Understanding and Teaching Earth and Space Sciences

Consider the following statements about Earth and space sciences:

W
We learn geology the morning after the earthquake.
—Ralph Waldo Emerson

T
The primary role of the geologist is to recognize the existence of phenomena before trying to explain them.
—B.M. Keilhau, 1828

F
Finally we shall place the Sun himself at the center of the Universe. All this is suggested by the system of procession of events and the harmony of the whole Universe, if only we face the facts, as they say, ‘with eyes wide open.’
—Nicolas Copernicus

T
Telescopes are in some ways like time machines. They reveal galaxies so far away that their light has taken billions of years to reach us. We in astronomy have an advantage in studying the universe, in that we can actually see the past.
—Sir Martin Rees, Astronomer Royal of Great Britain
With every passing hour our solar system comes forty-three thousand miles closer to globular cluster 13 in the constellation Hercules, and still there are some misfits who continue to insist that there is no such thing as progress.

—Ransom K. Ferm

The Place of Earth and Space Science in Science Education

When the Apollo 11 astronauts landed on the moon in 1969, they were able to gain a new perspective on the Earth—the metaphor of a blue marble hanging in space. Humankind’s limited forays beyond our biosphere have highlighted how we are suspended in a great void, a sphere hurtling through a mostly empty universe, a world both fragile and resilient.

The Earth and space sciences bring together aspects of each of the other science disciplines that will be discussed in this text. Like physics, the historical roots of the Earth sciences are grounded in attempts to understand the physical forms at work in our lives. The Earth sciences, however, did not generally have the prominence of the other sciences in the Renaissance and early modern period when physics, chemistry, and biology were flourishing. It was not until the eighteenth century that the beginnings of a modern field of geology began to develop with the work of men such as James Hutton (1726–1797) and Charles Lyell (1797–1875). During this time, the first attempts were made to explain the sources of materials such as fossils that were found in different geological formations.

The need to better understand the Earth came to be associated with the conquest and empire building of the great colonial powers. These European powers went to different regions of the world to gather natural resources such as diamonds in Africa, tin in Argentina, and silver and gold in Mexico. More recently, in the 20th century, the exploitation of oil and natural gas led to an increased interest in better understanding certain aspects of Earth science and the processes that led to the creation of these resources. While Earth science continues to play a central role in the quest for natural resources, Earth scientists today are also involved in a wide range of research to better understand the varied processes that shape the Earth.

In the first chapter of this book, we talked about the work of anthropologist Gregory Bateson. Bateson believed the ultimate goal of any researcher, whether astronomer or anthropologist, should be to observe and understand the pattern that connects. Implicit in understanding the idea of patterns in the Earth and space sciences is the realization that our planet Earth functions as a system. This means that nothing operates in a void, but instead, the existence of one condition or phenomenon in a geographic,
oceanographic, or atmospheric system is shaped by other connected phenomena. Thus, taking the example of a hurricane, the forces that determine its strength and path are the results of a complex set of factors that come together to create a weather system (see Image 6.1).

Scientists who study the various systems on our dynamic planet have begun to learn how these systems work and how they interact. Some of the most important Earth systems that make up the whole are

- **Biosphere**—all of Earth’s living organisms
- **Atmosphere**—Earth’s relatively thin covering of gases
- **Lithosphere**—Earth’s surface and interior
- **Hydrosphere**—Earth’s circulating water systems
- **Energy system**—the energy that powers all Earth’s systems

As the human population of our planet continues to grow (there are currently more than six billion people living on Earth), humans are having a growing impact on each of these Earth systems. Our technologies and practices have the potential to dramatically change systems such as the Earth’s climate, atmosphere, and the numbers and kinds of other living organisms. This ability to change the way our planet works presents both dangers and opportunities. In this chapter, we will examine the extraordinary
Measuring and Estimating in Earth and Space Science

In the Earth and space sciences, objects need to be understood and considered on the local, the global, and sometimes even on the interplanetary scale. The ability to understand concepts of distance, time, and scale that range from the minute to the nearly infinite is essential to understanding many of the ideas in this discipline. Thus, measurement is a logical place to begin our experiments in the Earth and space sciences.

Estimating Large Numbers of Objects

Imagine that you were given the task of determining how many grains of sand were in a sandbox. How would you go about determining what that number might be? You certainly couldn’t count every grain. A sandbox five inches deep and four feet by four feet in area might very well have several billion grains of sand. If we want to find out the number of grains, we need a system of estimating. We would probably do this by determining the total volume of sand, to get a total number of cubic inches, and then we would have to figure out how many grains of sand are in one cubic inch. Even counting the grains in one cubic inch might be tedious, so we might measure out a quarter of a cubic inch and then do the math to estimate the total number of grains of sand.

Earth scientists frequently need to estimate large numbers of objects. Whether studying changes in plant coverage from satellite photographs, crystals in a mineral sample, or bone fragments in a fossil bed, accurate estimating is an important skill for a student of the Earth sciences. The following investigation will help you improve your skill at estimating large numbers of objects. (See Experiment 1.)

Determining Direction Using a Compass

The compass is arguably one of the most important inventions in human history. Prior to its introduction, people had to determine direction by the position of the Sun and stars. This was impossible to do during overcast weather and in parts of the world where the Sun is not visible for days on end. Such environmental conditions could make navigation quite challenging. The first compasses were used in China during the fourth century B.C. Compasses work because of the magnetic field caused by the rotation of the Earth, which can be detected using a metal needle free to pivot around a central point. While extremely simple in its operation, the compass’s importance cannot be overemphasized. (See Experiment 2.)
Experiment 1: Estimating the Number of Books in Your School Library

In this activity, you will estimate the number of books in your school library.

Materials You Will Need for This Activity
- Access to your school library

What You Will Do
1. Look around the library and make an initial estimate of how many books you think there are. Write this number down. How can we improve the accuracy of our estimation? (Hint: One way is to break the estimate into pieces.)
2. Now focus on one bookshelf on just one bookcase. Estimate how many books are on that one shelf.
3. Count the books on that one shelf. How close was your estimate?
4. Estimate and then count the books on a second shelf of the same bookcase. Was your estimate more accurate the second time? Were there the same number of books on each shelf?
5. Now that you know about how many books are on each shelf, you need to estimate how many shelves are in the library.
6. Estimate how many shelves are on the typical bookcase in the library.
7. Next, count or estimate the total number of bookcases in the library.
8. Multiply the number of bookcases by the number of shelves per bookcase by the number of books per shelf to get your estimate of the total number of books in the library.
9. Ask the librarian whether he or she knows the actual number of books. How accurate was your estimate?

What you will learn: Estimating complex problems can be improved by breaking the estimate down into smaller pieces.

Core concept demonstrated: Estimation of large numbers of objects

Thinking like a scientist: When geologists or archaeologists are studying a fossil site, one of the first things they usually do is to mark out a grid of intersecting lines across the site. Why do you think they do this?

Correlation With National Science Standards: A.1; G.3

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Experiment 2: Orienteering

In the following activity, you will use a compass to practice accurately finding directions.

Materials You Will Need for This Activity

- A large open field
- A coin
- An orienteering compass (one with degrees as well as cardinal directions)

What You Will Do

1. Place a coin on the ground at your feet.
2. Set the compass to 60° and turn your body to face that bearing.
3. Walk forward 10 paces as straight as you can along this bearing and stop. It is important to keep your paces as regular in size as possible.
4. Add 120° to your current bearing. Your compass should now read 180° on the dial. Turn your body to face this new bearing and walk another 10 paces in the new direction. Stop.
5. Add an additional 120° to your last bearing so that the compass dial now reads 300°. Again, walk 10 paces along this new bearing.
6. You should have walked in a triangle and if you have been extremely accurate, your coin should be at your feet. Is it?
7. If you are not close to the coin, try again, focusing on keeping your paces as regular as possible and your line straight along the compass bearings.

What you will learn: Accurate measurement of distance and direction will allow you to navigate back to your starting point.

Core concept demonstrated: Determining direction with a compass

Thinking like a scientist: How can a compass help you find your way if you are hiking in the woods or sailing on a boat? Read about modern global positioning systems (GPS). How is GPS similar to a compass? How is it different?

Correlation With National Science Standards: A.1; E.2; F.5; G.1

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Measuring Deep Time: How Old Is the Earth?

The history of the Earth (known as geologic time) is much longer than human history. Geological events take place over millions or even billions of years, whereas human history is much shorter. Humans have existed for between one and two million years. Modern human history dates back only three or four thousand years. Compare this to the history of the Earth, which was created between five and six billion years ago. Thus, the Earth has existed approximately four to five thousand times longer than humans have existed. If one compares Earth’s history to modern human history (say, 5,000 years), the Earth has existed approximately one million times longer. This idea can be quite difficult for children (and even adults) to grasp. (See Experiment 3.)

The Cosmos: The Sun, Planets, Solar System, Stars, and Beyond

The planet Earth is a remarkably fragile spaceship making its way through the vast universe. Understanding the scale of solar and interstellar distances is essential to comprehending the place of the Earth in a remarkable and seemingly infinitely large universe. At the scale of our solar system, the radiant power of the Sun and its influence on all living things on Earth is equally remarkable.

Scale of the Solar System

As we saw in Experiment 3, one of the ways we can understand the size of extremely large things is by using a scale. For example, visualizing the distance from the Earth to the Sun—93,000,000 miles—is pretty difficult. But if you were to take the distance to the Sun and divide it by the circumference of the Earth (93,000,000/24,000 = 3,875), you could begin to imagine how far away the Sun is. Thus, to travel to the Sun would be the equivalent of going around the Earth nearly 4,000 times.

The distance from the Sun to Jupiter is 484,000,000 miles, equivalent to approximately 20,000 trips around the Earth. In Experiment 4, we establish a scale for measuring distances in the solar system that will help you grasp the relative distances of the planets from the Sun and from one another. (See Experiment 4.)

The Expanding Universe

Cosmology is the search for origins and answers to questions such as how the universe began. One such explanation is the Big Bang theory that has resulted from several important observations. In 1927, Edwin Hubble first observed that light from distant galaxies is “red shifted”; that is, it appears to be more red than it should be. Red shift occurs when the object you are observing is
**Experiment 3: Geologic Time on a Football Field**

In the following activity, you will explore the age of the Earth and significant events in Earth’s history using a football field time line.

### Materials You Will Need for This Activity
- Football field with the yard lines marked
- Paper and markers

### What You Will Do

1. Go out to a football field.
2. Imagine that the goal line at one end of the field represents the time of the Earth’s formation (about 4.6 billion years ago) and the other goal line represents the present time.
3. The teacher will assign each person, pair, or small group (depending on class size) one of the events in the Earth’s history listed below.
4. Write the name of your assigned significant event in large letters on a piece of paper.
5. The teacher will tell each person where to position himself or herself on the field based on the age of his or her event, starting with the oldest events first. At this scale, each 10-yard increment represents 460 million years (each yard represents a 46 million-year period).
   - Earth’s crust forms—own goal line
   - Oldest rocks found on Earth—own 17-yard line
   - First fossil evidence (blue-green algae)—own 21-yard line
   - First multi-celled organisms—visitor’s 30-yard line
   - First jellyfish—visitor’s 15-yard line
   - First fish—visitor’s 11-yard line
   - First land plants—visitor’s 10-yard line
   - First amphibians—visitor’s 8-yard line
   - First reptiles—visitor’s 7-yard line
   - First dinosaur—visitor’s 5-yard line
   - First mammal—visitor’s 4-yard line
   - First bird—visitor’s 3-yard line
   - First flowering plant—visitor’s 2-yard line
moving away from you at a high speed. This is similar to the Doppler shift effect you hear whenever something like a fire truck or a race car moves past you quickly and you hear the pitch of the sound get lower. The red shift that Hubble observed indicated that the galaxies in all directions were moving farther and farther away from us. Second, Hubble determined that the farther away a galaxy is from us, the faster it is moving away. If the universe is expanding, then it must be the case that the galaxies of our universe were once closer together than they are now. By measuring how far apart galaxies are and how fast they are moving, one can calculate that it probably took about 15 billion years for the universe to grow to its present size. From these observations, one can theorize that the universe must have begun its expansion at a time when all the matter of the universe was together in one place: the awesome event that astronomers call the Big Bang. (See Experiment 5.)

**Star Power**

All stars produce both light and heat, but when we look into the night sky, not all stars look the same. Some stars appear brighter than others and some appear to be different colors. Some stars actually do produce more light than other stars, but one star may also appear brighter than another because it is closer to us here on Earth. Thus, a star that is closer may appear brighter than another star that actually produces more light and heat. Stars appear...
In the following activity, you will create a model showing the relative distances between the planets.

Materials You Will Need for This Activity

- Pictures of the Sun and planets
- Roll of toilet paper
- Markers

What You Will Do

1. Place pictures of the Sun and planets at the front of the room where everyone can see them. List as many ways as possible to classify (group) the pictures.
2. In a hallway or open area, unroll a roll of toilet paper, and mark off the distances to the planets using a scale of one toilet paper square = 10,000,000 miles (see the chart below for distances).
3. Hold up the unrolled toilet paper and have someone hold each planet picture at the appropriate distance along the scale.

<table>
<thead>
<tr>
<th>Object</th>
<th>No. of Toilet Paper Sheets From the Sun</th>
<th>No. of Toilet Paper Sheets From Previous Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Mercury</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Venus</td>
<td>6.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Earth</td>
<td>9.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Mars</td>
<td>14.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Jupiter</td>
<td>48.4</td>
<td>34.3</td>
</tr>
<tr>
<td>Saturn</td>
<td>88.7</td>
<td>40.3</td>
</tr>
<tr>
<td>Uranus</td>
<td>178.4</td>
<td>90</td>
</tr>
<tr>
<td>Neptune</td>
<td>279.7</td>
<td>101.0</td>
</tr>
<tr>
<td>Pluto (avg. orbit)</td>
<td>366.1</td>
<td>86.4</td>
</tr>
</tbody>
</table>

What you will learn: The inner planets are relatively close to the Sun and relatively close to each other.

The outer planets are substantially more spread out, both from the Sun and from each other.

Core concept demonstrated: Relative distances between the planets of the solar system

Thinking like a scientist: Why is it so difficult for humans to travel between planets in our solar system? The closest star to us besides the Sun is Alpha Centauri, at a distance of 46 trillion miles. At the same scale used above, how many sheets of tissue would it take to represent the distance to Alpha Centauri?

Correlation With National Science Standards: D.2; D.6
In the following activity, you will study a model of the expanding universe.

**Materials You Will Need for This Activity**
- A balloon
- A pen
- A ruler
- A paper strip
- A paper clip

**What You Will Do**
1. Use the ruler to mark off the measurements on the paper strip.
2. Inflate a balloon just a little bit (1 breath) and then make 10 dots on the balloon, numbering them from 1 to 10.
3. Inflate the balloon part way (about 4 breaths). Fold the end of the balloon and paper clip it so no air escapes (don’t tie it yet).
4. Using the paper strip, measure and record the distance between dot number one and each of the other numbered dots.
5. In the table below, record what happens to the 10 dots.
6. Now, blow up the balloon to about double the size it was before (this time you can tie the balloon). Again, use the paper strip to measure the distance from dot number one to all the other dots.
7. Calculate the difference for each dot between slightly inflated and half inflated and again between half inflated and fully inflated.

**Half Inflated**

<table>
<thead>
<tr>
<th>Dot</th>
<th>Initial Distance From Dot 1</th>
<th>Difference Between Slightly Inflated and Half Inflated</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
What you will learn: The more the balloon is inflated, the further the dots move apart and the more rapidly this happens.

Core concept demonstrated: The expanding universe

Thinking like a scientist: Do the dots get larger as the balloon expands? What happens to galaxies as the universe expands? If an object moving quickly away appears more red than normal (red shift), what do you think happens when an object is moving quickly toward you?

Correlation With National Science Standards: A.1; A.2; B.2; D.3; E.4; G.1; G.4
to be different colors because they are different temperatures. Hotter stars will usually appear white or blue and cooler stars will appear orange or red.

All stars, regardless of brightness or color, are giant balls of glowing gas. They shine because the gas inside them is so hot that a process of nuclear fusion takes place. Nuclear fusion occurs when two atoms fuse to form a different kind of atom. This fusion process gives off a lot of energy in the form of light and heat.

Energy from the Sun hits the Earth as heat and light. Of all this energy, about 19% is absorbed by the atmosphere and another 35% of the energy is reflected by clouds. Most of the remaining energy is in the form of visible and ultraviolet light. This energy is used by plants for photosynthesis and by animals for warmth. Humans also use this energy that has been stored for hundreds, thousands, or even millions of years when we burn wood and fossil fuels like coal and gas. (See Experiment 6.)

Astronomy: Observing the Heavens
From Earth in the Past and Present

To a remarkable extent, the planets, the moon, and the stars that we observe in the night sky today appear nearly the same to us as they did to our distant ancestors. While the universe is constantly expanding and evolving, from our perspective, the march of the heavenly bodies through our sky is a consistent marker of the passing days, months, and years. In a certain sense, these vast celestial mechanisms function with the precision and consistency of the best-designed clockworks. It appears to be human nature to try to understand and predict the movement of these celestial objects, and nearly all cultures throughout history have explored the science of astronomy.

Phases of the Moon

For as long as humans have walked the Earth, we have gazed up into the heavens in wonder. One of the most fascinating aspects of the night sky is the constantly shifting appearance of the moon. As the moon goes through its lunar cycle, the light from the Sun reflects off it at different angles. The result is what we observe from Earth as the shifting phases of the moon: the new moon, crescent moon, quarter moon, full moon, and so on. In Experiment 7, you will create a model of these shifting phases.

Changes in the Seasons

Why do the seasons change? According to an ancient Greek myth, Persephone was the daughter of Demeter, the goddess of the harvest. Hades, who was the god of the Underworld, fell in love with Persephone and took her to his kingdom to be his wife. Demeter searched everywhere for her daughter but could not find her. Zeus, the king of the gods, finally
Experiment 6: Hot Enough to Fry an Egg

In the following activity, you will capture and focus the energy of the Sun and study star power.

Materials You Will Need for This Activity

- 3 eggs
- 2 dark frying pans
- A piece of thick glass

What You Will Do

1. Take three eggs, two black frying pans, and one piece of thick glass outside on a hot, sunny day.
2. Crack one egg and put it directly on the sidewalk.
3. Crack the second egg and put it in one pan without a cover.
4. Crack the third egg and place it in the other pan and cover it with the piece of glass.
5. Observe the eggs carefully. Note which one fries the quickest.
6. Be sure you clean up the egg from the sidewalk afterwards. If you like, have an egg sandwich with the other eggs.

What you will learn: Solar energy heats the surface of the Earth. This energy can be concentrated by absorbing it with a dark surface, and it can be concentrated even more by focusing and trapping the heat with a glass covering.

Core concept demonstrated: Solar energy

Thinking like a scientist: Venus is very cloudy but also very hot. Why might this be? How would the solar energy on a planet with no atmosphere be different from the solar energy on a similar planet with an atmosphere?

Correlation With National Science Standards: A.1; B.3; D.4; F.5; G.1

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In the following activity, you will model the phases of the moon and explain why the moon appears to change its appearance when viewed from Earth.

Materials You Will Need for This Activity
- 8 small Styrofoam balls
- 1 medium Styrofoam ball
- 1 large Styrofoam ball
- Toothpicks
- Flat sheet of Styrofoam packing material or thick cardboard
- Flashlight
- Black marker

What You Will Do
1. Before making your model, you should keep a moon journal every night for at least a week (a month of observations is better). Each night, draw a picture of the moon. If you can’t see the moon on a given night, the newspaper will probably have a drawing of the moon phase on the weather page.
2. To make your model, stick a toothpick in the large Styrofoam ball and stick the other end of the toothpick in the flat piece of Styrofoam or cardboard near one edge. This ball represents the Sun.
3. Do the same for the medium ball and place it in the center of the flat piece of Styrofoam. This ball represents the Earth.
4. Using the marker, color exactly half of each of the small balls black. These will represent the phases of the moon.
5. Draw a diagram on a piece of paper that shows the position of the moon, Sun, and Earth during each of the following phases of the moon. Be sure to label the diagram to indicate the names of each phase. You can look up the information in a book or on the Internet.
   - New
   - Waxing Crescent
   - First Quarter
   - Waxing Gibbous

(Continued)
6. Create a 3-D model of your diagram by using toothpicks to attach the Styrofoam moon balls to the flat piece of Styrofoam in their proper positions relative to the Earth and Sun. Try to position the white and black sides of each moon in the proper orientation so it would been seen in the correct phase if you were standing on your Earth ball.

7. Darken the room and hold a flashlight next to your Sun to test your model. Move the balls as necessary to get the correct phase. Label each moon phase on the Styrofoam base.

8. Pick a phase of the moon and explain to a partner why we see that phase of the moon when we do.

What you will learn: We see the various moon phases from Earth as a result of the relative positions of the Sun, Earth, and Moon. The moon travels through a predictable series of phases approximately every 28 days.

Core concept demonstrated: Phases of the moon

Thinking like a scientist: What do you think it would be like to have several moons revolving around Earth? Would it change our calendar? Our poetry? Our tides?

What views do you think astronauts have of Earth and the moon as they orbit Earth?

Would the moon phases change if the moon revolved around Earth in the opposite direction? How?

Correlation With National Science Standards: A.1; B.2; D.3; G.1
told Demeter where Persephone was. Hades would not give her up completely but agreed that Persephone would live for half the year with Hades and for the other half with her mother. During the time that Persephone lived with Hades in the Underworld, Demeter was unhappy, and all the plants withered and died. But when Persephone returned each year, Demeter rejoiced and the plants grew again. This myth thus explained the reason for the changing seasons.

People are still interested in, and affected by, the consequences of these changes in season. In fact, the seasons have had a profound effect on human history: They establish the crop growing patterns in many regions, have led to historical migrations, and have even led to the development of hibernation among certain animal species. (See Experiment 8.)

### Experiment 8: The Changing Seasons

In the following activity, you will create a model showing how the tilt of the Earth is responsible for the change in seasons.

**Materials You Will Need for This Activity**

- A sharp pencil or cooking skewer
- A medium Styrofoam ball
- A black marker
- A lamp

**What you will do:**

1. Push a pencil or skewer straight through the center of the Styrofoam ball. This represents the Earth’s axis. Label the North and South Poles where the pencil pokes through.
2. Draw a circle around the middle of the ball, halfway between the poles, to represent the equator.
3. Darken the room and turn on the lamp.
4. Bring the ball a few feet from the lamp and tilt it slightly so the North Pole is about 23 degrees from straight up and down and pointing away from the lamp.

(Continued)
5. Describe the pattern of light and shadow on the ball on this day. What season do you think this is in the Northern Hemisphere? In the Southern Hemisphere?

6. Slowly move the ball counterclockwise around the lamp. Try to maintain the tilt—always pointing the North Pole out in the same direction in space (toward the same object in the room you are in).

7. Stop when you have gone a quarter of the way around the Sun. Describe the pattern of light and shadow on the ball on this day. What season do you think this is in the Northern Hemisphere? In the Southern Hemisphere?

8. Continue moving the ball counterclockwise. Stop when you have gone another quarter revolution. Describe what you observe as before.

9. Continue counterclockwise, stopping each quarter turn and describing the position and the season, until you get back to the starting point.

**What you will learn:** The Earth rotates on an axis that is tilted. In other words, our planet never stands upright—it is always leaning to the side. The direction of this lean never changes. As the Earth travels along its orbit, any particular place on the Earth sometimes leans toward the Sun and sometimes away from the Sun. This tilt determines the seasons by influencing the amount of direct sunlight that hits a given part of the Earth’s surface.

**Core concept demonstrated:** Why the seasons change during the year

**Thinking like a scientist:** Many people believe that the seasons change because the Earth moves closer to and farther from the Sun during the year. Where do you think this belief comes from?

Would there be seasons on Mars? If so, how would the seasons on Mars be similar to or different from the seasons on Earth?

**Correlation With National Science Standards:** A.1; A.2; B.2; D.3; D.6; G.1
Exploring Shadows

The sundial is the oldest known device for measuring time and is probably the most ancient of all scientific instruments. A sundial works because the shadow of an object will move from one side of the object to the other as the Sun appears to travel across the sky during the day.

Sundials probably date back to the Sumerian civilization, about 3500 B.C. By 2500 B.C., both the ancient Babylonians and Egyptians were building obelisks to serve as timekeepers, dividing the day into two parts by indicating noon. Later, additional markers were added around the base of the monument to allow further time divisions.

In modern times, sundials have been replaced by clocks that are both more accurate and more convenient. It is, of course, still possible to estimate time using the Sun’s shadow on a straight object. (See Experiment 9.)

Restless Earth: Earth’s Composition, Layers, Movements, and Impacts in Surface Features

Looking down on the Earth from outer space, one might have the impression that the Earth is like a ball, round and smooth and unchanging. Nothing, in fact, could be further from the truth. In addition to the Earth’s movement through space, which we have previously discussed, the internal and external features of the Earth are in constant and dynamic motion. This motion is the result of a number of interrelated systems shaped by tectonic forces, physics, chemistry, and even biology.

Convection Currents: Heat Within the Earth

The German geologist Alfred Wegener (1880–1930) was the first scientist to propose theories of continental drift and plate tectonics. He argued that a super-continent he called Pangaea had broken up about 200 million years ago, with the pieces drifting to their present positions. As evidence, he cited the fit of South America and Africa, fossil evidence, and similarity of rock structures across now-distant continents. Because he could not explain the mechanism for this continental drift, however, his ideas were widely discredited.

About 15 years after Wegener proposed his theory, the British geologist Arthur Holmes (1890–1965) proposed that the Earth’s mantle undergoes thermal convection and that this could be the missing mechanism. This idea is based on the fact that as a liquid is heated, its density decreases and it rises to the surface until it is cooled and sinks again. This repeated heating and cooling results in a current, and this current might be enough to propel the great continents around the planet. While Holmes’s idea received very little attention at the time, it turned out to be the correct mechanism to explain plate tectonics. (See Experiment 10.)
Experiment 9: Changing Lengths of Shadows

In the following activity, you will explore how the lengths of shadows change during the day.

Materials You Will Need for This Activity
- Meter tapes
- Chalk
- Meter sticks
- Long pieces of paper (from a roll of paper) about 2 meters long

What You Will Do
1. Trace the length of the meter stick on the long piece of paper and record the length.
2. Take the paper and meter stick outside in the morning. Cast the shadow of the meter stick on the paper by placing one end of the meter stick on the ground, being sure to hold it as vertical as possible.
3. Trace the resulting shadow, measure it, and record the length and the time of day.
4. Repeat this procedure every 1 to 2 hours during the day. If possible, continue until the Sun goes down.
5. Compare the length of shadow cast at each time of day to the actual height of the meter stick.

What you will learn: When the Sun is lower in the sky, both in the morning and evening, shadows are extended and are longer than the height of the actual object. In the middle of the day when the sunlight is shining down closer to vertical, shadows are shorter than the length of the actual object.

Core concept demonstrated: How shadows are affected by the shifting angle at which sunlight strikes the Earth

Thinking like a scientist: Given what you have learned about the changing shadow length, how could you use this information to construct a basic sundial? Do you think the changing seasons would affect the lengths in your shadow experiment? Why or why not? If possible, repeat this activity three or four months after the first trial to answer this question: Would the changing seasons affect the way a sundial tells time? Why or why not?

Correlation With National Science Standards: A.1; A.2; B.2; D.3; D.6; G.1; G.4
In the following activity, you will create a model to demonstrate how convection currents can move objects.

**Materials You Will Need for This Activity**

- 1 glass bread loaf
- 1 pan or 8” x 8” square glass baking dish
- 2 ceramic coffee cups
- 2 cans Sterno
- Vegetable oil
- Ground spice such as cinnamon or nutmeg
- Spoon
- Matches
- Small pieces of balsa wood (optional)

**What You Will Do**

1. Pour a 1½ to 2-inch layer of the vegetable oil into the glass baking dish.
2. Mix in the spice. Stir thoroughly to distribute the spice. Carefully balance the dish on the coffee mugs, leaving space to place the Sterno cups in the center under the pan.
3. Observe the oil and spice mixture and describe what you see. Is there any movement of the liquid or the spices?
4. Light the Sterno cans and let the liquid heat up for a couple of minutes. Again, observe the oil and spice mixture and describe what you see. Is there any movement of the liquid or the spices now?
5. Look at the model several times during the experiment, both from above the dish and from the side of the dish. Draw a picture of what you observe.
6. If you have the balsa wood pieces, put them carefully in the center of the pan. Observe them for several minutes and describe what happens.

* Safety Notice—Both the lit Sterno cans and the hot oil are dangerous and can cause severe burns. Be sure that the experiment is placed on a solid and level surface and that students remain at a safe observing distance at all times.

**What you will learn:** The flow of the heating and cooling oil creates a convection current in which upward flow above the flame, due to heating, causes horizontal flow near the surface of the liquid. Cooling of the liquid near the ends of the container leads to an increase in the density of the liquid and produces sinking and a return horizontal flow toward the center of the container. This cycle of flow is known as a convection cell.

**Core concept demonstrated:** Convection currents

**Thinking like a scientist:** Is the pattern approximately symmetrical on the two sides of the heated area? Where do you observe upward flow? Where do you see downward flow? Where do you observe horizontal flow? How is this similar to or different from what goes on in plate tectonics?

**Correlation With National Science Standards:** A.1; A.2; B.2; D.1; D.4; D.5; G.1; G.4
Plate Tectonics

As discussed in the previous section, the English geologist Arthur Holmes discovered that convection currents explained how Alfred Wegener’s theory of continental drift might be possible. But how and where exactly these convection currents might be operating was still unknown. The answer turned out to be hidden on the bottom of the oceans. American geologists Harry Hess and Robert Dietz studied ocean floor data collected by U.S. Navy submarines during World War II and concluded that the sea floors were gradually spreading apart and that new sea floor crust is continually being created along oceanic spreading ridges and then destroyed along the continental boundaries in deep trenches called subduction zones. This sea floor spreading served as the conveyor belt resulting from the convection currents below and, in turn, pushing the continents. As the continents were pushed in this way, they sometimes collided, resulting the creation of new mountain ranges. (See Experiment 11.)

Earthquake Simulation

In 1906, San Francisco was struck by an enormous earthquake that virtually destroyed the city. Arnold Gente, among others, left a remarkable photo record of the damage caused by the earthquake (see Image 6.8). Earthquakes are more common than many of us would like to believe. For example, a series of three massive quakes struck along fault lines near New Madrid, Missouri in 1811 and 1812. These quakes were so strong they could be felt as far north as Michigan and as far east as the Carolinas. More recently, a huge quake hit the city of Kobe, Japan in 1995, killing 5,000 people and causing billions of dollars in damage. As great as the damage was, it was mitigated by the fact that Japan, as a highly developed nation, is able to ensure that most structures are built to be somewhat earthquake resistant. Less-developed nations often struggle to ensure that buildings meet such safety codes. This sad reality could be clearly seen in the Asian tsunami of 2004 and the Pakistan earthquake of 2005, both of which caused horrific damage and loss of life. As more and more development occurs in earthquake-prone areas, structurally sound construction becomes critical. (See Experiment 12.)
Experiment 11: Mountain Building With Towels

In the following activity, you will make a model to demonstrate how mountains are built up and erode as a result of plate tectonics.

Materials You Will Need for This Activity
- Three pairs of towels of three different colors/patterns

What You Will Do
1. Fold each towel into quarters, and make two identical stacks with three towels in each stack.
2. Place the two stacks of towels next to each other to serve as your model.
3. The towels represent different sedimentary rock layers. Where are the oldest rock layers in your model? (They are at the bottom of the stack, and the youngest will be at the top because newer sedimentary rocks are deposited over older rocks.)
4. The surface of the Earth in the model is represented by the top of the stack of towels. (The rest of the towels represent rock layers underground.)
5. Slowly begin to push the stacks of towels together. Describe what happens to the ground surface. How is this like what happens during the process of mountain building when two continental plates collide? (The rocks are pushed up as they crush together and the mountains gradually grow taller.)
6. Additionally, the process of erosion takes place as the younger rocks on top are gradually eroded away by water, wind, and ice. Simulate this erosion by slowly pulling back the top towels from both sides of the mountain and folding them under, while maintaining the tilt of the layers against the mountain flanks.
7. Model what will happen over time when the plates stop colliding and only erosion is now working on the mountains.

What you will learn: The continental plates move as a result of sea floor spreading. When two continental plates collide, the rock layers bend and fold and form mountains. The mountains will continue to grow as long as the plates are moving together. Erosion also takes place, and once the plates stop moving together, erosion will slowly decrease the height of the mountains as they are worn away bit by bit.

Core concept demonstrated: Mountain building as a result of plate tectonics

Thinking like a scientist: The two longest mountain ranges in the U.S. are the Rockies in the west and the Appalachians in the east. The Rockies are significantly taller. Give two possible explanations for this. How could you gather evidence to determine which of these explanations is correct?

Correlation With National Science Standards: A.2; B.5; D.1; D.4; D.5

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In the following activity, you will design model buildings to resist the effects of a simulated earthquake.

**Materials You Will Need for This Activity**

- 10 index cards
- 2 sheets of notebook paper
- 10 drinking straws
- 16 paper clips
- Metric ruler
- Tape measure
- Shoebox lid or Tupperware container
- Marbles to fill shoebox lid
- Tape

**What You Will Do**

1. The teacher will divide the class into three teams; each team will receive one of the structure challenges described below.
2. Construct a building at least 30 cm tall that passes the test for your team’s challenge.
3. **Challenge #1:** Design a structure that will remain standing even when a heavy book is dropped onto the floor next to the structure.
4. **Test:** Put your building on a piece of paper on the floor. Trace the outline of the building on the paper. You may not fasten the building to the paper. Drop a heavy book onto the floor directly next to the structure from a height of 2 meters. Retrace the outline of the building on the paper and measure the distance that the foundation moved.
5. **Challenge #2:** Design a structure on a slanted surface so that it doesn’t slide downhill even when an impact strikes the hillside. Build the structure on a slant so that one side of the bottom of the structure is about 8 cm higher than the other side.
6. **Test:** Trace the foundation of the building on a piece of paper and place the paper on the hillside. Drop a small weight, like a box of crayons or a pack of index cards, from a height of about 30 cm above the uphill side of the structure. Retrace the outline of the building on the paper and measure the distance that the foundation moved.
7. **Challenge #3:** Build a structure on an unstable surface that will not fall down even when the surface moves beneath the building.
8. **Test:** Fill most of the shoebox lid or medium Tupperware container with a single layer of marbles so that the marbles can still roll. Set the building on the marbles. Slide the box back and forth a distance of 5 cm in each direction about once every 5 seconds. Increase the speed slowly until you are shaking
Rocks and Minerals: Formation, Identification, and Human Use of Common Rocks and Minerals

The Earth is composed of a great variety of rocks and minerals. These rocks and minerals are created as a result of tectonic forces, volcanic activities, and other chemical processes and even the erosion of the older rocks and minerals. Understanding where rocks and minerals come from is essential to understanding how the Earth was formed as well as how it constantly renews itself. These processes, in turn, play an integral part in how life thrives and becomes abundant on the planet.

Growing Crystals

Have you ever seen a piece of rock candy or looked at table salt under a magnifying glass? Both the rock candy and the salt exhibit crystalline structures. How are these structures similar to or different from rock crystals that you have seen? Even though they are different in terms of their chemical composition, each of these crystals formed in approximately the same way. (See Experiment 13.)
In the following activity, you will compare the structures of several types of crystals.

**Materials You Will Need for This Activity**
- Magnifying glass
- Table salt
- Epsom salt
- Jar of honey
- Measuring cups and spoons
- Pencil
- String
- Sugar
- Paper clips
- A glass jar
- Hot plate, stove, or other heat source

**What You Will Do**
1. Use your magnifying glass to closely observe the table salt, the Epsom salt, and the rim of the honey jar.
2. Draw pictures of what you observe. In what ways are the crystals similar and different?
3. Dissolve 1 teaspoon of salt in 1 cup of water and heat the mixture over a low flame to evaporate the water.
4. Observe what is left using your magnifying glass and draw a picture of these crystals.
5. Pour 1 cup of boiling water into a dish and add 2 cups of sugar. Stir until the sugar is completely dissolved. Let the sugar water cool and then pour it into the glass jar.
6. Straighten out a paper clip so that it can lie across the mouth of the jar.
7. Tie a piece of string to the clip so that it can hang down into the jar and reach nearly to the bottom (but not touch the bottom).
8. Observe every day. After a few days, remove the string and examine the crystals under the magnifying glass.

* Safety Note—This experiment uses boiling water. Be sure that children maintain a safe distance from hot liquids and containers.

**What you will learn:** When liquids cool, they solidify. In some cases, under the right conditions, crystals will form. Crystals are made up of molecules that fit neatly together in an orderly way. All crystals of the same material formed under the same conditions should have the same structure and shape.

**Core concept demonstrated:** Development and appearance of crystal structures

**Thinking like a scientist:** How are the salt and sugar crystals that you grew in this activity similar to or different from the ones that you observed at the beginning of the activity? How are they similar to or different from mineral crystals you have seen before?

**Correlation With National Science Standards:** A.1; B.4; D.1
Mineral Identification Strategies

Geologists have developed a number of procedures by which to identify and differentiate the minerals in the Earth. A mineral is a naturally occurring, inorganic, crystalline solid that has a definite chemical composition. A rock is a combination of one or more minerals. Mineral identification can be important because some minerals (i.e., gold) are highly valuable and other minerals (i.e., pyrite, also known as fool’s gold) are less so. Many minerals have properties that are desirable for manufacturing and building, and other minerals are sought simply because of their natural beauty. There are several simple tests that can be done to categorize and classify minerals. (See Experiment 14.)

What’s in Soil?

We take the soil that we find beneath our feet pretty much for granted, but in fact soil is a complex mix of organic and inorganic materials that is essential for life on Earth. Soil typically includes small particles of rock, plant material in various states of decomposition, animal material both living and dead, and a variety of minerals. Soil is necessary for plant growth, which, in turn, is essential for all animal life. (See Experiment 15.)

Earth Cycles: Many Processes on Earth Operate in Cycles

What happens in the Earth’s atmosphere, on the surface of the land, in the oceans, and deep underground is all part of a complex series of closely connected and interrelated phenomena. The Earth is a dynamic system in which there are many cycles. Three of the main cycles are the atmospheric cycle, the water cycle, and the rock cycle. These cycles provide evidence of two important facts about the Earth. First, the Earth is essentially a closed system with almost no net gain or loss in matter. That is, the matter on the Earth gets cycled through various systems, but there is very little new matter that comes into or leaves the system. Second, changes in one part of any of these systems can affect other parts of the system, and even other systems. Another way to think about this is that almost nothing occurs in isolation. Understanding the interrelationships between these cycles is fundamental to any understanding of Earth science.

Water Cycle

A rock formation that is porous and permeable enough to store water is called an aquifer. Water can be drawn from an aquifer through a well. Wells are holes drilled into and through the layers of rocks and down to a layer that contains stored water. Water that seeps into the ground, either from rainfall or another source, refills an aquifer. Thus, aquifers are renewable resources,
In the following activity, you will conduct several basic tests useful in mineral identification.

Materials You Will Need for This Activity
- Glass plate (for testing hardness)
- Streak plate (for testing streak)
- Iron nail (for testing for presence of carbonates)
- Vinegar (for testing for presence of carbonates)
- Magnet (for testing for presence of iron)
- 5 mineral samples (quartz, calcite, magnetite, pyrite, and galena)

What You Will Do
1. Observe the five mineral samples and describe each sample in as much detail as you can.
2. Construct a data table to record each of the test results for each of the samples.
3. Begin with the first mineral sample and conduct each of the tests on the sample. See below for the test procedures. When you have completed the tests, try to identify the mineral.
4. Follow the same procedures for each of the other mineral samples.
5. When you are done, compare your results with those of other students in your class.

Streak Test: Hold the ceramic tile flat on the desktop. Press a corner of the mineral firmly on the tile and try to draw a line using the mineral. Based on your observation, write “colored streak” or “no colored streak” in the streak column of your data table.

Hardness Test: Hold the glass plate flat on the desktop. Press a corner or edge of the mineral firmly on the glass and try to scratch the glass with the mineral. Write “does scratch” or “does not scratch” in your data table under the hardness column.

Fizz Test: Use the nail to scratch a small area on the mineral specimen. Put a drop of vinegar in this area. Watch closely to see whether the vinegar fizzes, so you know whether it reacts with the mineral. Write “fizz” or “no fizz” in your data table.

Luster Test: Look at the mineral sample closely. Does it look like it is made of metal? Is it shiny? Write “metallic” (if it looks like a metal) or “non-metallic” (if not).

Magnetism Test: Hold a magnet next to the mineral sample. Is the magnet attracted to the mineral? Write “magnetic” or “not magnetic” in the magnetic column of your data table.
but if water is drawn out faster that it is replenished, eventually the aquifer will be depleted. Also, if the area near the aquifer becomes polluted, the water that seeps into the aquifer will become polluted, too. Aquifers have the ability to filter some pollutants out of the water, but groundwater can easily become polluted when people living above the aquifer are not careful about what goes into the ground. (See Experiment 16.)

**Rock Cycle**

The creation of geologic formations is a dynamic process in which different types of rock are formed and reformed. Molten rock, which is known as magma or lava, can cool to form igneous or crystalline rocks. These igneous rocks can then be transformed through additional heating and pressure into metamorphic rocks. Both igneous and metamorphic rocks can also be eroded, deposited in layers, and then compressed into sedimentary rocks. This cycle can occur over and over again with the same molecules passing from one form of rock to another. (See Experiment 17.)

* Safety Note—Mineral samples can have sharp points and edges, as do the glass and streak plates and the nail. It is important to set clear expectations and give clear instructions to students before beginning this activity.

**What you will learn:** Many common minerals can be identified through a series of simple tests.

- quartz—no streak, does scratch, no fizz, non-metallic, non-magnetic
- calcite—no streak, does not scratch, yes fizz, non-metallic, non-magnetic
- pyrite—yes streak, does scratch, no fizz, metallic, non-magnetic
- galena—yes streak, does not scratch, no fizz, metallic, non-magnetic
- magnetite—yes streak, does scratch, no fizz, metallic, magnetic

**Core concept demonstrated:** Physical and chemical characteristics of common minerals

**Thinking like a scientist:** Which mineral was the easiest to identify? What made this mineral easy to identify? Which two minerals were the most difficult to tell apart? What made them difficult to distinguish? If you were a field geologist, what tools would you want to take with you to help identify different minerals?

**Correlation With National Science Standards:** A.1; A.2; B.1; D.1; F.7
**Experiment 15: Determining Soil Type**

In the following activity, you will use a classification system developed by soil scientists to identify several soil samples.

**Materials You Will Need for This Activity**
- Soil samples brought from class members’ yards or neighborhoods
- Magnifying glass
- Tweezers
- Paper towels

**What You Will Do**

1. Spread the first soil sample out on a paper towel and observe it closely using the magnifying glass.
2. Take notes on what you observe. Consider observations such as the texture of the particles, presence of identifiable objects (leaf, twig, etc.), presence of any living organisms, and so on.
3. Using the flow chart in Image 6.11, follow the directions to determine the classification of your soil.
4. Repeat Steps 1 to 3 with a second soil sample.
5. Compare the soil type of your samples with the soil types of your classmates. Make a graph of the class results.

**What you will learn:** Soil is composed of several different types of particles (silt, clay, sand, and loam) and can be classified depending on the relative amounts of these constituents.

**Core concept demonstrated:** Components and classification of soils
**Image 6.11. Soil Classification Chart**

**Thinking like a scientist:** Why might an engineer or an architect need to know about the types of soil present before planning a new construction project? Why might a gardener? Why do you think gardeners add peat moss or topsoil to their garden if it has a high clay content?

**Correlation With National Science Standards:** A.1; A.2; B.1; D.1; F.3; G.1
Experiment 16: Building an Aquifer Model

In the following activity, you will build a model of an aquifer and explore the effect of pollution on groundwater.

Materials You Will Need for This Activity
- Two-liter soda bottle
- Clay
- Gravel
- Topsoil
- Sand
- Pencil
- Piece of nylon cut from a stocking
- Twist tie
- Eye dropper

What You Will Do
1. Cut the top half off a clear two-liter bottle and remove the label.
2. Layer clay, gravel, topsoil, and sand in the bottom half of the bottle. Observe the layers in the bottle. How do they appear similar and different?
3. Wrap the piece of nylon around the end of a pencil and secure it with the twist tie.
4. Make a simulated well by drilling a hole through the various layers with the pencil. Drill until you hit the clay layer.
5. Slowly, pour water in the area around the well and observe. Does the water filter through the layers like it would in a natural aquifer?
6. Untie the twist tie and slip the pencil out, leaving the nylon in the hole.
7. Use the eyedropper to extract water from the well. Describe what happens and observe the water.
8. Now, add a large amount of food coloring to the areas outside the well to simulate adding pollution to the aquifer.
9. Continue drawing water from the well using the eyedropper. What do you observe?

What you will learn: Water filters through the rock layers of an aquifer and can be pumped out of a well into the aquifer. If pollution is added anywhere it can seep into the aquifer, it is likely that the water will become contaminated.

Core concept demonstrated: How water is stored and filtered by aquifers

Thinking like a scientist: You caused your “pollution” with food coloring. What types of things in your home might actually contaminate drinking water if poured on the ground? In the model, only a few drops of food coloring were enough to “pollute” the well. How much of a pollutant do you think is necessary in the real world to pollute an aquifer or a well?

Correlation With National Science Standards: A.1; A.2; B.1; D.1; D.4; F.1; F.8; G.1

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In the following activity, you will create a tasty model that demonstrates part of how the rock cycle occurs.

**Materials You Will Need for This Activity**

- Bowl
- Mixing spoon
- Wax paper
- Measuring cups and spoons
- \( \frac{1}{2} \) cup evaporated milk (silt; erosion)
- 1 cup sugar (quartz crystals; uplift)
- 1 tablespoon margarine (organic sediments; time)
- 1 cup mini-marshmallows (limestone pieces; ocean)
- \( \frac{1}{4} \) cup pecans or walnuts (sandstone pieces; weathering)
- \( \frac{3}{4} \) cup chocolate chips (basalt pieces; heat)
- \( \frac{1}{2} \) teaspoon vanilla extract (crude oil; pressure)

**What You Will Do**

1. Measure and add the silt, quartz crystals, and organic sediments to the bowl.
2. Mix them thoroughly with the spoon to simulate the effects of plate tectonics.
3. Place the bowl in the microwave for 45 seconds and then stir it to simulate increases in temperature and pressure. Repeat this step 3 times.
4. Break the sandstone pieces into smaller pieces to simulate weathering.
5. Measure and add the limestone, sandstone, basalt, and crude oil to the bowl.
6. Stir the sediments as they undergo metamorphosis, finally melting the limestone and basalt back into magma.
7. Use the spoon to scrape the magma back out onto the Earth’s surface (wax paper).
8. Add another sheet of the Earth’s surface (wax paper) over the top of the cooling igneous rocks.
9. Set aside overnight in a cool place or in the refrigerator. The next day, observe the newly formed igneous rocks.
10. Cut the rock into squares and enjoy!

**What you will learn:** Rocks many go through the rock cycle numerous times as they cool, are exposed to new temperatures and pressures, are eroded and deposited, are uplifted or subducted, are re-melted and reformed.

**Core concept demonstrated:** The rock cycle
Atmospheric Cycle

Heat from the Sun warms the Earth. As air in the atmosphere is heated, it will rise, lowering the air pressure in the area. Colder air higher up in the atmosphere (higher up because it was once warm air) will fall, raising the air pressure in the area. Air then flows horizontally between high and low pressure areas, resulting in the atmospheric cycle. This movement between high and low pressure areas can be on a local scale, a global scale, or any scale in between. High-pressure areas are generally associated with clear skies and stable weather. Low-pressure areas are generally associated with unstable weather and also with cloudy skies, due to the increased evaporation of moisture in the upper atmosphere.

Clouds are nothing more than water vapor that condenses and gathers together into a visible form. Clouds are usually formed when moisture-filled air near the Earth’s surface is raised higher into the atmosphere by the heat of the Sun. As the air is lifted, the pressure drops and the air is subsequently cooled. The combination of these two processes causes water vapor to condense. (See Experiment 18.)

Weather and Climate: Weather Patterns, Climate Zones, and Climatic Change Over Time

Weather and climate both result from the interactions of the various cycles that make up our dynamic Earth. Water, wind, temperature, topography, latitude, season—these and many other features influence the weather and climate that we experience. But what is the difference between weather and climate? Weather is the variety of atmospheric events that we observe on a daily basis.
In the following activity, you will create a model that simulates cloud formation in the atmosphere.

Materials You Will Need for This Activity
- A clear 2-liter plastic bottle with cap
- A measuring cup
- Cold and hot water
- Matches

What You Will Do
1. Pour $\frac{1}{3}$ cup of cold tap water into the clear bottle and place the cap on it.
2. Shake the bottle for 30 seconds and then set it on the table.
3. Squeeze the bottle and then release the pressure. Repeat this process several times.
   (Explanatory note—When you squeeze the bottle you increase the pressure and saturate the atmosphere inside the bottle. The increased pressure in the bottle also increases the air temperature. When the air is heated, more water moves into the air. When you release the pressure on the bottle, you decrease the air pressure inside. This lowers the air temperature and causes condensation in the bottle. You don’t yet, however, have everything you need to make a cloud. There are not enough particles in the air to which water vapor molecules can attach themselves.)
4. Now, remove the cap from the bottle and light a match. Hold the match over the mouth of the bottle. Quickly squeeze the bottle to extinguish the match, then slowly release the pressure to draw smoke into the bottle.
5. Replace and tighten the cap.
6. Squeeze the bottle again and release. A cloud should now have formed above the water inside the bottle. Again, squeezing the bottle forced condensation inside the bottle. Now that smoke has been added to the bottle, the water has something to condense around. The condensed water forms the small cloud inside the bottle.
7. Finally, rinse the bottle thoroughly and pour $\frac{1}{3}$ cup of hot tap water into it. Shake the bottle for 30 seconds and place it on your table.
8. Squeeze the bottle and then release the pressure. Repeat this process several times. Then repeat the process of extinguishing a match over the mouth of the bottle and drawing the smoke inside. Squeeze and release the bottle again to create a cloud.

(Continued)
Climate is that larger pattern that helps us to understand the weather. Weather can change very rapidly, depending on whether it is hot or cold, wet or dry. The atmosphere reacts to a wide range of features that are changing hour to hour. Thus, the weather can change multiple times in a single day.

Meteorologists are scientists who study weather and climate. They record the weather every day, and this database of weather information helps us to understand the climate of an area. Climate is the average weather in a location over a prolonged period of time. For example, a location like Hawaii that gets large amounts of rain over many years would have a wet climate. A place like Alaska, where it stays cold for most of the year, would have a cold climate. Understanding the climate of an area is helpful for predicting the weather in that area.

So, when you look out the front door in the morning, you see weather. If you keep looking out the door every morning, and keep observing the weather each day, then you will begin to understand some things about the climate in your area.

**Tracking Rainfall**

Throughout history, people have been interested in forecasting the weather to guide agricultural practices like planting and harvesting, migrations, and even the timing of festivals. The ancient Babylonians, Chinese, and Greeks all developed systems for weather forecasting. However, these predictions were generally based on lore and personal observations with few systematic attempts at
measurement using tools. It was not until the Renaissance that tools such as the thermometer and barometer were used systematically in weather observation.

Accurate record keeping and sharing of data across locations did not become common until the 1860s, which is generally considered to be the beginning of modern meteorology. Keeping accurate records over time is an extremely important part of weather prediction. Knowing the tracks of storms is important because weather patterns often repeat themselves. Thus, in an area like the southeastern United States, it is known that hurricanes appear consistently at certain times of the year and follow certain consistent tracks. This is also true for other types of weather in the north, like snow storms and blizzards.

Recording rainfall is one of the many types of data collection that are done as part of weather forecasting. (See Experiment 19.)

**Measuring Wind**

Hurricanes, which are called typhoons in the Pacific, are the most powerful storms in the Earth’s atmosphere. They can have winds as high as 170 miles per hour and cause huge devastation not only because of the destructive winds, but also because of flooding from tidal surges and massive rainfall. In August, 2005, Hurricane Katrina destroyed much of the Gulf Coast region of the United States, flooding the city of New Orleans and causing tens of billions of dollars of damage. Even when it is not blowing with such destructive force, wind is an important aspect of both weather and climate. (See Experiment 20.)

**Rainforest Terrarium**

Rainforests are some of the most incredible ecosystems on Earth. They are forests full of tall, dense plant life that regularly receive high amounts of rainfall and are well-known for having an incredible range of biodiversity. While the vast majority of rainforests are in tropical and subtropical regions, smaller rainforests can be found in more temperate climate zones. Rainforests currently cover approximately 6% of the Earth’s surface, but are thought to contain more than half of the world’s plant and animal species. The climate of a rainforest is very hot and humid and is usually considered to have four distinct layers.

At the bottom is the forest floor, where it is usually very dark and, as a result, almost no plants grow there. Things on the forest floor tend to decompose very quickly; thus, the soil of the forest floor is rich in nutrients. Above the forest floor is the understory layer. There is still only a little sunshine that reaches down to this area, so many plants grow large leaves to reach the sunlight. Animals in the understory layer in tropical rainforests include jaguars, tree frogs, and leopards, as well as a large concentration of insects.

Above the understory is the canopy layer, which is the primary layer of the forest and forms a roof over the two layers below it. Trees in the canopy layer receive abundant sunlight, and most have smooth, oval leaves. Trees

(Text continues on page 188)
Experiment 19: Tracking Rainfall

In the following activity, you will keep track of the rain that falls at your school over a one-week period.

Materials You Will Need for This Activity

- Glass or clear plastic container at least 10 inches high
- Marbles
- A permanent water-resistant marker
- A 12-inch plastic ruler

What You Will Do

1. Place marbles into the container and add about one inch of water. Draw a line on the bottle to indicate this water level. This will be your rain gauge. The marbles and water will steady the container and keep it from tipping over in the wind.
2. Put the rain gauge outside on a level surface, away from any overhanging trees or other things that could block rainfall. Leave the gauge outside all week.
3. Make a hypothesis about how much rain you think will fall over the next week.
4. Measure the rainfall every day at about the same time of day. Have one student hold the ruler against the side of the container, with the ruler’s bottom end even with the base line. Have another student read the height of the water column.
5. Record readings and comments about the weather on an observation chart.

What you will learn: Rainfall may vary a great deal from day to day. If you keep accurate data over time, it becomes possible to see patterns and make predictions.

Core concept demonstrated: Systematic collection of weather data

Thinking like a scientist: Could you make accurate climate predictions about rainfall based on your one week of rain data? Why or why not? What could you do to improve your ability to make predictions? Could you use your rainfall data to predict other aspects of the weather, like temperature? Why or why not? What could you do if you wanted to predict other aspects of the weather as well?

Correlation With National Science Standards: A.1; A.2; D.3; E.2; F.5; G.1
Experiment 20: Making an Anemometer

In the following activity, you will build a tool to measure wind speed and use it to make wind measurements.

Materials You Will Need for This Activity
- Plastic drinking straws
- Tape
- 4 small paper cups (the kind used in bathroom dispensers)
- A straight pin
- A pencil with an eraser
- A Marker
- A Beaufort wind scale

What You Will Do
1. Form a cross with two drinking straws and tape the straws together where they cross.
2. Tape one small paper cup to the end of each straw, making sure all the cups have their opening pointed the same way (right or left).
3. Push the straight pin through the center of the straws where they cross and then push the pin into the eraser on the end of the pencil.
4. Mark one cup with the marker to be a reference you can use to count as the cups spin around in the wind.
5. Go outside and measure the wind speed by counting the number of times the anemometer spins around in one minute.
6. Measure the wind speed in several different locations and record your results in a data table. (Your measurements will be in revolutions per minute, not miles per hour. Store-bought anemometers make this conversion for you.)
7. Compare the results you measure with your anemometer with the Beaufort wind scale (below). Look at the observable effects of the wind and then use the scale to estimate the wind speed in miles per hour.

What you will learn: Wind speed can be measured through direct measurement using an anemometer or through indirect measurement using the Beaufort wind scale and observed wind effects.

Core concept demonstrated: Measuring wind speed

Thinking like a scientist: Can you compare the measurements of the two systems? Why or why not? What would you have to do to compare them? How much did the wind speed change from place to place? If you wanted to keep accurate data over time, what would you need to do?

Correlation With National Science Standards: A.1; A.2; B.5; D.3; E.2; F.5; G.1

(Continued)
Wind Speed Scale Description (miles per hour) Observable Effects

<table>
<thead>
<tr>
<th>Scale</th>
<th>Description</th>
<th>Wind Speed (miles per hour)</th>
<th>Observable Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Calm</td>
<td>less than 1</td>
<td>Smoke will rise vertically.</td>
</tr>
<tr>
<td>1</td>
<td>Light Air</td>
<td>1–3</td>
<td>Rising smoke drifts; weather vane is inactive.</td>
</tr>
<tr>
<td>2</td>
<td>Light Breeze</td>
<td>4–7</td>
<td>Leaves rustle, can feel wind on your face, weather vane is inactive.</td>
</tr>
<tr>
<td>3</td>
<td>Gentle Breeze</td>
<td>8–12</td>
<td>Leaves and twigs move around. Lightweight flags extend.</td>
</tr>
<tr>
<td>4</td>
<td>Moderate Breeze</td>
<td>13–18</td>
<td>Moves thin branches, raises dust and paper.</td>
</tr>
<tr>
<td>5</td>
<td>Fresh Breeze</td>
<td>19–24</td>
<td>Trees sway.</td>
</tr>
<tr>
<td>6</td>
<td>Strong Breeze</td>
<td>25–31</td>
<td>Large tree branches move; umbrellas are difficult to keep under control.</td>
</tr>
<tr>
<td>7</td>
<td>Moderate Gale</td>
<td>32–38</td>
<td>Large trees begin to sway; noticeably difficult to walk.</td>
</tr>
<tr>
<td>8</td>
<td>Fresh Gale</td>
<td>39–46</td>
<td>Twigs and small branches are broken from trees; walking into the wind is very difficult.</td>
</tr>
<tr>
<td>9</td>
<td>Strong Gale</td>
<td>47–54</td>
<td>Slight damage occurs to buildings; shingles are blown off of roofs.</td>
</tr>
<tr>
<td>10</td>
<td>Whole Gale</td>
<td>55–63</td>
<td>Large trees are uprooted; building damage is considerable.</td>
</tr>
<tr>
<td>11</td>
<td>Storm</td>
<td>64–75</td>
<td>Extensive widespread damage.</td>
</tr>
<tr>
<td>12</td>
<td>Hurricane</td>
<td>above 75</td>
<td>Extreme destruction.</td>
</tr>
</tbody>
</table>

in the canopy layer are generally so close together that animals can easily move from tree to tree while remaining in the canopy. Many animals live in the canopy, including various snakes, birds, and tree frogs. Finally, trees that extend up above the canopy make up the emergent layer. These trees can be more than 200 feet tall with trunks that measure up to 16 feet around. There is plentiful sunlight in the emergent layer, and the trees tend to have broad leaves. Eagles, monkeys, bats, and butterflies are just some of the animal inhabitants of the emergent layer. (See Experiment 21.)
In addition to their incredible biodiversity, rainforests are interesting because they tend to create their own microclimates and localized weather.

**Atmosphere: Atmospheric Movement, Layers, Pressure and Cloud Formation, Smog and Pollution**

We live in a complex ocean of air that clings to the surface of our planet and forms our atmosphere. The atmosphere protects all the life on Earth by blocking out dangerous rays from the Sun. The atmosphere is composed of a mixture of gases that are thickest at the surface of the planet and gradually become thinner as they reach space and then disappear. The Earth’s atmosphere is composed mainly of two gases: nitrogen (78%) and oxygen (21%). The remaining 1% is a mix of many other gases.

Oxygen is, perhaps, the most important gas in the atmosphere because it allows animals, including humans, to breathe. Some of the oxygen has gradually been converted into ozone, which is a special form of oxygen. The ozone in the atmosphere is primarily responsible for filtering out the Sun’s harmful rays. A number of recent research studies have shown how humans have caused a hole to form in the ozone layer. This hole allows more dangerous radiation to reach the Earth’s surface.

Another way in which humans are affecting the Earth’s atmosphere is through a process often referred to as the greenhouse effect. Certain gases that we produce with our cars and industry, such as carbon dioxide, trap some of the heat that would normally be radiated away from the Earth. While there is some scientific and political debate about the environmental impact of this greenhouse effect, most atmospheric scientists now believe that the Earth’s atmosphere is having trouble maintaining the balance that has generally existed for millennia. Still, the atmosphere that surrounds us is resilient in response to the various forces that act upon it. How the dynamics of this atmosphere affect the formation of clouds, the appearance of natural light, and even the creation of nuisances like smog is an important piece of the Earth sciences.

**Why Are Clouds White?**

You will learn in Chapter 9 that color is light energy and that when all (or most) of the colors of the visible spectrum (red, orange, yellow, green, blue, indigo, and violet) are present, the light appears white. If an object absorbs some of the wavelengths of the visible spectrum, the color of the object will be something other than white. If all of the wavelengths are absorbed, the object will appear black. Thus, if clouds appear white, they must be reflecting all of the wavelengths of the visible spectrum. But how does this occur? (See Experiment 22.)
In the following activity, you will make a model rainforest in a bottle and observe how water cycles through this ecosystem.

**Materials You Will Need for This Activity**
- Heat lamp
- Small tropical houseplants
- Carrot seeds to simulate fern-like plants
- Bean seeds to simulate vines
- Potting soil
- Plastic 2-liter bottle (the kind with the extra plastic piece on the bottom)
- Ruler

**What You Will Do**
1. Rinse out a plastic 2-liter bottle and cut it in half about in the middle.
2. Pull the colored bottom piece away from the clear plastic.
3. Fill the colored plastic bottom piece with potting soil.
4. Arrange a few small tropical houseplants in the soil and drop carrot and bean seeds around the soil.
5. Add about ¼ cup of water to the soil.
6. Invert the clear plastic rounded part of the bottle and tightly seal it on the colored bottom.
7. The terrarium should remain closed from now on. Do not open it to water or observe.
8. Spread the terrariums for the class in various places so that they have different growing conditions. Place at least a few under a low heat lamp or plant light.
9. Observe your terrarium every day and take measurements of plant growth from the outside of the bottle.
10. Compare the growth in the various terrariums.

**What you will learn:** Plants will not suffocate in a closed container because they can use the same air over and over again. They do not need to be watered because water is also recycled in the terrarium. Plants take water from the soil and then release it through their leaves as water vapor. Normally this water vapor is transported away from the plant, but in a closed container, this vapor turns back into water droplets, drips back into the soil, and can be used all over again by the plants.
Why Is the Sky Blue?

Almost every child has asked his or her parents why the sky is blue. Like most things in nature, the answer to this question has to do with basic physical principles. While the sky is usually blue, it does, in fact, gradually change colors throughout the day. This has to do with the angle at which sunlight is filtered through the atmosphere. (See Experiment 23.)

Making Smog

Have you ever seen a picture of Mexico City or Los Angeles or another big city where the air looks brown with pollution? This kind of air pollution is usually called “smog,” from a combination of the words “smoke” and “fog.” The term “smog” was first used in London in the late 1800s to describe the haze produced by the condensation of water vapor on soot particles from factories.

When the Sun heats two common kinds of air pollutants (hydrocarbons and nitrogen oxides), a chemical reaction takes place that produces smog (which is actually ground-level ozone). More than two-thirds of all the smog-producing pollutants come from the emissions of vehicles. Most of the rest of the pollutants come from smoke stacks and from chemical solvents. Either a lack of wind or a weather condition called a thermal inversion (where the warm air over a city, which would normally rise and escape, gets stopped by another air mass above it that prevents it from escaping) can cause smog to be trapped over an area. Smog has been shown to cause medical problems for people, such as irritation of the respiratory system and aggravation of asthma, emphysema, and other breathing problems. (See Experiment 24.)
In the following activity, you will determine why clouds generally appear white and how this occurs.

Materials You Will Need for This Activity
- Hard candy of various colors
- Hammer
- Magnifying glass
- Paper towels

What You Will Do
1. Observe several pieces of colored hard candy. What do you know about why they appear to be the color that they are?
2. Carefully crush several of the candies into a powder with the hammer (wrapping the candy in a paper towel before hitting it with the hammer will minimize flying candy pieces).
3. Observe the crushed candy pieces closely. Do they still appear to be their original color? Why or why not?
4. You may need to continue to crush the candy. At some point, the pieces will begin to lose their color and turn white. Why is this happening?
5. Use the magnifying glass to compare the sizes of candy pieces that maintain their color and pieces that now appear white. Try using the width of a human hair as a point of comparison. What do you observe?

What you will learn: Clouds reflect all visible wavelengths of the sunlight. Color scattering is usually due to particles whose size is smaller than the wavelength of the light. The water droplets in the clouds are generally many times larger than the wavelength of visible light, and there are many droplets and many surfaces to reflect the light, so the clouds scatter almost all the light and look white.

Core concept demonstrated: Why clouds appear white due to scattering of sunlight off water droplets

Thinking like a scientist: Clouds don’t always appear white. For example, when the Sun is going down, the sky often appears red and this includes the clouds, which sometimes appear bright red. Why do you think this might occur? For a clue, think about this: What will happen if you shine a red flashlight on a white piece of paper? Why?

Correlation With National Science Standards: A.1; B.4; D.3
Experiment 23: Why Is the Sky Blue?

In the following activity, you will demonstrate why the sky is blue during the day and reddish near dawn and dusk.

Materials You Will Need for This Activity

- Clear glass container, about the size of a pitcher (clear plastic can be used, too, but glass works best)
- Flashlight
- Some milk or cream (whole milk or cream works best; if using skim milk, you’ll need to add a bit more)

What You Will Do

1. Fill the container with water and add a few drops of the milk. Mix the milk in completely. Make sure the water is milky enough so that it’s hard to see through the water.
2. Shine the flashlight into one side of the container.
3. Look at the water at a 90° angle from the light beam. Describe the color of the water.
4. To make a comparison, shine the flashlight away from the container for a moment and shine it back in, while looking at the milky water. Does the color of the water change at all?
5. Now look through the container directly at the incoming light.
6. Describe what you observe. Is there a difference in color compared to when you were looking from the side?

What you will learn: The light in the sky is scattered sunlight. The scattering is done by small particles. Even when the sky is “clear,” there are still a great number of molecules and particles in it that can reflect the light, but these particles have a greater ability to reflect at the violet end of the spectrum. Thus, the color of the sky should really appear to be more “purplish,” but our eyes are not very sensitive to violet. They are sensitive to the next most represented color, blue. There are decreasing amounts of green, yellow, and red, so overall, the sky usually appears blue.

Core concept demonstrated: Color scattering

Thinking like a scientist: Now that you understand why the sky appears blue during most of the day (the blue light is scattered because of collisions with molecules and particles in the atmosphere), can you explain why the sky often appears red in the evening shortly before sunset? Think about how much atmosphere the sunlight passes through and how this differs between midday and sunset. What would happen if all the blue light got scattered away before the light got to you?

Correlation With National Science Standards: A.1; A.2; B.3; B.4; D.3; G.1
In the following activity, you will create a model of smog that will demonstrate what it looks like and how it behaves.

**Materials You Will Need for This Activity**

- Clean, dry wide-mouth canning or mayonnaise jar
- Heavy-duty aluminum foil (6” × 6” square)
- 2 or 3 ice cubes
- 6” × 2” strip of paper
- Matches
- Salt

**What You Will Do**

1. Fold the piece of paper in half lengthwise and twist it into a rope.
2. Make a lid for the jar out of the piece of aluminum foil. Put a slight depression in the foil lid where the ice cubes can rest without sliding off.
3. Put a little water in the jar, swish it around to wet the whole inside of the jar, and pour the remaining water out.
4. Light the twisted paper with a match, and drop both the paper and the match into the jar.
5. Quickly put the foil lid on the jar, making as tight a seal as you can, and put the ice cubes on top of the lid.
6. Sprinkle a little salt on the ice to help it melt.
7. Observe and describe what you see taking place in the jar. Draw a sketch.

**What you will learn:** Fog (a low lying cloud) is formed when warm, moist air is cooled. If smoke particles are present at the same time, then the smoke will mix with the fog, producing smog.

**Core concept demonstrated:** Creation and appearance of smog

**Thinking like a scientist:** How does vehicle use affect smog levels? Do you think that all vehicles contribute the same amount to smog production? Why or why not? Why are some cities, such as Mexico City, Los Angeles, and Denver, particularly prone to being blanketed in a layer of smog? Why was smog more common in London 150 years ago than it is today?

What do you think people with breathing problems should do on particularly smoggy days?

**Correlation With National Science Standards:** A.1; B.4; D.3; F.1; F.4; F.8
Water and Oceans: Fresh Water/Salt Water Distribution, Interactions, and Contamination

It has often been noted that when viewed from the far reaches of space, the Earth looks like a big blue marble. Any extraterrestrial visitor coming upon the Earth would identify it as our solar system’s ocean planet. The oceans cover approximately 140,000,000 square miles, or 72% of the Earth’s surface. While all of the oceans are, in fact, connected, geographers have traditionally identified five distinct oceans: the Antarctic, Arctic, Atlantic, Indian, and Pacific Oceans.

The Pacific Ocean is far and away the largest of the oceans, covering nearly 35% of the Earth, or nearly half of the ocean surface. The Pacific Ocean stretches from Asia in the west to North and South America in the east. The Atlantic Ocean is the second largest, covering nearly 21% of the Earth’s surface. The Atlantic Ocean stretches from North and South America to Europe and Africa. The Indian Ocean is the third largest, covering 15% of the Earth’s surface and stretching from Africa to Asia. The Antarctic Ocean (also known as the Southern Ocean) circles the globe, surrounding Antarctica. Finally, the Arctic Ocean covers the Earth’s North Pole, and includes the great Arctic icecap and many icebergs.

The oceans play many important functions in the Earth’s dynamic systems, such as influencing the planet’s weather and temperature. For example, the ocean currents distribute the Sun’s heat energy more evenly around the globe, heating the land and air during winter and cooling it during the summer. The chemical composition of the oceans, the tidal movements and currents, and the geology and life below the ocean surface are all core concepts in the Earth sciences.

How Salty Is the Ocean?

Water from rain runs through the soil and across the ground as it makes its way into streams and rivers. Water in rivers runs across the riverbed as it flows toward the sea. Throughout this process, the flowing water picks up small amounts of mineral salts from the rocks and soil of the ground. This very slightly salty water flows into the oceans and seas. Once in the ocean, this water only leaves by evaporating or by freezing into polar ice. In either case, the salt remains behind, dissolved in the ocean; it does not evaporate. Thus, the remaining seawater gets saltier and saltier. Over the history of the Earth, this process has led to the increasing concentration of salt in the oceans.

Salt, as a mineral, can literally be mined from the sea through evaporation of seawater, releasing fresh water into the atmosphere and leaving the salt crystals behind. Thus, rain is never salty even though most of the water that makes rain is evaporated out of the oceans. But just how salty is the ocean? The oceans
are about three and a half percent salt (by weight). Salinity is generally reported in parts per thousand (ppt), which is equivalent to the number of pounds of salt per 1,000 pounds of water. The average ocean salinity is 35 ppt. (See Experiment 25.)

Probing the Ocean Floor
There is a famous parable about three men who are blind and who try to describe an elephant while each one holds a different part of the elephant's body. One man feels the elephant’s trunk and says that an elephant is like a snake, one grasps its tail and claims an elephant is like a rope, and the third grabs its leg and says an elephant is like a tree. In fact, each has described a part of the animal but none has gotten a complete picture. This experience is very much like the process of sampling the sea floor with probes, like oceanographers did before the recent inventions of satellite imaging and global positioning system (GPS) technology. (See Experiment 26.)

Oil Spill Clean-Up Activity
In March, 1989, the oil tanker *Exxon Valdez* ran aground on a reef in Alaska’s Prince William Sound, rupturing its hull and spilling nearly 11 million gallons of oil into the sea. This remains the largest oil spill ever to occur in U.S. waters and one of the largest anywhere in the world.

In addition to major oil spills like the *Exxon Valdez*, however, small oil spills in marine waters occur frequently, and their cumulative impact can also be quite large. These small spills generally receive little media attention and are rarely reported or cleaned up.

When oil spills in the ocean it floats on the surface (oil usually floats on fresh water as well). Oil usually spreads out quickly from the spill and forms a thin layer called an oil slick that gets thinner and thinner as it spreads farther and farther out.

Spilled oil can be extremely damaging to the environment and especially to the marine life that makes its home near where oil is spilled. There are many famous pictures from the aftermath of the *Exxon Valdez* spill of birds, otters, and other marine life dead or dying from being covered in oil.

Cleaning up an oil spill, however, is very difficult. The equipment used includes “booms,” which are floating barriers that can be placed around a tanker that is leaking to collect the oil; “skimmers,” which are boats that skim spilled oil off the water’s surface; and “sorbents,” which are like big sponges used to absorb oil. Chemical and biological agents can also be used to break down the oil into less hazardous chemical components. (See Experiment 27.)
Experiment 25: How Salty Is Too Salty?

In the following activity, you will compare the salt content of fresh, brackish, and ocean water.

Materials You Will Need for This Activity

- 3 glasses
- Water
- Salt
- Measuring spoon

What You Will Do

1. Fill three clean eight-ounce glasses with water from the sink.
2. Label the first glass “fresh,” the second glass “brackish,” and the third glass “ocean.”
3. Add nothing to the first glass; add \(\frac{1}{8}\) teaspoon of salt to the second glass; add one teaspoon of salt to the third glass.
4. Take a sip from each glass and describe the taste.
5. Do you taste any salt in the “fresh” water glass? Is the “brackish” water drinkable? Is the “ocean” water drinkable?

* Safety Note—Be careful not to swallow the salt water because ingesting too much salt can make you sick.

What you will learn: Freshwater salinity is usually less than 0.5 ppt. Water between 0.5 ppt and 17 ppt is called brackish and exists in the mixing zones where fresh river water meets with salty ocean water. The average ocean salinity is 35 ppt. This number varies between about 32 and 37 ppt. Rainfall, evaporation, river runoff, and ice formation cause these variations.

Core concept demonstrated: Salinity of fresh, brackish, and sea water

Thinking like a scientist: The Red Sea and the Persian Gulf have the saltiest seawater while the oceans in the polar regions are the least salty. Look at these regions on a globe—what might explain the greater and lesser salt concentrations? Why can’t freshwater fish survive in sea water or ocean fish in fresh water? What must brackish water fish do when the tide moves in and out?

Correlation With National Science Standards: B.4; C.8; D.1; F.7
Experiment 26: Mapping the Ocean Floor

In the following activity, you will simulate how sonar has been used to map the surface of the sea floor.

Materials You Will Need for This Activity

- Graph paper
- Box of colored pencils
- A wooden dowel
- A completed shoebox (prepared in advance by teacher—this is done by spreading modeling clay or play dough across the bottom of the box to create whatever landforms are desired, such as mountains, plateaus, trenches, etc. To create the box lid, poke 3 rows of regularly spaced holes in the lid that are the correct size for the wooden dowel to fit through but small enough to prevent “spying”)
- Ruler
- Modeling clay or play dough

What You Will Do

1. The shoebox has three rows of holes. Select one row to test first.
2. Insert the wooden dowel in the first hole of the row and measure the depth from the ocean surface (box lid) by marking it with your finger. Pull the dowel out and measure the distance from the end of the dowel to your finger. Record this data in a data table and on your graph paper.
3. Use the same procedure for each hole in the first row. Connect the dots on the graph to see the estimated topography of the sea floor underneath your first row of holes.
4. Using this one row of measurements, predict what the sea floor in the rest of the shoebox might look like.
5. Repeat the same testing procedure for the second row of holes, but use a different colored pencil on the graph. Compare your results from the first two rows. Are they the same? Does this change your prediction of what the rest of the sea floor in the box looks like?
6. Now, repeat the same testing procedure for the last row of holes, again using a different colored pencil on the graph.
7. When everything has been measured and graphed, open your shoebox and examine the bottom. Compare the results of your graph with the actual bottom of the shoebox.
What you will learn: Using a probing method that collects equally spaced data points will normally give a fairly good estimate of what is being probed. It is possible, however, that entire important features will be missed if they happen to fall between the probe points.

Core concept demonstrated: Strategies for getting information about difficult-to-observe locations such as the sea floor.

Thinking like a scientist: How accurate or inaccurate were your predictions about your sea floor? Were some groups’ predictions more accurate than others? Why do you think this was? If you needed to increase the accuracy of your prediction, how might you change your data collection?

Correlation With National Science Standards: A.1; A.2; B.2; D.4; E.2; E.3; F.5; G.1; G.3

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**Experiment 27: Oil Spill Clean-Up**

In the following activity, you will simulate the clean-up of an oil spill.

**Materials You Will Need for This Activity**

- Flat aluminum pan
- Cotton balls
- String
- Spoon
- Medicine dropper
- Piece of nylon stocking
- Piece of cardboard
- Straw (or dry grass)
- Drinking straws
- Plastic gloves
- Piece of sponge
- Cat litter
- Paper towels
- Plastic bags
- Salad oil

**What You Will Do**

1. You will pretend that each group has been contracted to control or eliminate an oil spill that has just occurred in the ocean. You will have several materials to work with and can choose among them.
2. Fill the pans with water.
3. Lay out and discuss all the possible clean-up materials that can be used.
4. Predict which material(s) will be the most successful in cleaning up the oil spill. Each group should decide in advance what method they want to try first.

(Continued)
5. Pour a small amount (about 10 ml) of salad oil on the surface of the water. Together, the group members should attempt the cleanup using the method decided upon.
6. After about two minutes, assess the level of clean-up that has taken place in each group so far. At this point, groups can try other materials or other strategies or stick with the same strategy.
7. After another two minutes, check the results again.
8. As an extension, a simulation can be done of cleaning up the spill in “rough water.” Repeat the clean-up process while one member of the group gently shakes the pan.

What you will learn: Oil spills are extremely difficult to clean up. A number of materials and techniques are used in attempts to clean up spills, but none are 100% effective. As the size of the actual spill increases and the location and/or conditions around the spill become more challenging, the effectiveness of the clean-up efforts are likely to decrease.

Core concept demonstrated: Oil spills and their consequences

Thinking like a scientist: Which materials and methods seemed to be the most effective at cleaning up the spill? Why do you think this method worked best?
Which materials and methods seemed to be the least effective at cleaning up the spill? Why do you think this method did not work well?
Can you think of any new methods that could be invented to make the clean-up more effective?

Correlation With National Science Standards: A.1; A.2; B.4; C.3; D.1; E.2; F.6; F.7; F.8; F.10; G.1

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Reflections on Science

1. In the introduction to this chapter, we discussed five major Earth systems that together make up the whole of our dynamic Earth system:
   - The biosphere—all of Earth’s living organisms
   - The atmosphere—Earth’s relatively thin covering of gases
   - The lithosphere—Earth’s surface and interior
   - The hydrosphere—Earth’s circulating water systems
   - The energy system—the energy that powers all Earth’s systems

What have you learned in this chapter about each of these systems and the role that each plays in the larger Earth system?

2. At the university level, astronomy is generally considered to be a part of physics. At the K–12 level, space science is generally taught with Earth science. Why do you think this might be?

3. Earth science tends to address topics that are more geographically localized than topics in the other science disciplines. For example, earthquakes, hurricanes, volcanoes, mountains, beach erosion, saltwater intrusion, and so on are topics that are directly observed and experienced by students in some parts of the country (and the world) but not in others. Is it important to teach these topics to students in all places, regardless of any direct experience they may have with these phenomena, or should Earth science education be taught in a more localized and targeted way? Explain your answer.
Internet Connections: Earth and Space Science

The following Web sites provide additional resources that may prove useful in teaching Earth and space science:

United States Geological Survey (USGS) Science Resources for Primary Grades (K–6)—a range of activities and information
http://education.usgs.gov/common/primary.htm

United States Geological Survey (USGS) Educational Resources for Secondary Grades—a range of more advanced activities and information useful for middle school and for teacher background knowledge
http://education.usgs.gov/common/secondary.htm

Geological Society of America (GSA) Resources for K–12 Earth Science

Educators—activities, information, and resources
http://www.geosociety.org/educate/resources.htm

Mineral Information Institute Resources for Teachers—lesson plans and activities to teach about minerals and their uses
http://www.mii.org/teacherhelpers.html

NASA education and public outreach site for studies of the Earth’s magnetic field
http://image.gsfc.nasa.gov/poetry/

Center for Educational Resources (CERES) Project—activities, information, and support for teaching astronomy in K–12 education
http://btc.montana.edu/ceres/

Franklin Institute’s Space Science Hot List—many links to information on space science, organized by topic
http://sln.fi.edu/tfi/hotlists/space.html