flowing air or horizontal airflow is one way that surface winds are created.

As warm moist air rises into the cooler atmosphere, it cools to the **dew point**, the temperature at which water vapor condenses into liquid water. This condensation creates clouds. If condensation continues and the drops get bigger, they can no longer be held up by gravity and they fall as **precipitation** (which can be frozen or liquid). The cold dry air is now denser than the surrounding air. This air mass then sinks to the earth's surface where it is warmed and can gather more moisture, thus starting the **convection cell** rotation again.

Convection Cell



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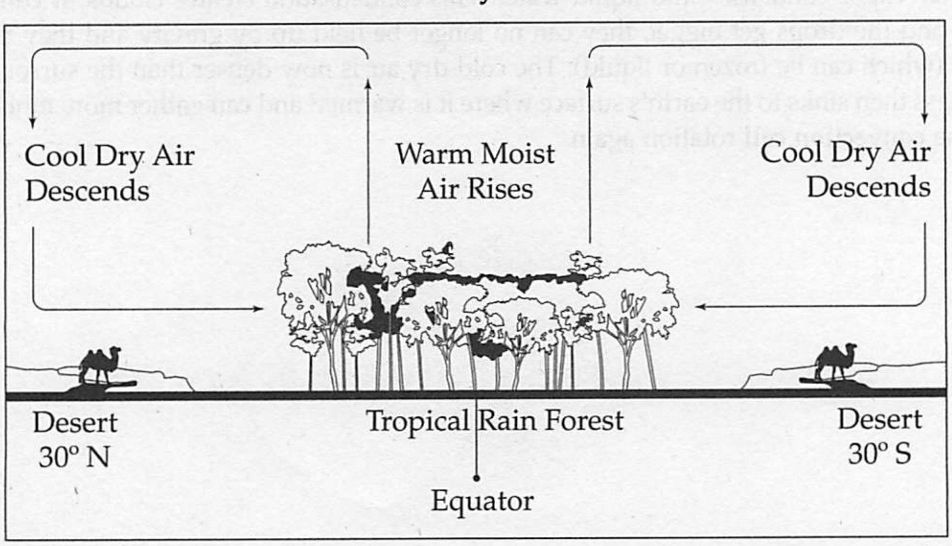
On a local level this phenomena accounts for land and sea breezes. On a global scale these cells are called **Hadley cells**. A large Hadley cell starts its cycle over the equator, where the warm moist air evaporates and rises into the atmosphere. The precipitation in that region is one cause of the abundant equatorial rain forests. The cool dry air then descends about 30 degrees north and south of the equator, forming the belts of deserts seen around the earth at those latitudes.

Hadley Cell



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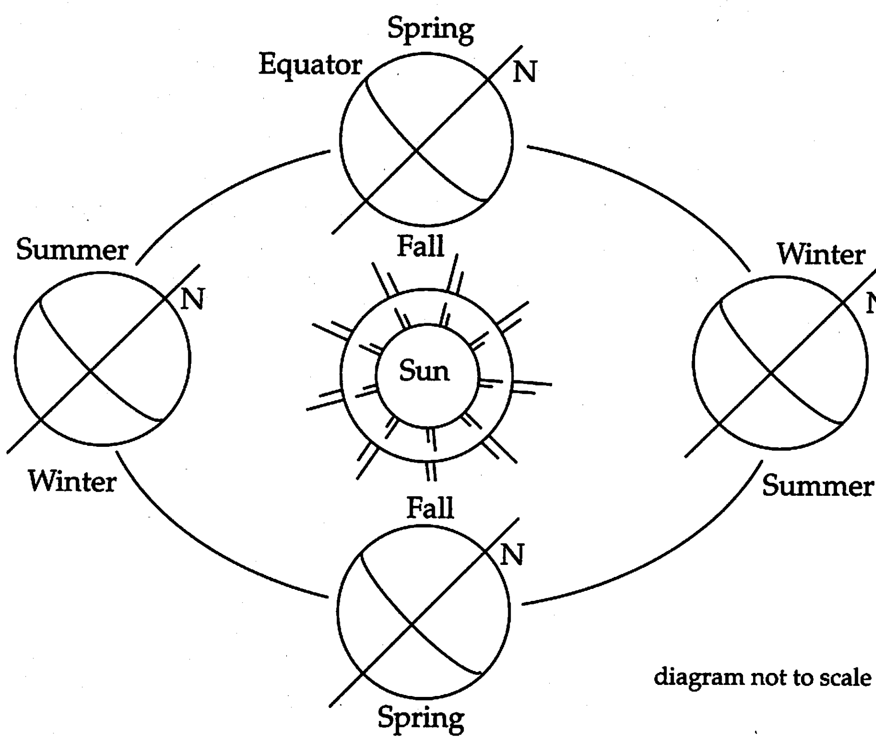
Seasons

The motion of Earth around the sun—and the fact that Earth is tilted on its axis by 23.5 degrees—together create the seasons that we experience on Earth. When Earth is in the part of its orbit in which the Northern Hemisphere is tilted toward the sun, the northern half of the planet receives more direct sunlight for longer periods of time each day than does the Southern Hemisphere. This means that when the Northern Hemisphere is experiencing summer, the Southern Hemisphere is experiencing winter.

Interestingly, because of the earth's tilt, the sun rises and sets just once a year at the North and South Poles. Approximately six months of the year at the poles are daytime, while the other six months are dark, and considered nighttime.

Seasons



Let's move on to discuss wind. You might be thinking, "I know what wind is, so I can skip this section!" Don't skip it! The AP Environmental Science Exam may ask you about the specific types of winds and air movements below—so it's better to be safe than sorry.

Types of Winds

So, what is "wind"? Why does everyone refer to wind when they're discussing weather? Well, the term "wind" is widely used to refer to air currents, and we already know that air currents tend to flow from regions of high pressure to regions of low pressure. But let's review some important details you'll need to know about wind before we move on to our review of the hydrosphere. Formally speaking, **wind** is air that's moving as a result of the unequal heating of the earth's atmosphere. It is part of the Earth's circulatory system, and moves heat, moisture, soil, and even pollution around the planet.

One crucial wind-related phenomenon that you'll need to know about for the AP Environmental Science Exam is trade winds. **Trade winds** were named for their ability to quickly propel trading ships across the ocean. The trade winds that blow between about 30 degrees latitude and the equator are steady and strong, and travel at a speed of about 11 to 13 mph. In the Northern Hemisphere, the trade winds blow from the northeast and are known as the **Northeast Trade Winds;** in the Southern Hemisphere, the winds blow from the southeast and are called the **Southeast Trade Winds.**

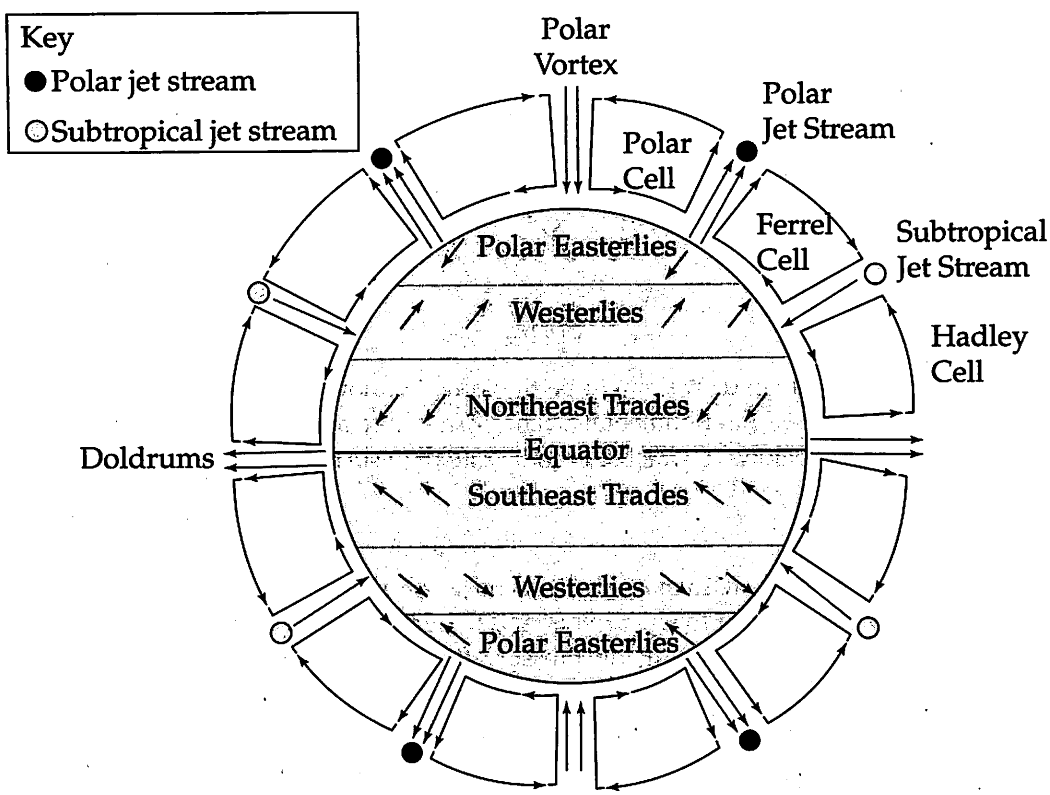
Another important type of moving air mass, called a **westerly,** travels south and west in the Northern Hemisphere and north and west in the Southern Hemisphere near the equator (between 30 degrees and 60 degrees). Westerlies are another result of the Coriolis effect. **Polar easterlies** are formed by similar forces; in polar easterlies, winds between latitudes 60 degrees and the North Pole blow from the north and east, and winds between 60 degrees and the South Pole blow from the south and east.

Between the wind belts mentioned above, air movement is less predictable, and often no wind blows at all for days. For example, between about 30 degrees to 35 degrees north and 30 degrees to 35 degrees south of the equator lies the region known as the **horse latitudes** (or the subtropical high). This region of subsiding dry air and high pressure results in very weak winds. Some people say that sailors gave the region of the subtropical high the name "horse latitudes" because ships relying on wind were unable to sail in these areas—afraid of running out of food and water, sailors threw their horses (and other live cargo) overboard to save on food and water and to make the ship lighter and easier to move.

Similarly, the air near the equator is relatively still because air at these locations is constantly rising, and not blowing. For this reason, early sailors called this region the **doldrums.** The doldrums, which exist between 5 degrees north and 5 degrees south of the equator, are also known as the Intertropical Convergence Zone, or ITCZ for short. The trade winds converge in the region of the ITCZ, producing convectional storms that produce regions with some of the world's heaviest precipitation.

The last type of moving air system that you'll need to be familiar with for the exam is the **jet stream.** Jet streams are high-speed currents of wind that occur in the upper troposphere; these fast-moving air currents have a large influence on local weather patterns.

Winds Around The World

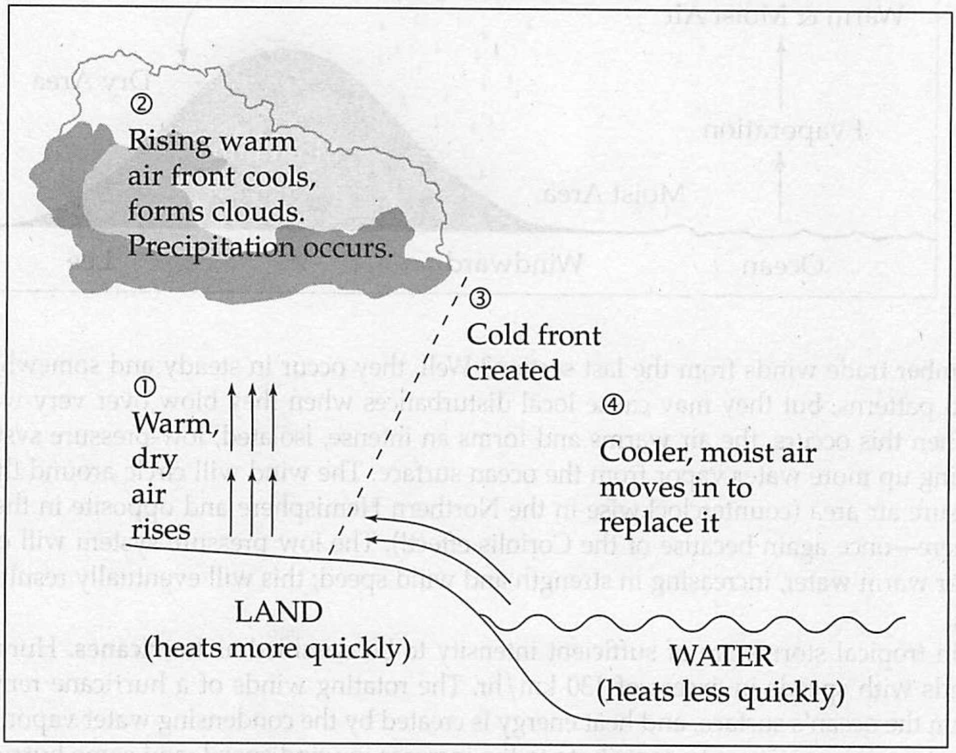


Got it? Let's move on to review the types of weather that result from all of these moving air masses.

WEATHER EVENTS

Let's start by discussing the monsoon. **Monsoons,** which occur primarily in coastal areas, are caused by the fact that land heats up and cools down more quickly than water does. In a monsoon, hot air rises from the heated land, and a low-pressure system is created. The rising air is quickly replaced by cooler moist air that blows in from over the ocean. As this air rises, it cools, and the moisture it carries is released in a steady seasonal rainfall. This process happens in reverse in the dry season, when masses of air that have cooled over the land blow out over the ocean. Check out the illustration below.

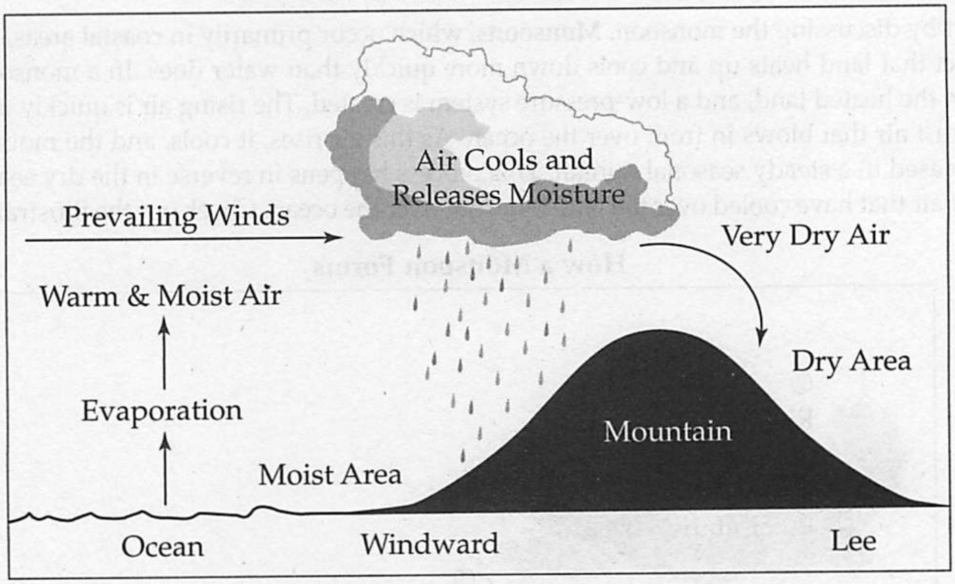
How a Monsoon Forms



On a smaller scale, this effect can be seen on the shores of large lakes or bays. In these areas, again the land warms faster than does the water during the day, so the air mass over the land rises. Air from over the lake moves in to replace it, and this creates a breeze. At night, the reverse happens; the land cools more quickly than the water and the air over the lake rises. The air mass from the land moves out over the lake to replace the rising air, and this creates a breeze as well. If you live in Chicago or San Francisco, you may have experienced this small-scale monsoon effect!

As we mentioned above, the air that moves in from over the ocean or a large body of water contains large amounts of water. If an air mass is forced to climb in altitude—if, for instance, it encounters an obstruction such as a mountain, the air will be forced to rise. When the air mass rises, it will cool and water will precipitate out on the ocean side of the mountain. By the time the air mass reaches the opposite side of the mountain, it will be virtually devoid of moisture. This phenomenon is known as the **rain shadow effect,** and is responsible for the impressive growth of the Olympic rainforest on the Washington State coast. Interestingly, the Olympic rainforest receives up to 5 m of rain per year, while the opposite side (the leeward side) receives less than 50 cm of rain per year.

How The Rainshadow Effect Works



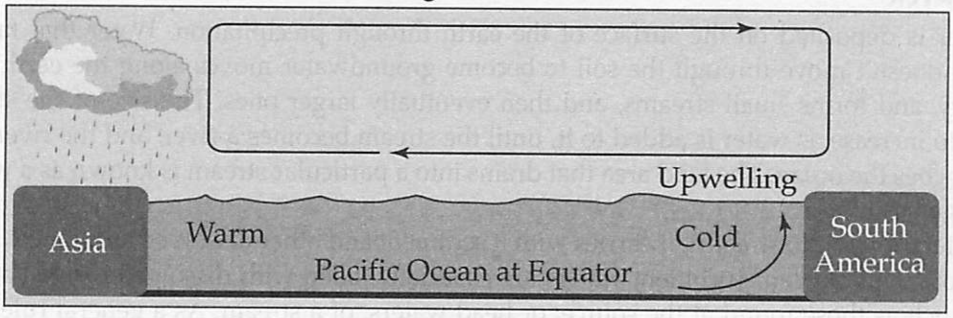
Remember trade winds from the last section? Well, they occur in steady and somewhat predictable wind patterns, but they may cause local disturbances when they blow over very warm ocean water. When this occurs, the air warms and forms an intense, isolated, low-pressure system, while also picking up more water vapor from the ocean surface. The wind will circle around this isolated low-pressure air area (counterclockwise in the Northern Hemisphere and opposite in the Southern Hemisphere—once again because of the Coriolis effect!). The low pressure system will continue to move over warm water, increasing in strength and wind speed; this will eventually result in a tropical storm.

Certain tropical storms are of sufficient intensity to be classified as **hurricanes.** Hurricanes can have winds with speeds in excess of 130 km/hr. The rotating winds of a hurricane remove water vapor from the ocean's surface, and heat energy is created by the condensing water vapor. This addition of heat energy continues to contribute to the increase in wind speed, and some hurricanes have winds traveling at speeds of nearly 400 km per hour! A major hurricane contains more energy than that released during a nuclear explosion, but since the force is released more slowly, the damage is generally less concentrated. Another important note about this type of storm is that they are referred to as hurricanes in the Atlantic Ocean, but they are called **typhoons** or cyclones when they occur in the Pacific Ocean. Go figure!

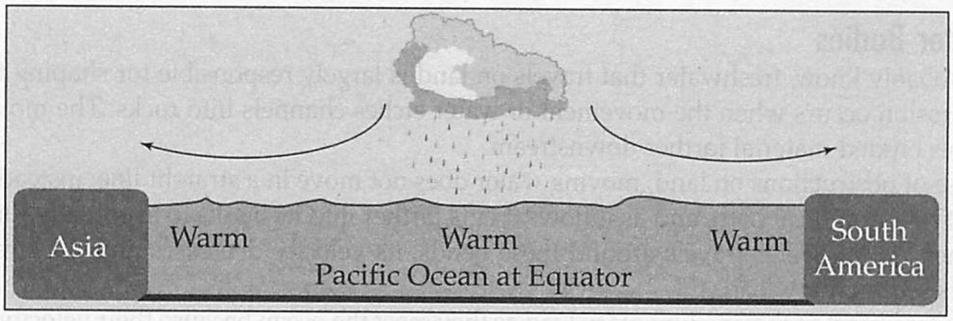
El Niño is a climate variation that takes place in the tropical Pacific once about every three to seven years, and it lasts for about one year. Under normal weather conditions, trade winds move the warm surface waters of the Pacific away from the west coast of Central and South America. As a result, the cold ocean water that lies under the displaced water moves to the surface (causing the thermocline to rise), bringing nutrients with it and keeping the temperature of the coastal water relatively cool.

During El Niño, the normal trade winds are weakened or reversed because of a reversal of the high and low pressure regions on either side of the tropical Pacific. This reversal of pressure systems is known as the **Southern Oscillation.** Without these regular trade winds off the Central and South American coast, the process of upwelling slows or stops, and the water off the coast becomes warmer and contains fewer nutrients. This means that during El Niño, the northern United States and Canada experience warmer winters and a less intense hurricane season; the eastern United States and regions of Peru and Ecuador that are typically dry have higher-than-average rainfall; and the Philippines, Indonesia, and Australia are drier than normal.

Differing Wind Patterns



Normal Conditions



El Niño Conditions

One environmentally important effect that El Niño has on humans is that, because of the suppression of upwelling, the offshore fish populations of certain coastal areas decline. In countries like Peru, which relies heavily on fishing, El Niño has devastating economic effects.

The reverse of El Niño is known as **La Niña.** During La Niña, the surface waters of the ocean surrounding Central and South America are colder than normal. Finally, the alternation of atmospheric conditions that lead to El Niños or La Niñas is referred to as **ENSO** events. (This stands for El Niño and Southern Oscillation.)

Now let's move on to a subject we've already touched upon—the hydrosphere. Remember, go back to your textbook for more information on any topics with which you don't feel totally comfortable.

THE HYDROSPHERE

Water covers about 75 percent of planet Earth. Most of the water on Earth's surface is salt water. On average, the salt water in the world's oceans has a salinity of about 3.5 percent. This means that for every 1 liter (1,000 ml) of sea water, there are 35 grams of salts (mostly, but not entirely, sodium chloride) dissolved in it. In fact, one cubic foot of seawater would evaporate to leave about 1 kg of sea salt! However, **sea water** is not uniformly saline throughout the world. The planet's freshest sea water is in the Gulf of Finland, part of the Baltic Sea. The most saline open sea is the Red Sea, where high temperatures and confined circulation result in high rates of surface evaporation.

Freshwater is water that contains only minimal quantities of dissolved salts, especially sodium chloride. All freshwater ultimately comes from precipitation of atmospheric water vapor, which reaches inland lakes, rivers, and groundwater bodies directly, or after melting of snow or ice. Let's start with a discussion of freshwater before discussing the world's oceans. We will end this section with a review of the ways in which humans use water, global problems associated with water usage, and issues of water conservation.

FRESHWATER

Freshwater is deposited on the surface of the earth through precipitation. Water that falls on the earth and doesn't move through the soil to become groundwater moves along the earth's surface, via gravity, and forms small streams, and then eventually larger ones. The size of the stream will continue to increase as water is added to it, until the stream becomes a river, and the river will flow until it reaches the ocean. The land area that drains into a particular stream is known as a **watershed,** or drainage basin.

As water moves into streams, it carries with it sediment and other dissolved substances, including small amounts of oxygen. Turbulent waters are especially laden with dissolved oxygen and carbon dioxide, such as those found at the source, or head waters, of a stream. As a general rule, the more turbulent the water, the more dissolved gases it will contain.

Freshwater Bodies

As you probably know, freshwater that travels on land is largely responsible for shaping the earth's surface. Erosion occurs when the movement of water etches channels into rocks. The moving water then carries eroded material farther downstream.

Because of obstructions on land, moving water does not move in a straight line; instead it follows the lowest topographical path, and as it flows it cuts farther into its banks to eventually form a curving channel. As the water travels around these bends, its velocity decreases and the stream drops some of its sedimentary load.

Rivers drop most of their sedimentary load as they meet the ocean because their velocity decreases significantly at this juncture. At these locations, landforms called **deltas** (which are made of deposited sediments) are created. Another important freshwater body that you should know about is the estuary. **Estuaries** are sites where the "arm" of the sea extends inland to meet the mouth of a river. Estuaries are often rich with many different types of plant and animals species, because the freshwater in these areas usually has a high concentration of nutrients and sediments. The waters in estuaries are usually quite shallow, which means that the water is fairly warm and that plants and animals in these locations can receive significant amounts of sunlight. Some subcategories of estuarine environments that you should know for the exam are salt water marshes, mangrove forests, inlets, bays, and river mouths.

Some of Earth's most important ecologically diverse ecosystems are the areas along the shores of fresh bodies of water known as **wetlands.** Types of wetlands include marshes, swamps, bogs, prairie potholes (which exist seasonally), and flood plains (which occur when excess water flows out of the banks of a river and into a flat valley). So, those are the main types of freshwater bodies you'll need to know. Let's review the stratification of freshwater bodies, get through oceans, and move on to the fun stuff—the impacts of water use on humans.

Vertical Stratification in Freshwater Biomes

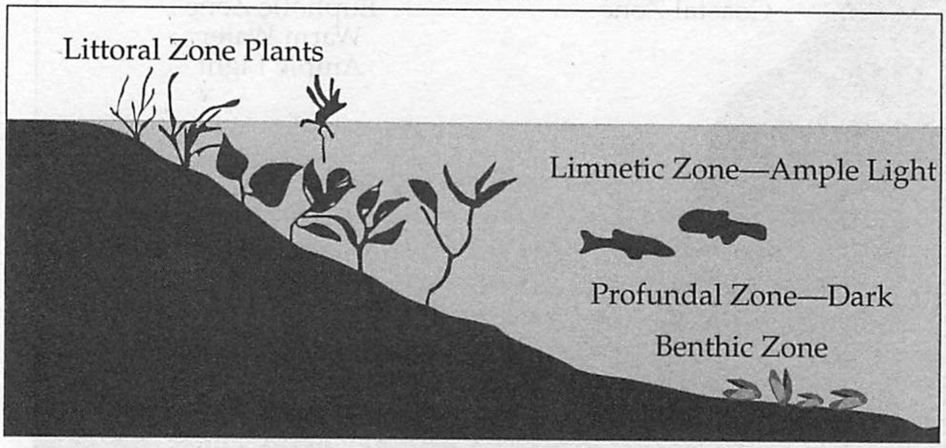
In all natural bodies of water, there exist layers of water that vary significantly in their temperature, oxygen content, and nutrient levels. These layers are affected differently by seasonal changes and other disturbances, and this also contributes to how they are categorized.

In freshwater, the layers are the **epilimnion**, which is the uppermost, and thus the most oxygenated, layer; and the **hypolimnion,** which is the lower, colder, and denser layer. The demarcation line between these two layers, at which the temperature shifts dramatically, is the **thermocline.**

These layers are also often delineated based on the types of organisms that can live in them. You should definitely be familiar with the following terms for the AP Environmental Science test, so take note!

- **Littoral zone:** Begins with the very shallow water at the shoreline. Plants and animals that reside in the littoral zone receive abundant sunlight. The end of this zone is defined as the depth at which rooted plants stop growing.
- **Limnetic zone:** Surface of open water; the region that extends to the depth that sunlight can penetrate. Organisms that are residents in this zone are short-lived and rely on sunlight to carry out photosynthesis.
- **Profundal zone:** Water that is too deep for sunlight to penetrate. Because the profundal zone is an **aphotic** zone (a zone that light cannot reach), photosynthesizing plants or animals cannot live in this region.
- **Benthic zone:** The deepest layer in a body of water; characterized by very low temperatures and low oxygen levels.

Freshwater Lake Zones



The World's Oceans

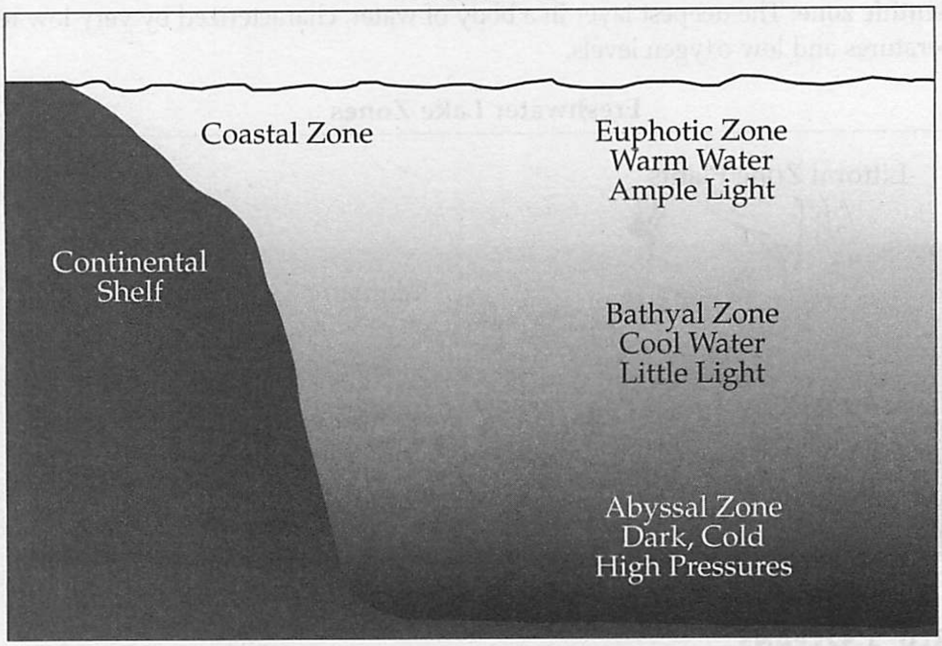
Before we get into our review of the world's oceans, let's consider another aquatic ecosystem (besides wetlands and estuaries) that's an important source of biodiversity; this one is a saltwater ecosystem. Certain landforms that lie off coastal shores are known as **barrier islands.** Because barrier islands are created by the buildup of deposited sediments, their boundaries are constantly shifting as water moves around them. These spits of land are generally the first hit by offshore storms, and they are important buffers for the shoreline behind them.

In tropical waters, a very particular type of barrier island called a **coral reef** is quite common. These barrier islands are formed not from the deposition of sediments, but from a community of living things. The organisms responsible for the creation of coral reefs are cnidarians that secrete a hard, calciferous shell; these shells provide homes and shelter for an incredible diversity of species, but they are also extremely delicate and thus very vulnerable to physical stresses, changes in light intensity, and changes in water temperature.

Like freshwater bodies, oceans are divided into zones based on changes in light and temperature. They're listed below, and again, know them cold for the test!

- **Coastal zone**: This zone consists of the ocean water closest to land. Usually it is defined as being between the shore and the end of the continental shelf.
- **Euphotic zone:** The photic, upper layers of water. The euphotic zone is the warmest region of ocean water; this zone also has the highest levels of dissolved oxygen.
- **Bathyal zone:** The middle region; this zone receives insufficient light for photosynthesis and is colder than the euphotic zone.
- **Abyssal zone:** This is the deepest region of the ocean. This zone is marked by extremely cold temperatures and very low levels of dissolved oxygen, but very high levels of nutrients because of the decaying plant and animal matter that sinks down from the zones above.

Ocean Zones



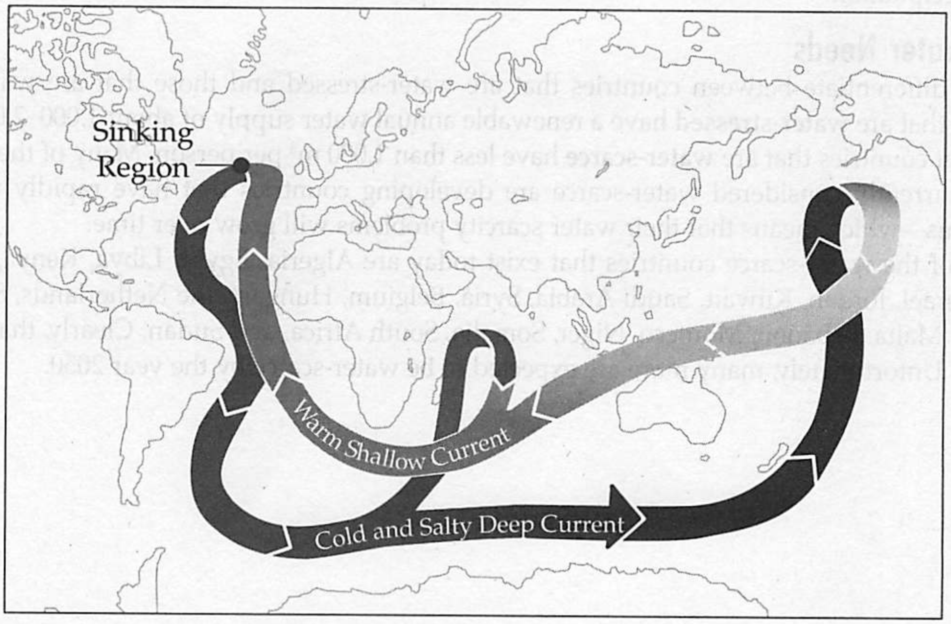
Both freshwater and saltwater bodies experience a seasonal movement of water from the cold and nutrient-rich bottom to the surface. These **upwellings** provide a new nutrient supply for the growth of living organisms in the photic regions. Therefore, they are followed by an almost immediate exponential growth in the population of organisms in these zones, especially the single cell algae, which may form blooms of color called algal blooms. These algae can also produce toxins that may kill fish and poison the beds of filter feeders, such as oysters and mussels. One notorious recurring toxic algal bloom is referred to as **red tide;** this is caused by a proliferation of dinoflagellates.

Ocean Currents

Ocean currents play a major role in modifying conditions around the earth that can affect where certain climates are located. As the sun warms water in the equatorial regions of the globe, prevailing winds, differences in salinity (saltiness), and Earth's rotation set ocean water in motion. For example, in the Northern Hemisphere, the Gulf Stream carries sun-warmed water along the east coast of the Unites States and as far as Great Britain. This warm water displaces the colder, denser water in the polar regions, which can move south to be re-warmed by the equatorial sun. Northern Europe is kept 5 to 10°C warmer than it would be were the current not present.

Oceanographers also study a major current, the "ocean conveyer belt" that moves cold water in the depths of the Pacific Ocean while creating major upwellings in other areas of the Pacific.

Ocean Circulation



WATER, WATER, EVERYWHERE...OR NOT?

As you know, we all need water in order to live. In particular, communities need water for many different industries, including fisheries, recreation, transportation, and agriculture. Agriculture is one of the biggest water-users of all—about 73 percent of the global demand for water is for crop irrigation. Industry accounts for about 21 percent of all water use, and domestic use accounts for about 6 percent.

Since the 1950s, global water use has tripled—mostly due to population growth and improvements in the global standard of living. One way that humans have recently dealt with potential water shortages in communities is through **interbasin transfer**. During interbasin transfer, water is transported very long distances from its source, through aqueducts or pipelines. An example of this type of engineering is the pipeline that now exists between the western and eastern slopes of the Rocky Mountains in Colorado. Known as the Big Thompson Project, 213,000 acre feet of water are delivered annually to the eastern slope of Colorado. However, this method has several negative effects. It can result in different geographic areas arguing over water rights. It can also have serious environmental repercussions; interbasin transfer can increase the salinity of the water and even change the climate of an ecosystem.

In North America especially, humans rely on groundwater as a primary source of water for everyday use. **Groundwater** refers to any water that comes from below the ground; that is, from wells or **aquifers,** which are underground beds or layers of earth, gravel, or porous stone that yield water. Water found in an **unconfined aquifer** is free to flow both vertically and horizontally. A **confined aquifer,** however, has boundaries that don't readily transport water. Our reliance on and use of groundwater has several detrimental environmental effects; for example, it can result in a depressed water table and the drying up of local groundwater sources. In the late 1990s, a drought in Florida resulted in such a severe reduction in the aquifers that roads collapsed for lack of structural support.

Additionally, aquifers can become compacted—meaning that the mineral grains collapse on each other and the area is unable to hold as much water.; and in some urban areas, humans have rendered the groundwater incapable of being replenished by building structures and roads that are impermeable to precipitation.

Global Water Needs

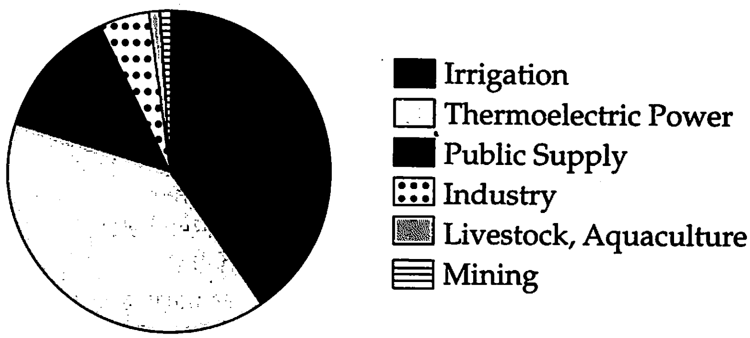
Scientists differentiate between countries that are water-stressed and those that are water-scarce. Countries that are **water-stressed** have a renewable annual water supply of about 1,000–2,000 m^3 per person, but countries that are **water-scarce** have less than 1,000 m^3 per person. Many of the countries that are currently considered water-scarce are developing countries that have rapidly increasing populations—which means that their water scarcity problems will grow over time.

Some of the water-scarce countries that exist today are Algeria, Egypt, Libya, Kenya, Rwanda, Tunisia, Israel, Jordan, Kuwait, Saudi Arabia, Syria, Belgium, Hungary, the Netherlands, Singapore, Barbados, Malta, Lebanon, Morocco, Niger, Somalia, South Africa, and Sudan. Clearly, that's a lot of countries. Unfortunately, many more are expected to be water-scarce by the year 2050.

Water Use in the United States

The United States is not considered water-scarce, but certain regions of the United States are considered water-stressed. Additionally, water use in the United States is out of control—we use water more quickly than it can possibly be replenished, so water scarcity is definitely in our future if we continue to use water at our present, furious rate.

The hydrologic cycle supplies the water that we use for all of our activities. Water used in our home; manufacturing; cooling equipment that generates electricity; and irrigating croplands are a few examples. The following chart shows the use of freshwater in the United States in 2000, the latest year of available data.



Use	Percentage
Irrigation	40%
Thermoelectric Power	39%
Public Supply	13%
Industry	5%
Livestock, Aquaculture	1%
Mining	1%

What Are We Doing About It?

Water is a tricky business; it's difficult for politicians and lawmakers to put restrictions on water use because many people think that water should be free—after all, it falls from the sky; we can take a bucket from the lake down the street and no one will arrest us for stealing.

For the AP Environmental Science Exam, you should know about certain concepts of human water rights. The first is the idea of riparian right. "Riparian" means "of, on, or relating to the banks of a natural course of water," and **riparian right** is the right of people who have legal rights to a riparian area; to use that area. Alternately, in **prior appropriation,** water rights are given to those who have historically used the water in a certain area. In other words, prior appropriation can be thought of as water squatters' rights!

It has been proposed that, in order to solve current global water crises, we simply take the tons of ocean water and desalinate it—this is a fairly simple process chemically, but unfortunately it isn't economically viable, because it takes a great deal of energy to remove the salt. As water becomes scarcer globally, it will be important for countries to think of ways to regulate the use of water.

That's everything you'll be expected to know for the exam about water, and you're done with your study of Earth's interdependent systems! Do the questions in the drill below and move on to the next chapter.

KEY TERMS

Use this list to review the key terms in this chapter. Keep these terms in mind when you are brainstorming hot buttons for your essays!

Lithosphere
- geologic time scale
- core
- mantle
- asthenosphere
- lithosphere
- crust
- continental plates
- plate boundaries: convergent, divergent, transform
- volcano
- earthquake
- subduction
- tsunami
- rock cycle
- sedimentary
- metamorphic
- igneous

Soil
- abiotic, biotic
- clay, silt, sand
- acidity, alkalinity
- humus
- leaching
- illuviation
- arable
- loamy
- salinization
- land degradation
- drip irrigation

Atmosphere
- troposphere
- greenhouse effect
- stratosphere
- weather
- climate
- prevailing winds
- Coriolis effect
- convection currents
- horizontal airflow
- dew point
- precipitation
- convection cell
- Hadley cell
- trade winds
- jet stream
- monsoon
- rain shadow effect
- typhoon
- El Niño
- La Niña
- ENSO events

Hydrosphere
- watershed
- delta
- estuary
- wetland
- epilimnion
- hypolimnion
- thermocline
- freshwater zones: littoral, limnetic, benthic
- barrier island
- saltwater zones: euphotic, bathyal, abyssal
- upwelling
- red tide
- interbasin transfer
- groundwater
- aquifer
- unconfined aquifer
- confined aquifer
- water-stressed, water-scarce
- riparian
- prior appropriation

CHAPTER 3 QUIZ

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

1. A seismograph active area encircling the Pacific Ocean is commonly known as the

   (A) Intercoastal region
   (B) Estuary
   (C) Ring of Fire
   (D) Tectonic plate region
   (E) Subduction zone

2. The aurora borealis occurs in which of the following parts of the atmosphere?

   (A) Troposphere
   (B) Thermosphere
   (C) Mesosphere
   (D) Hydrosphere
   (E) Stratosphere

3. Which of the following are the two most important factors in determining a habitat's climate?

   (A) Temperature and wind speed
   (B) Wind direction and precipitation
   (C) Wind speed and rate of evaporation
   (D) Rate of evaporation and temperature
   (E) Temperature and precipitation

4. The atmosphere is warmed as gases such as water vapor and carbon dioxide absorb the infrared heat radiated from the earth. This process is best described as

   (A) ozone depletion
   (B) the greenhouse effect
   (C) biomagnification
   (D) ionization
   (E) convection

5. The hydrosphere includes all of the following EXCEPT

   (A) watershed
   (B) wetlands
   (C) parent rock
   (D) rivers
   (E) lakes

6. An area where there are cold waters, low oxygen levels, and bottom-dwelling fish. This description best fits the

(A) benthic zone
(B) littoral zone
(C) limnetic zone
(D) open water zone
(E) profundal zone

7. The amount of the earth's surface that is covered by water is approximately

(A) 12 percent
(B) 36 percent
(C) 50 percent
(D) 75 percent
(E) 93 percent

8. An area where salt and freshwater mix that has a very high level of productivity is correctly called

(A) the open ocean
(B) the abyssal zone
(C) the headwaters
(D) an estuary
(E) the littoral zone

9. Which of the following correctly describes the waters in an upwelling area?

(A) Cold and nutrient rich
(B) Warm and nutrient poor
(C) Cold and nutrient poor
(D) Heavily polluted by human waste
(E) Shallow and full of light

10. Which of the following best describes an unconfined aquifer? It is an area where

(A) water always comes to the surface
(B) water is free to flow in all directions
(C) water is held in place by impenetrable rocks
(D) pollutants enter the aquifer
(E) an aquifer's discharge area is located

11. Which of the following organisms is not likely to be found as a member of the detritus food web?

(A) Ants
(B) Earthworms
(C) Fungi
(D) Deer
(E) Bacteria

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each question or best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 12-16 deal with the atmosphere.

(A) atmosphere
(B) troposphere
(C) wind
(D) convection currents
(E) stratosphere

12. Ozone in this layer blocks UV light from the sun.

13. The location of our daily weather

14. The vertical heating and cooling of air

15. The movement of air between masses with different pressures

16. The collection of all gases held to the earth by gravity

Free-Response Question

1. Scientists designed an experiment to learn about the functioning of the hydrologic cycle and the phosphorus cycle in a forest. Using two areas of the same size and geologic features, they cut all the trees down from one plot and did not disturb the other plot. They were able to accurately measure the amount of water that flowed out of the two plots as well as measure the amounts of phosphorus found in the runoff.

   (a) Describe what the differences would be in the volume of water running off the two plots and give one reason why. Assume that the two areas received the same amounts of precipitation.

   (b) Describe the differences in the levels of phosphorus found in the runoff of the two plots. Assume that both plots started off with the same amount of phosphorus in the soil.

   (c) Describe one negative effect that might occur in a stream that receives the runoff water and sediment.

   (d) When a tropical rain forest is cut down and used as farmland, the fertility of the soil only lasts a few years. Give an explanation as to why there is little organic matter in rain forest soil and what would happen to that material after deforestation.

ANSWERS AND EXPLANATIONS

Multiple-Choice Answers

1. **C** This refers to the area of plate boundary interactions that occur along the outer area of the Pacific Ocean.

2. **B** The aurora borealis occurs in the thermosphere, or ionosphere. This is the highest level of the atmosphere, extending 60 miles and higher. The aurora borealis is caused by electrons from the Sun striking oxygen atoms in the thermosphere.

3. **E** Climate is the 30-year average of temperature and precipitation in a certain area, and the temperature and precipitation of a region are the most important factors in determining the rate of plant growth. Finally, since the amount of plant matter determines the amount of animal life, the communities found in a particular habitat are directly related to its temperature and precipitation.

4. **B** As the sun's light passes through the atmosphere, it strikes the solid Earth. The earth, with its soil, water, buildings, asphalt, and concrete, absorbs this radiant energy. This energy is then radiated back into the atmosphere as infrared radiation. This radiation can be reflected back into the atmosphere (the greenhouse effect) or it can pass back into space.

5. **C** All of the answer choices listed are parts of the hydrosphere except for choice (C), parent rock.

6. **A** Lakes are divided into various zones depending on light and temperature. The littoral zone is where rooted plants live, while the limnetic zone is open, sunlit water that's generally warm. The profundal zone is the deep open water where no photosynthesis occurs and the benthic zone is the cold, dark zone at the bottom. Only organisms that can tolerate cold and low oxygen levels can live in the benthic zone.

7. **D** Approximately 75 percent of the Earth's surface is covered by water; this includes both saltwater and freshwater.

8. **D** An area where saltwater and freshwater mix that has a very high level of productivity is correctly called an estuary. Estuaries are sites where the "arm" of the sea extends inland to meet the mouth of a river. Estuaries are often rich with many different types of plant and animal species, because the fresh water in these areas usually has a high concentration of nutrients and sediments.

9. **A** Both freshwater and saltwater bodies experience a seasonal movement of water from the cold and nutrient-rich bottom to the surface; this is called an upwelling. Upwellings are composed of cold, nutrient-rich waters.

10. **B** Unconfined aquifers are ones where water is free to move vertically or horizontally through an area.

11. **D** Deer are herbivores feeding on plants, not members of the decay food web found in the soil.

12. **E** Ozone in the atmosphere is contained in the stratosphere.

13. **B** Most of our weather patterns occur in the troposphere.

14. **D** Convection currents are the vertical heating and cooling of air masses.

15. **C** Wind is the movement of air between masses with different pressures.

16. **A** The atmosphere can be defined as the collection of all gases held to the Earth by gravity.

Free-Response Answer

1. First of all, you might need some information from Chapter 4 to answer this question. However, this will give you an opportunity to see how prepared you are for this exam, before you review all of the major topics you'll need to know. How did your answer compare to the one below?

(a) The runoff volume would be much greater in the clear-cut plot than the forested plot. In the forested area the trees help hold water in the soil. Also, the leaves slow down the speed of the raindrops, making them have less of an impact on the soil. The roots also help bind the soil and hold it in place, so there is no erosion. In the cut area the water stays closer to the surface, so there is more water for runoff. The rain can fall onto the soil with full force and erosion can take place. The soil is not held together and the particles have a greater likelihood of moving. *(2 points maximum—1 for the correct answer and 1 point for a correct explanation)*

(b) The phosphate levels would be much higher in the runoff from the cut plot. The phosphate would be leached out of the soil in the clear-cut plot because of all the water running off the soil. Another explanation would be that the trees absorb most of the phosphorus out of the soil. There would be less phosphate in the soil of the forested land, so the runoff would contain less.
(2 points maximum—1 for the correct answer and 1 point for a correct explanation)

(c) There are several possible negative effects. First, the added nutrients could cause an algal bloom in the stream. The bloom might make the stream less habitable for fish or insect larvae. As the algae decompose, the amount of dissolved oxygen would go down. The sediment might increase the water's turbidity, making it cloudier, and thus lowering the ability of producers to live in the stream. Also, the increased water volume might cause more erosion, or possibly flooding farther downstream. Finally, the lack of shade would increase the water's temperature. This increase would lower the dissolved oxygen (DO) levels.
(2 points maximum—1 for the correct answer and 1 point for a correct explanation)

(d) Because of the very rapid rate of decay and high metabolism of the living plants, there is little organic material in rain forest soil. Anything that falls to the forest floor is quickly decomposed, and the remains are rapidly absorbed by plants. When the forest is cut down, this soil is directly exposed to the large amounts of rain that falls in these forests. The rain quickly washes away the remaining organic matter, leaving even fewer nutrients in the soil.
(4 points maximum—2 for the correct explanation of why there are few nutrients and 2 for the correct explanation of the rapid loss of the remaining nutrients)