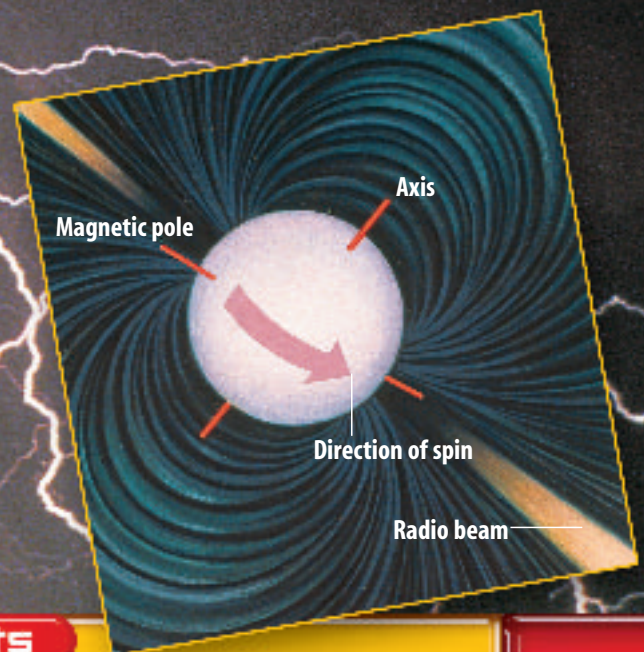




How Are Thunderstorms & Neutron Stars Connected?

In 1931, an engineer built an antenna to study thunderstorm static that was interfering with radio communication. The antenna did detect static from storms, but it also picked up something else: radio signals coming from beyond our solar system. That discovery marked the birth of radio astronomy. By the 1960s, radio astronomy was thriving. In 1967, astronomer Jocelyn Bell Burnell detected a peculiar series of radio pulses coming from far out in space. At first, she and her colleagues theorized that the signals might be a message from a distant civilization. Soon, however, scientists determined that the signals must be coming from something called a neutron star (below)—a rapidly spinning star that gives off a radio beam from its magnetic pole, similar to the rotating beam of a lighthouse.



unit projects

Visit blue.msscience.com/unit_project to find project ideas and resources. Projects include:

- **Career** Discover what is required to have a career in space exploration or space technology. Design an interview and present your findings to the class.
- **Technology** Research interesting information describing the planet of your choice in a newspaper article.
- **Model** After a thorough investigation of an existing neutron star, design a creative mobile to display your research information.



Sun and Energy uses online resources to explore the composition of the Sun and the possibilities of harnessing its energy for

everyday use

CONTENTS

(background)Steve Murray/PictureQuest, (cr)Davis Meltzer



The Sun-Earth-Moon System



chapter preview

sections

- 1 Earth
 - 2 The Moon—Earth's Satellite
Lab Moon Phases and Eclipses
 - 3 Exploring Earth's Moon
Lab Tilt and Temperature
-  **Virtual Lab** How do Earth and the Moon interact to cause the Moon's phases?

Full Moon Rising— The Real Story

Why does the Moon's appearance change throughout the month? Do the Sun and Moon really rise? You will find the answers to these questions and also learn why we have summer and winter.

Science Journal Rotation or revolution—which motion of Earth brings morning and which brings summer?

Start-Up Activities



Model Rotation and Revolution

The Sun rises in the morning; at least, it seems to. Instead, it is Earth that moves. The movements of Earth cause day and night, as well as the seasons. In this lab, you will explore Earth's movements.

1. Hold a basketball with one finger at the top and one at the bottom. Have a classmate gently spin the ball.
2. Explain how this models Earth's rotation.
3. Continue to hold the basketball and walk one complete circle around another student in your class.
4. How does this model Earth's revolution?
5. **Think Critically** Write a paragraph in your Science Journal describing how these movements of the basketball model Earth's rotation and revolution.



Preview this chapter's content and activities at blue.msscience.com

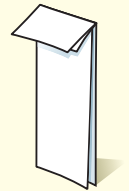
FOLDABLES™ Study Organizer

Earth and the Moon All on Earth can see and feel the movements of Earth and the Moon as they circle the Sun. Make the following Foldable to organize what you learn about these movements and their effects.

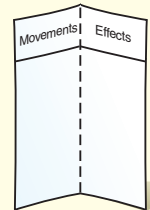
STEP 1 Fold a sheet of paper in half lengthwise.



STEP 2 Fold paper down 2.5 cm from the top. (Hint: From the tip of your index finger to your middle knuckle is about 2.5 cm.)



STEP 3 Open and draw lines along the 2.5-cm fold. Label as shown.



Summarize in a Table As you read the chapter, summarize the movements of Earth and the Moon in the left column and the effects of these movements in the right column.



as you read

What You'll Learn

- **Examine** Earth's physical characteristics.
- **Differentiate** between rotation and revolution.
- **Discuss** what causes seasons to change.

Why It's Important

Your life follows the rhythm of Earth's movements.

**Review Vocabulary**

orbit: the path taken by an object revolving around another

New Vocabulary

- sphere
- axis
- rotation
- revolution
- ellipse
- solstice
- equinox

Figure 1 For many years, sailors have observed that the tops of ships coming across the horizon appear first. This suggests that Earth is spherical, not flat, as was once widely believed.

Properties of Earth

You awaken at daybreak to catch the Sun “rising” from the dark horizon. Then it begins its daily “journey” from east to west across the sky. Finally the Sun “sinks” out of view as night falls. Is the Sun moving—or are you?

It wasn't long ago that people thought Earth was the center of the universe. It was widely believed that the Sun revolved around Earth, which stood still. It is now common knowledge that the Sun only appears to be moving around Earth. Because Earth spins as it revolves around the Sun, it creates the illusion that the Sun is moving across the sky.

Another mistaken idea about Earth concerned its shape. Even as recently as the days of Christopher Columbus, many people believed Earth to be flat. Because of this, they were afraid that if they sailed far enough out to sea, they would fall off the edge of the world. How do you know this isn't true? How have scientists determined the true shape of Earth?

Spherical Shape A round, three-dimensional object is called a **sphere** (SFIHR). Its surface is the same distance from its center at all points. Some common examples of spheres are basketballs and tennis balls.

In the late twentieth century, artificial satellites and space probes sent back pictures showing that Earth is spherical. Much earlier, Aristotle, a Greek astronomer and philosopher who lived around 350 B.C., suspected that Earth was spherical. He observed that Earth cast a curved shadow on the Moon during an eclipse.

In addition to Aristotle, other individuals made observations that indicated Earth's spherical shape. Early sailors, for example, noticed that the tops of approaching ships appeared first on the horizon and the rest appeared gradually, as if they were coming over the crest of a hill, as shown in **Figure 1**.





Additional Evidence Sailors also noticed changes in how the night sky looked. As they sailed north or south, the North Star moved higher or lower in the sky. The best explanation was a spherical Earth.

Today, most people know that Earth is spherical. They also know all objects are attracted by gravity to the center of a spherical Earth. Astronauts have clearly seen the spherical shape of Earth. However, it bulges slightly at the equator and is somewhat flattened at the poles, so it is not a perfect sphere.

Rotation Earth's **axis** is the imaginary vertical line around which Earth spins. This line cuts directly through the center of Earth, as shown in the illustration accompanying **Table 1**. The poles are located at the north and south ends of Earth's axis. The spinning of Earth on its axis, called **rotation**, causes day and night to occur. Here is how it works. As Earth rotates, you can see the Sun come into view at daybreak. Earth continues to spin, making it seem as if the Sun moves across the sky until it sets at night. During night, your area of Earth has rotated so that it is facing away from the Sun. Because of this, the Sun is no longer visible to you. Earth continues to rotate steadily, and eventually the Sun comes into view again the next morning. One complete rotation takes about 24 h, or one day. How many rotations does Earth complete during one year? As you can infer from **Table 1**, it completes about 365 rotations during its one-year journey around the Sun.



Earth's Rotation

Suppose that Earth's rotation took twice as long as it does now. In your Science Journal, predict how conditions such as global temperatures, work schedules, plant growth, and other factors might change under these circumstances.

Reading Check Why does the Sun seem to rise and set?

Table 1 Physical Properties of Earth

Diameter (pole to pole)	12,714 km
Diameter (equator)	12,756 km
Circumference (poles)	40,008 km
Circumference (equator)	40,075 km
Mass	5.98×10^{24} kg
Average density	5.52 g/cm ³
Average distance to the Sun	149,600,000 km
Period of rotation (1 day)	23 h, 56 min
Period of revolution (1 year)	365 days, 6 h, 9 min

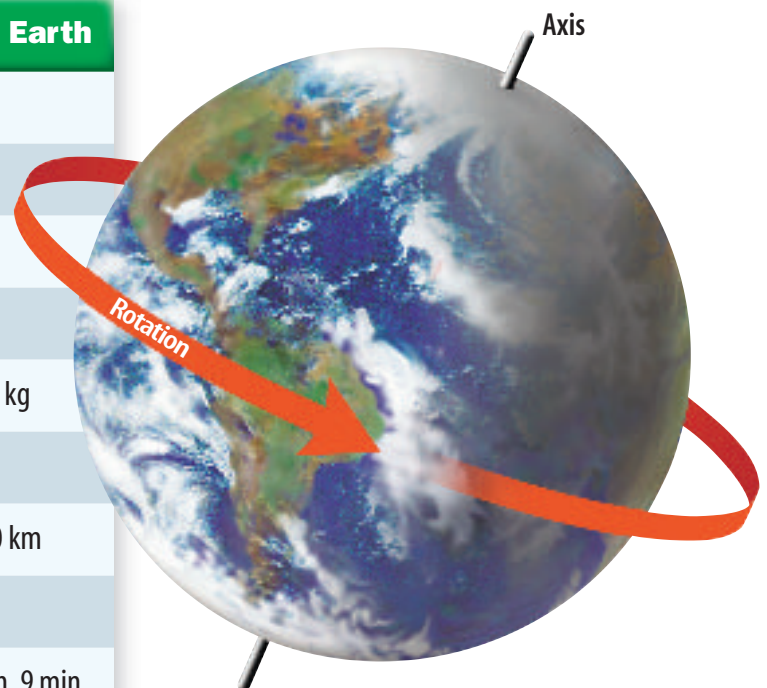
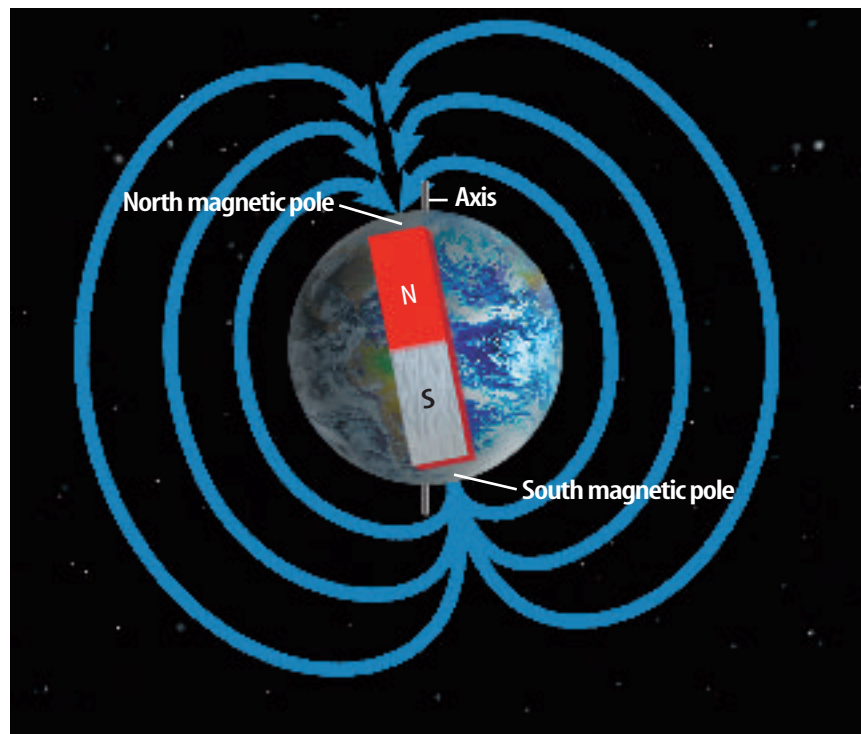




Figure 2 Earth's magnetic field is similar to that of a bar magnet, almost as if Earth contained a giant magnet. Earth's magnetic axis is angled 11.5 degrees from its rotational axis.



Mini LAB

Making Your Own Compass

Procedure



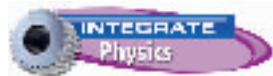
WARNING: Use care when handling sharp objects.

1. Cut off the bottom of a **plastic foam cup** to make a polystyrene disk.
2. Magnetize a **sewing needle** by continuously stroking the needle in the same direction with a **magnet** for 1 min.
3. **Tape** the needle to the center of the foam disk.
4. Fill a **plate** with **water** and float the disk, needle side up, in the water.

Analysis

1. What happened to the needle and disk when you placed them in the water? Why did this happen?
2. Infer how ancient sailors might have used magnets to help them navigate on the open seas.

Magnetic Field



Scientists hypothesize that the movement of material inside Earth's core, along with Earth's rotation, generates a magnetic field. This magnetic field is much like that of a bar magnet. Earth has a north and a south magnetic pole, just as a bar magnet has opposite magnetic poles at each of its ends. When you sprinkle iron shavings over a bar magnet, the shavings align with the magnetic field of the magnet. As you can see in **Figure 2**, Earth's magnetic field is similar—almost as if Earth contained a giant bar magnet. Earth's magnetic field protects you from harmful solar radiation by trapping many charged particles from the Sun.

Magnetic Axis When you observe a compass needle pointing north, you are seeing evidence of Earth's magnetic field. Earth's magnetic axis, the line joining its north and south magnetic poles, does not align with its rotational axis. The magnetic axis is inclined at an angle of 11.5° to the rotational axis. If you followed a compass needle, you would end up at the magnetic north pole rather than the rotational north pole.

The location of the magnetic poles has been shown to change slowly over time. The magnetic poles move around the rotational (geographic) poles in an irregular way. This movement can be significant over decades. Many maps include information about the position of the magnetic north pole at the time the map was made. Why would this information be important?



What causes changing seasons?

Flowers bloom as the days get warmer. The Sun appears higher in the sky, and daylight lasts longer. Spring seems like a fresh, new beginning. What causes these wonderful changes?

Orbiting the Sun You learned earlier that Earth's rotation causes day and night. Another important motion is **revolution**, which is Earth's yearly orbit around the Sun. Just as the Moon is Earth's satellite, Earth is a satellite of the Sun. If Earth's orbit were a circle with the Sun at the center, Earth would maintain a constant distance from the Sun. However, this is not the case. Earth's orbit is an **ellipse** (ee LIHPS)—an elongated, closed curve. The Sun is not at the center of the ellipse but is a little toward one end. Because of this, the distance between Earth and the Sun changes during Earth's yearlong orbit. Earth gets closest to the Sun—about 147 million km away—around January 3. The farthest Earth gets from the Sun is about 152 million km away. This happens around July 4 each year.

 **Reading Check** What is an ellipse?

Does this elliptical orbit cause seasonal temperatures on Earth? If it did, you would expect the warmest days to be in January. You know this isn't the case in the northern hemisphere, something else must cause the change.

Even though Earth is closest to the Sun in January, the change in distance is small. Earth is exposed to almost the same amount of Sun all year. But the amount of solar energy any one place on Earth receives varies greatly during the year. Next, you will learn why.

A Tilted Axis Earth's axis is tilted 23.5° from a line drawn perpendicular to the plane of its orbit. It is this tilt that causes seasons. The number of daylight hours is greater for the hemisphere, or half of Earth, that is tilted toward the Sun. Think of how early it gets dark in the winter compared to the summer. As shown in **Figure 3**, the hemisphere that is tilted toward the Sun receives more hours of sunlight each day than the hemisphere that is tilted away from the Sun. The longer period of sunlight is one reason summer is warmer than winter, but it is not the only reason.

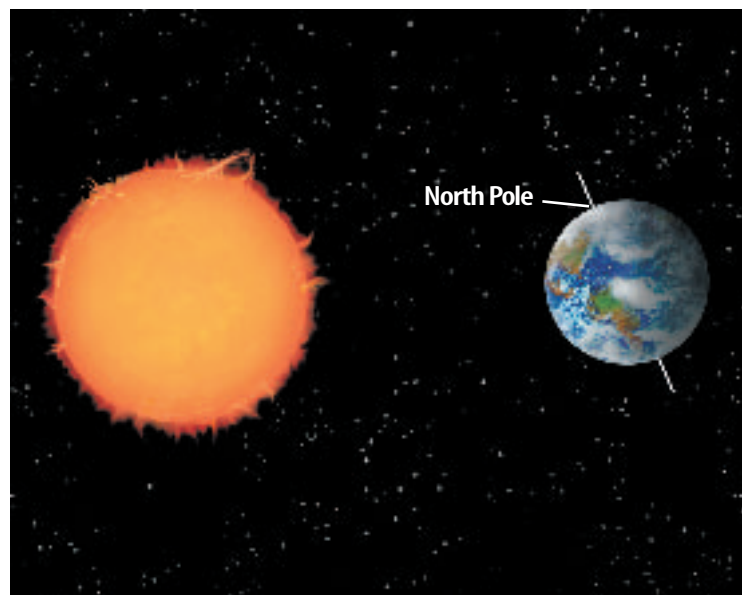


Figure 3 In summer, the northern hemisphere is tilted toward the Sun. Notice that the north pole is always lit during the summer.

Observe Why is there a greater number of daylight hours in the summer than in the winter?



Topic: Ellipses

Visit blue.msscience.com for Web links to information about orbits and ellipses.

Activity Scientists compare orbits by how close they come to being circular. To do this, they use a measurement called eccentricity. A circle has an eccentricity of zero. Ellipses have eccentricities that are greater than zero, but less than one. The closer the eccentricity is to one, the more elliptical the orbit. Compare the orbits of the four inner planets. List them in order of increasing eccentricity.



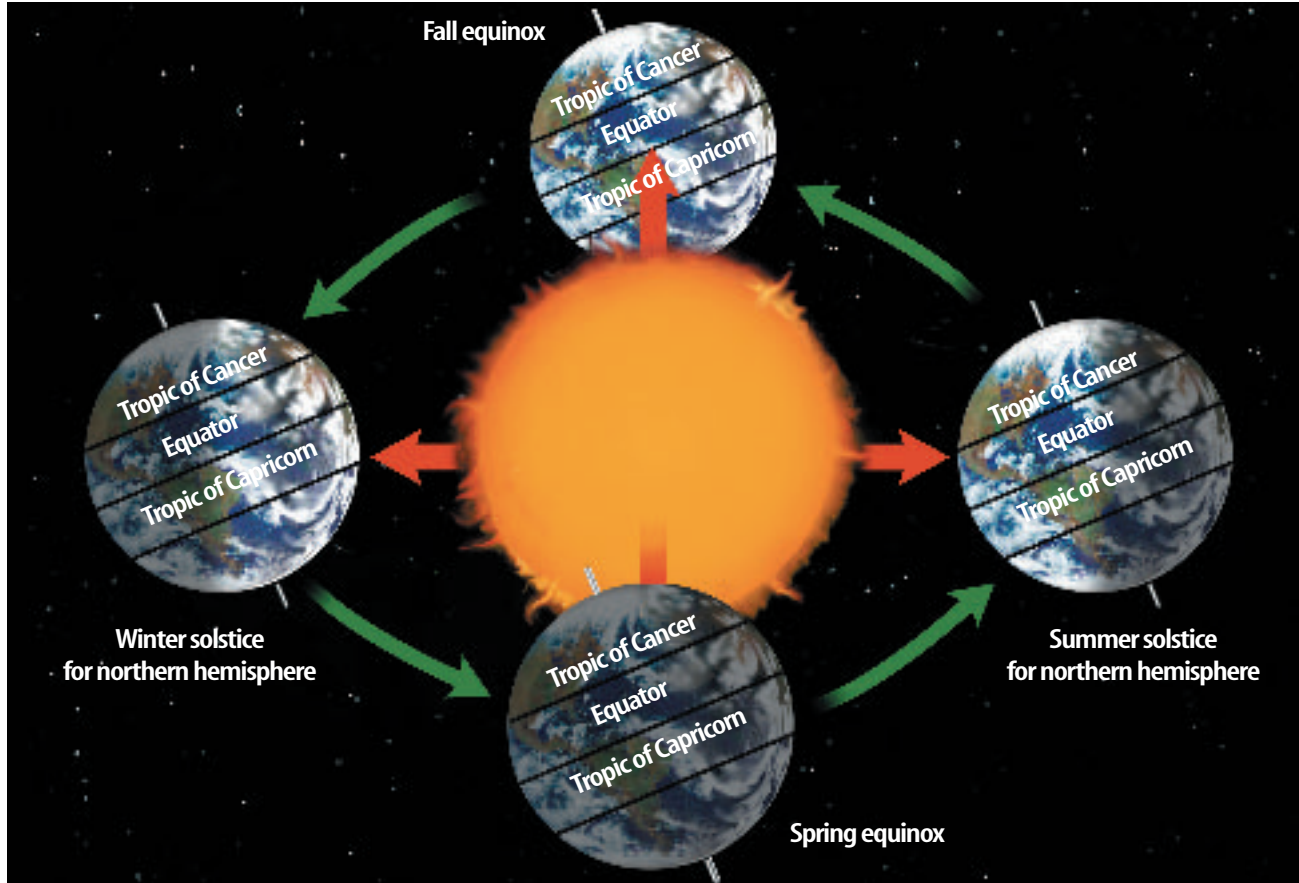
Radiation from the Sun Earth's tilt also causes the Sun's radiation to strike the hemispheres at different angles. Sunlight strikes the hemisphere tilted towards the Sun at a higher angle, that is, closer to 90 degrees, than the hemisphere tilted away. Thus it receives more total solar radiation than the hemisphere tilted away from the Sun, where sunlight strikes at a lower angle.

Summer occurs in the hemisphere tilted toward the Sun, when its radiation strikes Earth at a higher angle and for longer periods of time. The hemisphere receiving less radiation experiences winter.

Solstices

The **solstice** is the day when the Sun reaches its greatest distance north or south of the equator. In the northern hemisphere, the summer solstice occurs on June 21 or 22, and the winter solstice occurs on December 21 or 22. Both solstices are illustrated in **Figure 4**. In the southern hemisphere, the winter solstice is in June and the summer solstice is in December. Summer solstice is about the longest period of daylight of the year. After this, the number of daylight hours become less and less, until the winter solstice, about the shortest period of daylight of the year. Then the hours of daylight start to increase again.

Figure 4 During the summer solstice in the northern hemisphere, the Sun is directly over the tropic of Cancer, the latitude line at 23.5° N latitude. During the winter solstice, the Sun is directly over the tropic of Capricorn, the latitude line at 23.5° S latitude. At fall and spring equinoxes, the Sun is directly over the equator.





Equinoxes

An **equinox** (EE kwuh nahks) occurs when the Sun is directly above Earth's equator. Because of the tilt of Earth's axis, the Sun's position relative to the equator changes constantly. Most of the time, the Sun is either north or south of the equator, but two times each year it is directly over it, resulting in the spring and fall equinoxes. As you can see in **Figure 4**, at an equinox the Sun strikes the equator at the highest possible angle, 90° .

During an equinox, the number of daylight hours and nighttime hours is nearly equal all over the world. Also at this time, neither the northern hemisphere nor the southern hemisphere is tilted toward the Sun.

In the northern hemisphere, the Sun reaches the spring equinox on March 20 or 21, and the fall equinox occurs on September 22 or 23. In the southern hemisphere, the equinoxes are reversed. Spring occurs in September and fall occurs in March.

Earth Data Review As you have learned, Earth is a sphere that rotates on a tilted axis. This rotation causes day and night. Earth's tilted axis and its revolution around the Sun cause the seasons. One Earth revolution takes one year. In the next section, you will read how the Moon rotates on its axis and revolves around Earth.



Topic: Seasons

Visit blue.mssscience.com for Web links to information about the seasons.

Activity Make a poster describing how the seasons differ in other parts of the world. Show how holidays might be celebrated differently and how farming might vary between hemispheres.

section 1 review

Summary

Properties of Earth

- Earth is a slightly flattened sphere that rotates around an imaginary line called an axis.
- Earth has a magnetic field, much like a bar magnet.
- The magnetic axis of Earth differs from its rotational axis.

Seasons

- Earth revolves around the Sun in an elliptical orbit.
- The tilt of Earth's axis and its revolution cause the seasons.
- Solstices are days when the Sun reaches its farthest points north or south of the equator.
- Equinoxes are the points when the Sun is directly over the equator.

Self Check

1. **Explain** why Aristotle thought Earth was spherical.
2. **Compare and contrast** rotation and revolution.
3. **Describe** how Earth's distance from the Sun changes throughout the year. When is Earth closest to the Sun?
4. **Explain** why it is summer in Earth's northern hemisphere at the same time it is winter in the southern hemisphere.
5. **Think Critically** **Table 1** lists Earth's distance from the Sun as an average. Why isn't an exact measurement available for this distance?

Applying Skills

6. **Classify** The terms *clockwise* and *counterclockwise* are used to indicate the direction of circular motion. How would you classify the motion of the Moon around Earth as you view it from above Earth's north pole? Now try to classify Earth's movement around the Sun.



The Moon— Earth's Satellite

as you read

What You'll Learn

- **Identify** phases of the Moon and their cause.
- **Explain** why solar and lunar eclipses occur.
- **Infer** what the Moon's surface features may reveal about its history.

Why It's Important

Learning about the Moon can teach you about Earth.



Review Vocabulary

mantle: portion of the interior of a planet or moon lying between the crust and core

New Vocabulary

- | | |
|--------------|-----------------|
| ● moon phase | ● waning |
| ● new moon | ● solar eclipse |
| ● waxing | ● lunar eclipse |
| ● full moon | ● maria |

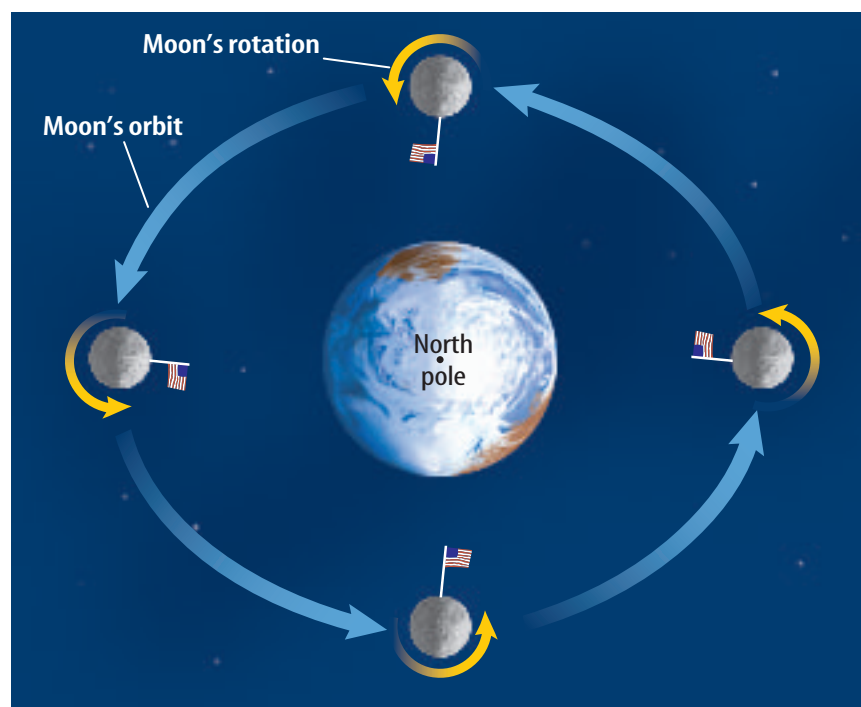
Figure 5 In about 27.3 days, the Moon orbits Earth. It also completes one rotation on its axis during the same period.

Think Critically Explain how this affects which side of the Moon faces Earth.

Motions of the Moon

Just as Earth rotates on its axis and revolves around the Sun, the Moon rotates on its axis and revolves around Earth. The Moon's revolution around Earth is responsible for the changes in its appearance. If the Moon rotates on its axis, why can't you see it spin around in space? The reason is that the Moon's rotation takes 27.3 days—the same amount of time it takes to revolve once around Earth. Because these two motions take the same amount of time, the same side of the Moon always faces Earth, as shown in **Figure 5**.

You can demonstrate this by having a friend hold a ball in front of you. Direct your friend to move the ball in a circle around you while keeping the same side of it facing you. Everyone else in the room will see all sides of the ball. You will see only one side. If the moon didn't rotate, we would see all of its surface during one month.





Reflection of the Sun The Moon seems to shine because its surface reflects sunlight. Just as half of Earth experiences day as the other half experiences night, half of the Moon is lighted while the other half is dark. As the Moon revolves around Earth, you see different portions of its lighted side, causing the Moon's appearance to change.

Phases of the Moon

Moon phases are the different forms that the Moon takes in its appearance from Earth. The phase depends on the relative positions of the Moon, Earth, and the Sun, as seen in **Figure 6** on the next page. A **new moon** occurs when the Moon is between Earth and the Sun. During a new moon, the lighted half of the Moon is facing the Sun and the dark side faces Earth. The Moon is in the sky, but it cannot be seen. The new moon rises and sets with the Sun.



Reading Check

Why can't you see a new moon?

Waxing Phases After a new moon, the phases begin waxing. **Waxing** means that more of the illuminated half of the Moon can be seen each night. About 24 h after a new moon, you can see a thin slice of the Moon. This phase is called the waxing crescent. About a week after a new moon, you can see half of the lighted side of the Moon, or one quarter of the Moon's surface. This is the first quarter phase.

The phases continue to wax. When more than one quarter is visible, it is called waxing *gibbous* after the Latin word for "humpbacked." A **full moon** occurs when all of the Moon's surface facing Earth reflects light.

Waning Phases After a full moon, the phases are said to be waning. When the Moon's phases are **waning**, you see less of its illuminated half each night. Waning gibbous begins just after a full moon. When you can see only half of the lighted side, it is the third-quarter phase. The Moon continues to appear to shrink. Waning crescent occurs just before another new moon. Once again, you can see only a small slice of the Moon.

It takes about 29.5 days for the Moon to complete its cycle of phases. Recall that it takes about 27.3 days for the Moon to revolve around Earth. The discrepancy between these two numbers is due to Earth's revolution. The roughly two extra days are what it takes for the Sun, Earth, and Moon to return to their same relative positions.



Comparing the Sun and the Moon

Procedure

1. Find an area where you can make a chalk mark on **pavement or similar surface**.
2. Tie a piece of **chalk** to one end of a 200-cm-long **string**.
3. Hold the other end of the string to the pavement.
4. Have a friend pull the string tight and walk around you, drawing a circle (the Sun) on the pavement.
5. Draw a 1-cm-diameter circle in the middle of the larger circle (the Moon).

Analysis

1. How big is the Sun compared to the Moon?
2. The diameter of the Sun is 1.39 million km. The diameter of Earth is 12,756 km. Draw two new circles modeling the sizes of the Sun and Earth. What scale did you use?





Figure 6 The phases of the Moon change during a cycle that lasts about 29.5 days.

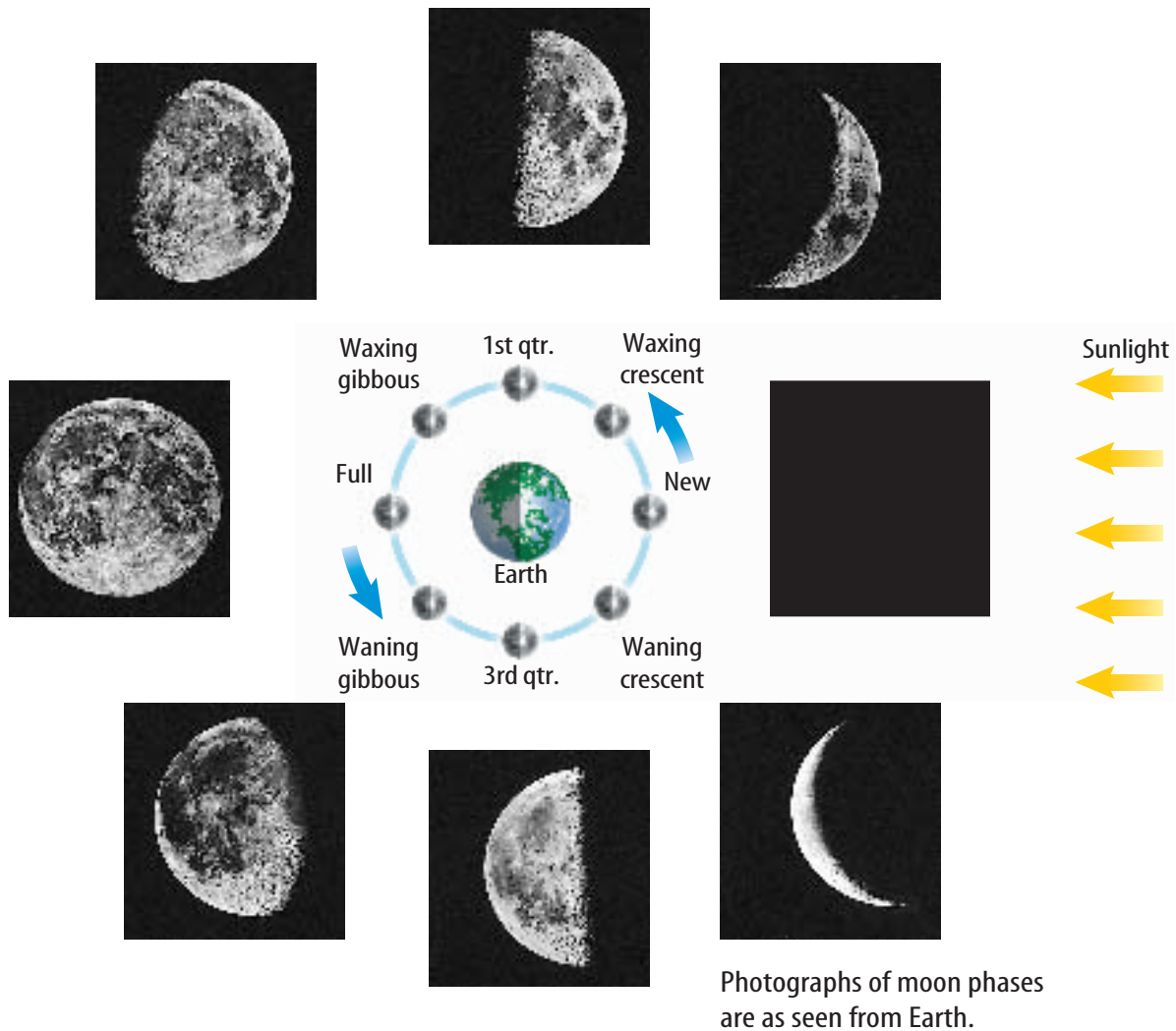


Figure 7 The outer portion of the Sun's atmosphere is visible during a total solar eclipse. It looks like a halo around the Moon.



Eclipses

Imagine living 10,000 years ago. You are foraging for nuts and fruit when unexpectedly the Sun disappears from the sky. The darkness lasts only a short time, and the Sun soon returns to full brightness. You know something strange has happened, but you don't know why. It will be almost 8,000 years before anyone can explain what you just experienced.

The event just described was a total solar eclipse (ih KLIPS), shown in **Figure 7**. Today, most people know what causes such eclipses, but without this knowledge, they would have been terrifying events. During a solar eclipse, many animals act as if it is nighttime. Cows return to their barns and chickens go to sleep. What causes the day to become night and then change back into day?



Reading Check

What happens during a total solar eclipse?



What causes an eclipse? The revolution of the Moon causes eclipses. Eclipses occur when Earth or the Moon temporarily blocks the sunlight from reaching the other. Sometimes, during a new moon, the Moon's shadow falls on Earth and causes a solar eclipse. During a full moon, Earth's shadow can be cast on the Moon, resulting in a lunar eclipse.

An eclipse can occur only when the Sun, the Moon, and Earth are lined up perfectly. Because the Moon's orbit is not in the same plane as Earth's orbit around the Sun, lunar eclipses occur only a few times each year.

Eclipses of the Sun A **solar eclipse** occurs when the Moon moves directly between the Sun and Earth and casts its shadow over part of Earth, as seen in **Figure 8**. Depending on where you are on Earth, you may experience a total eclipse or a partial eclipse. The darkest portion of the Moon's shadow is called the umbra (UM bruh). A person standing within the umbra experiences a total solar eclipse. During a total solar eclipse, the only visible portion of the Sun is a pearly white glow around the edge of the eclipsing Moon.

Surrounding the umbra is a lighter shadow on Earth's surface called the penumbra (puh NUM bruh). Persons standing in the penumbra experience a partial solar eclipse. **WARNING:** *Regardless of which eclipse you view, never look directly at the Sun. The light can permanently damage your eyes.*



Topic: Eclipses

Visit blue.msscience.com for Web links to information about solar and lunar eclipses.

Activity Make a chart showing the dates when lunar and solar eclipses will be visible in your area. Include whether the eclipses will be total or partial.

Figure 8 Only a small area of Earth experiences a total solar eclipse during the eclipse event.

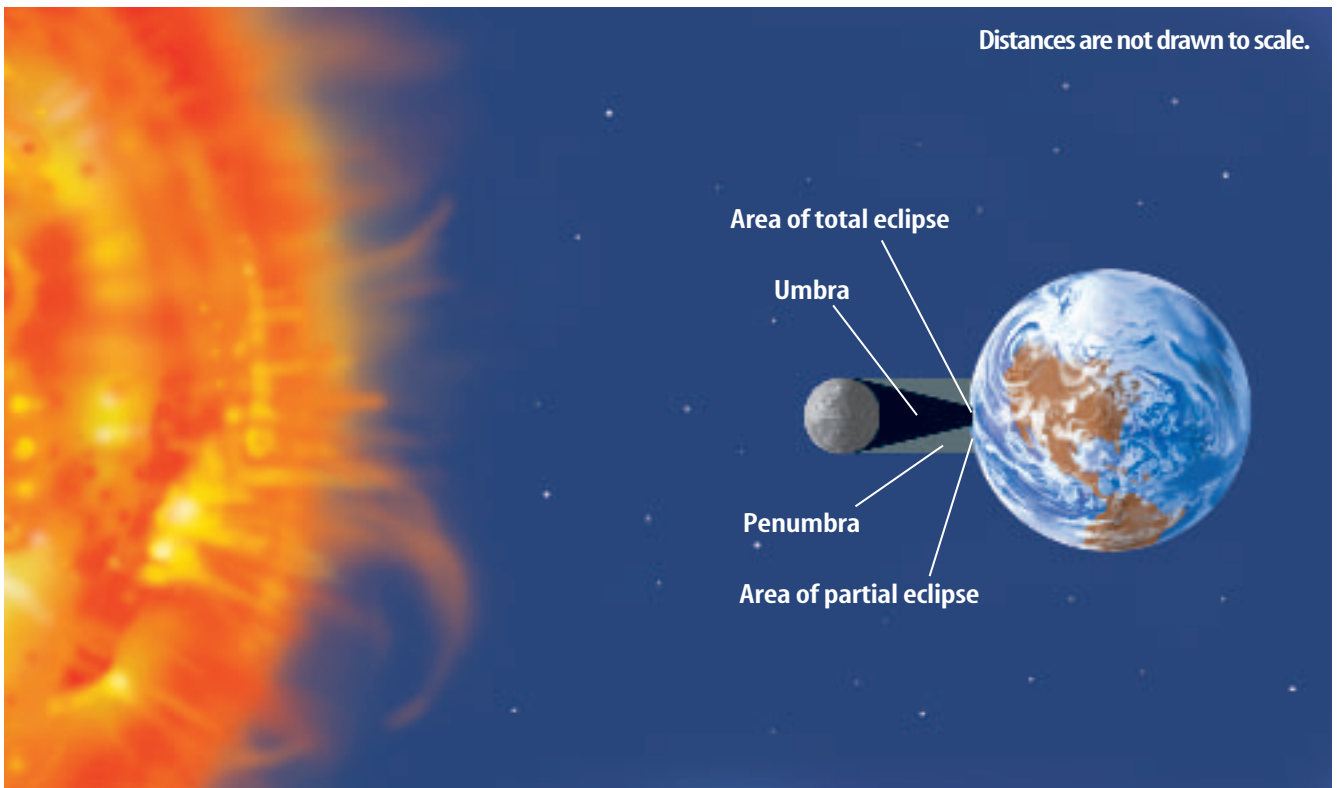
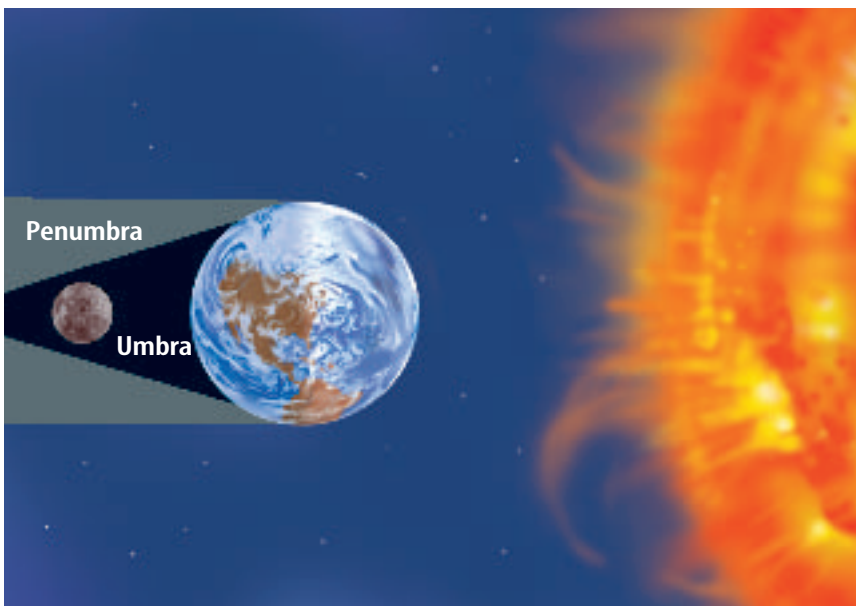




Figure 9 These photographs show the Moon moving from right to left into Earth's umbra, then out again.

Figure 10 During a total lunar eclipse, Earth's shadow blocks light coming from the Sun.



Eclipses of the Moon When Earth's shadow falls on the Moon, a **lunar eclipse** occurs. A lunar eclipse begins when the Moon moves into Earth's penumbra. As the Moon continues to move, it enters Earth's umbra and you see a curved shadow on the Moon's surface, as in **Figure 9**. Upon moving completely into Earth's umbra, as shown in **Figure 10**, the Moon goes dark, signaling that a total lunar eclipse has occurred. Sometimes sunlight bent through Earth's atmosphere causes the eclipsed Moon to appear red.

A partial lunar eclipse occurs when only a portion of the Moon moves into Earth's umbra. The remainder of the Moon is in Earth's penumbra and, therefore, receives some direct sunlight. A penumbral lunar eclipse occurs when the Moon is totally within Earth's penumbra. However, it is dif-

ficult to tell when a penumbral lunar eclipse occurs because some sunlight continues to fall on the side of the Moon facing Earth.

A total lunar eclipse can be seen by anyone on the nighttime side of Earth where the Moon is not hidden by clouds. In contrast, only a lucky few people get to witness a total solar eclipse. Only those people in the small region where the Moon's umbra strikes Earth can witness one.

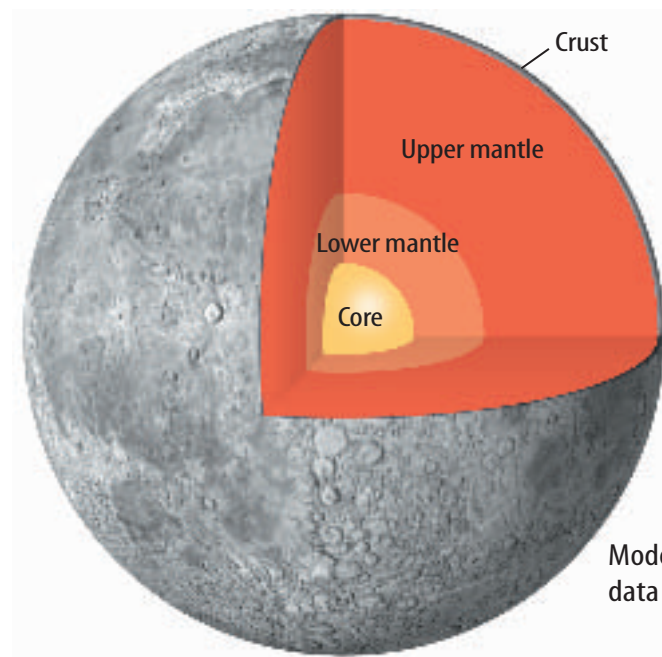


The Moon's Surface

When you look at the Moon, as shown in **Figure 12** on the next page, you can see many depressions called craters. Meteorites, asteroids, and comets striking the Moon's surface created most of these craters, which formed early in the Moon's history. Upon impact, cracks may have formed in the Moon's crust, allowing lava to reach the surface and fill up the large craters. The resulting dark, flat regions are called **maria** (MAHR ee uh). The igneous rocks of the maria are 3 billion to 4 billion years old. So far, they are the youngest rocks to be found on the Moon. This indicates that craters formed after the Moon's surface originally cooled. The maria formed early enough in the Moon's history that molten material still remained in the Moon's interior. The Moon once must have been as geologically active as Earth is today. Before the Moon cooled to the current condition, the interior separated into distinct layers.

Inside the Moon

Earthquakes allow scientists to learn about Earth's interior. In a similar way, scientists use instruments such as the one in **Figure 11** to study moonquakes. The data they have received have led to the construction of several models of the Moon's interior. One such model, shown in **Figure 11**, suggests that the Moon's crust is about 60 km thick on the side facing Earth. On the far side, it is thought to be about 150 km thick. Under the crust, a solid mantle may extend to a depth of 1,000 km. A partly molten zone of the mantle may extend even farther down. Below this mantle may lie a solid, iron-rich core.



Models of the Moon's interior were created from data obtained by scientists studying moonquakes.



Seismology A seismologist is an Earth scientist who studies the propagation of seismic waves in geological materials. Usually this means studying earthquakes, but some seismologists apply their knowledge to studies of the Moon and planets. Seismologists usually study geology, physics, and applied mathematics in college and later specialize in seismology for an advanced degree.

Figure 11 Equipment, such as the seismograph left on the Moon by the *Apollo 12* mission, helps scientists study moonquakes.

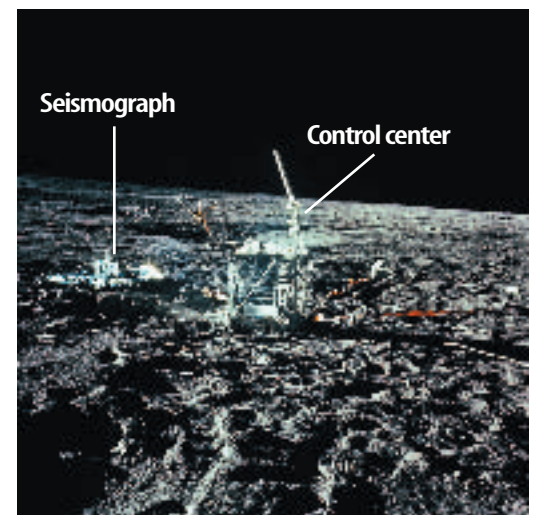


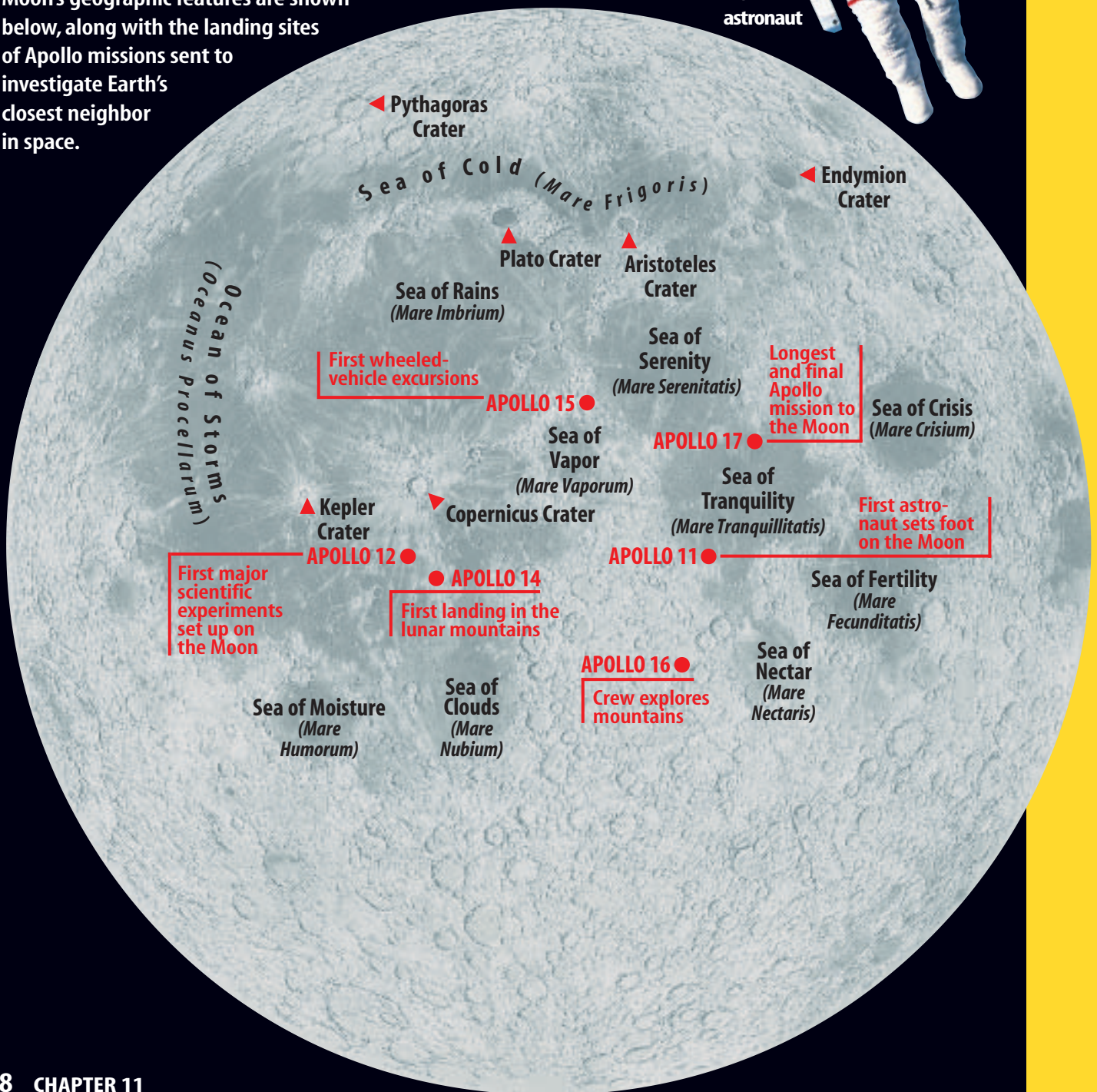


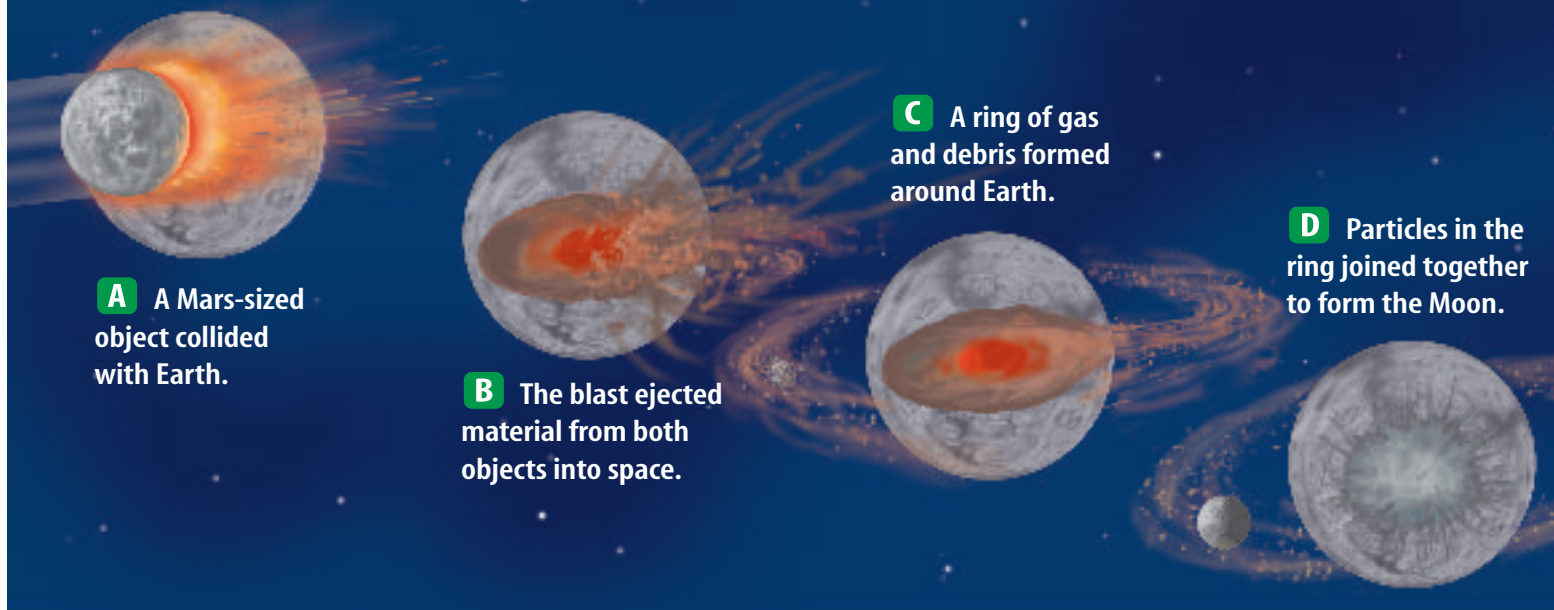
Figure 12

By looking through binoculars, you can see many of the features on the surface of the Moon. These include craters that are hundreds of kilometers wide, light-colored mountains, and darker patches that early astronomers called maria (Latin for “seas”). However, as the NASA Apollo missions discovered, these so-called seas do not contain water. In fact, maria (singular, mare) are flat, dry areas formed by ancient lava flows. Some of the Moon’s geographic features are shown below, along with the landing sites of Apollo missions sent to investigate Earth’s closest neighbor in space.



NASA astronaut





The Moon's Origin

Before the *Apollo* space missions in the 1960s and 1970s, there were three leading theories about the Moon's origin. According to one theory, the Moon was captured by Earth's gravity. Another held that the Moon and Earth condensed from the same cloud of dust and gas. An alternative theory proposed that Earth ejected molten material that became the Moon.

The Impact Theory The data gathered by the *Apollo* missions have led many scientists to support a new theory, known as the impact theory. It states that the Moon formed billions of years ago from condensing gas and debris thrown off when Earth collided with a Mars-sized object as shown in **Figure 13**.

Figure 13 According to the impact theory, a Mars-sized object collided with Earth around 4.6 billion years ago. Vaporized materials ejected by the collision began orbiting Earth and quickly consolidated into the Moon.

Applying Science

What will you use to survive on the Moon?

You have crash-landed on the Moon. It will take one day to reach a moon colony on foot. The side of the Moon that you are on will be facing away from the Sun during your entire trip. You manage to salvage the following items from your wrecked ship: food, rope, solar-powered heating unit, battery-operated heating unit, oxygen tanks, map of the constellations, compass, matches, water, solar-powered radio transmitter, three flashlights, signal mirror, and binoculars.

Identifying the Problem

The Moon lacks a magnetic field and has no atmosphere. How do the Moon's physical properties and the lack of sunlight affect your decisions?

Solving the Problem

1. Which items will be of no use to you? Which items will you take with you?
2. Describe why each of the salvaged items is useful or not useful.



Figure 14 Moon rocks collected by astronauts provide scientists with information about the Moon and Earth.

The Moon in History Studying the Moon's phases and eclipses led to the conclusion that both Earth and the Moon were in motion around the Sun. The curved shadow Earth casts on the Moon indicated to early scientists that Earth was spherical. When Galileo first turned his telescope toward the Moon, he found a surface scarred by craters and maria. Before that time, many people believed that all planetary bodies were perfectly smooth and lacking surface features. Now, actual moon rocks are available for scientists to study, as seen in **Figure 14**. By doing so, they hope to learn more about Earth.



Reading Check

How has observing the Moon been important to science?

section 2 review

Summary

Motions of the Moon

- The Moon rotates on its axis about once each month.
- The Moon also revolves around Earth about once every 27.3 days.
- The Moon shines because it reflects sunlight.

Phases of the Moon

- During the waxing phases, the illuminated portion of the Moon grows larger.
- During waning phases, the illuminated portion of the Moon grows smaller.
- Earth passing directly between the Sun and the Moon causes a lunar eclipse.
- The Moon passing between Earth and the Sun causes a solar eclipse.

Structure and Origin of the Moon

- The Moon's surface is covered with depressions called impact craters.
- Flat, dark regions within craters are called maria.
- The Moon may have formed as the result of a collision between Earth and a Mars-sized object.

Self Check

1. **Explain** how the Sun, Moon, and Earth are positioned relative to each other during a new moon and how this alignment changes to produce a full moon.
2. **Describe** what phase the Moon must be in to have a lunar eclipse. A solar eclipse?
3. **Define** the terms *umbra* and *penumbra* and explain how they relate to eclipses.
4. **Explain** why lunar eclipses are more common than solar eclipses and why so few people ever have a chance to view a total solar eclipse.
5. **Think Critically** What do the surface features and their distribution on the Moon's surface tell you about its history?

Applying Math

6. **Solve Simple Equations** The Moon travels in its orbit at about 3,400 km/h. Therefore, during a solar eclipse, its shadow sweeps at this speed from west to east. However, Earth rotates from west to east at about 1,670 km/h near the equator. At what speed does the shadow really move across this part of Earth's surface?

Moon Phases and Eclipses

In this lab, you will demonstrate the positions of the Sun, the Moon, and Earth during certain phases and eclipses. You also will see why only a small portion of the people on Earth witness a total solar eclipse during a particular eclipse event.

Real-World Question

Can a model be devised to show the positions of the Sun, the Moon, and Earth during various phases and eclipses?

Goals

- **Model** moon phases.
- **Model** solar and lunar eclipses.

Materials

light source (unshaded) globe
polystyrene ball pencil

Safety Precautions



Procedure

1. Review the illustrations of moon phases and eclipses shown in Section 2.
2. Use the light source as a Sun model and a polystyrene ball on a pencil as a Moon model. Move the Moon around the globe to duplicate the exact position that would have to occur for a lunar eclipse to take place.
3. Move the Moon to the position that would cause a solar eclipse.
4. Place the Moon at each of the following phases: first quarter, full moon, third quarter, and new moon. Identify which, if any, type of eclipse could occur during each phase. Record your data.

Moon Phase Observations

Moon Phase	Observations
First quarter	
Full moon	
Third quarter	Do not write in this book.
New moon	

5. Place the Moon at the location where a lunar eclipse could occur. Move it slightly toward Earth, then away from Earth. Note the amount of change in the size of the shadow.
6. Repeat step 5 with the Moon in a position where a solar eclipse could occur.

Conclude and Apply

1. **Identify** which phase(s) of the Moon make(s) it possible for an eclipse to occur.
2. **Describe** the effect of a small change in distance between Earth and the Moon on the size of the umbra and penumbra.
3. **Infer** why a lunar and a solar eclipse do not occur every month.
4. **Explain** why only a few people have experienced a total solar eclipse.
5. **Diagram** the positions of the Sun, Earth, and the Moon during a first-quarter moon.
6. **Infer** why it might be better to call a full moon a half moon.

Communicating Your Data

Communicate your answers to other students.



Exploring Earth's Moon

as you read

What You'll Learn

- **Describe** recent discoveries about the Moon.
- **Examine** facts about the Moon that might influence future space travel.

Why It's Important

Continuing moon missions may result in discoveries about Earth's origin.



Review Vocabulary

comet: space object orbiting the Sun formed from dust and rock particles mixed with frozen water, methane, and ammonia

New Vocabulary

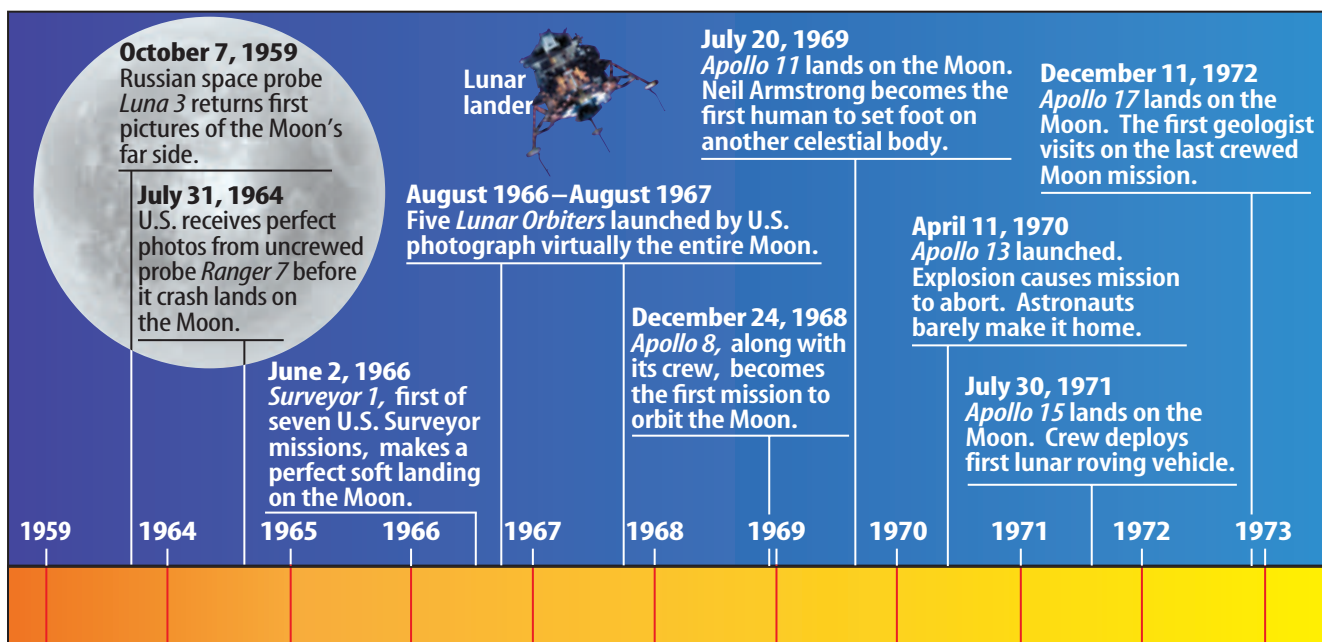
- impact basin

Missions to the Moon

The Moon has always fascinated humanity. People have made up stories about how it formed. Children's stories even suggested it was made of cheese. Of course, for centuries astronomers also have studied the Moon for clues to its makeup and origin. In 1959, the former Soviet Union launched the first *Luna* spacecraft, enabling up-close study of the Moon. Two years later, the United States began a similar program with the first *Ranger* spacecraft and a series of *Lunar Orbiters*. The spacecraft in these early missions took detailed photographs of the Moon.

The next step was the *Surveyor* spacecraft designed to take more detailed photographs and actually land on the Moon. Five of these spacecraft successfully touched down on the lunar surface and performed the first analysis of lunar soil. The goal of the *Surveyor* program was to prepare for landing astronauts on the Moon. This goal was achieved in 1969 by the astronauts of *Apollo 11*. By 1972, when the *Apollo* missions ended, 12 U.S. astronauts had walked on the Moon. A time line of these important moon missions can be seen in **Figure 15**.

Figure 15 This time line illustrates some of the most important events in the history of moon exploration.





Surveying the Moon There is still much to learn about the Moon and, for this reason, the United States resumed its studies. In 1994, the *Clementine* was placed into lunar orbit. Its goal was to conduct a two-month survey of the Moon's surface. An important aspect of this study was collecting data on the mineral content of Moon rocks. In fact, this part of its mission was instrumental in naming the spacecraft. Clementine was the daughter of a miner in the ballad *My Darlin' Clementine*. While in orbit, *Clementine* also mapped features on the Moon's surface, including huge impact basins.

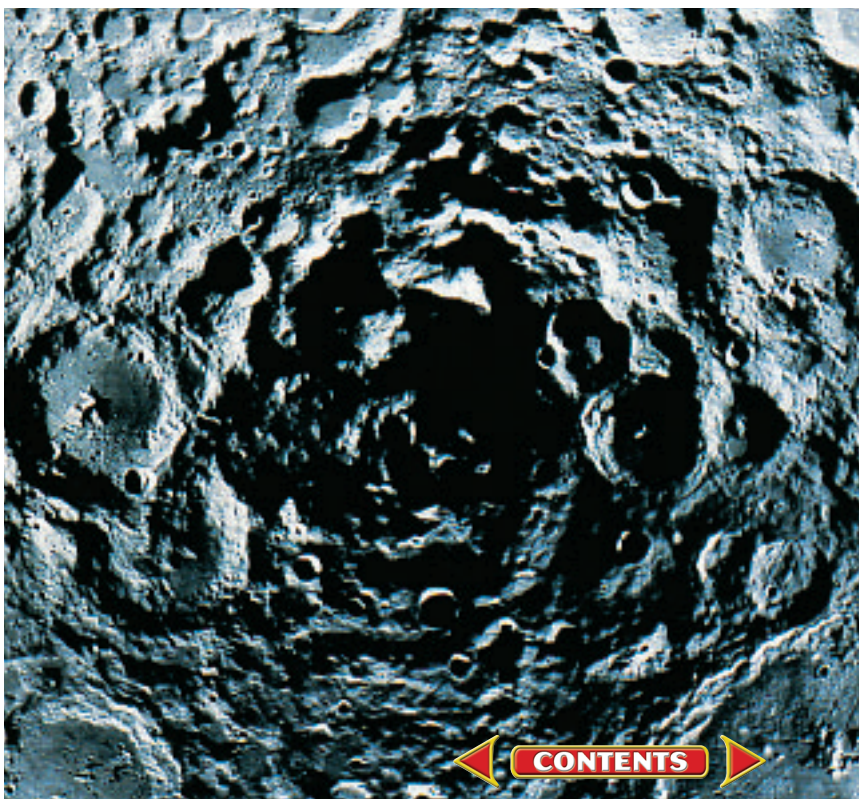


Reading Check

Why was Clementine placed in lunar orbit?

Impact Basins When meteorites and other objects strike the Moon, they leave behind depressions in the Moon's surface. The depression left behind by an object striking the Moon is known as an **impact basin**, or impact crater. The South Pole-Aitken Basin is the oldest identifiable impact feature on the Moon's surface. At 12 km in depth and 2,500 km in diameter, it is also the largest and deepest impact basin in the solar system.

Impact basins at the poles were of special interest to scientists. Because the Sun's rays never strike directly, the crater bottoms remain always in shadow. Temperatures in shadowed areas, as shown in **Figure 16**, would be extremely low, probably never more than -173°C . Scientists hypothesize that any ice deposited by comets impacting the Moon throughout its history would remain in these shadowed areas. Indeed, early signals from *Clementine* indicated the presence of water. This was intriguing, because it could be a source of water for future moon colonies.



Topic: The Far Side

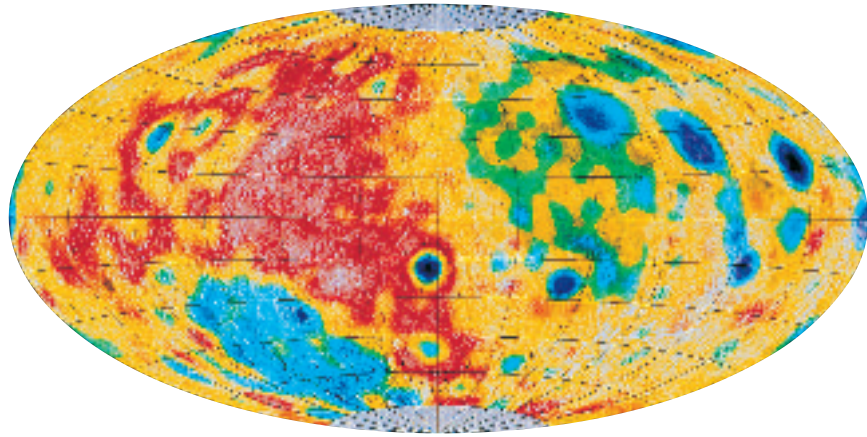
Visit blue.mssscience.com for Web links to information about the far side of the Moon.

Activity Compare the image of the far side of the Moon with that of the near side shown in **Figure 12**. Make a list of all the differences you note and then compare them with lists made by other students.

Figure 16 The South Pole-Aitken Basin is the largest of its kind found anywhere in the solar system. The deepest craters in the basin stay in shadow throughout the Moon's rotation. Ice deposits from impacting comets are thought to have collected at the bottom of these craters.



Figure 17 This computer-enhanced map based on *Clementine* data indicates the thickness of the Moon's crust. The crust of the side of the Moon facing Earth, shown mostly in red, is thinner than the crust on the far side of the Moon.



Mapping the Moon

A large part of *Clementine*'s mission included taking high-resolution photographs so a detailed map of the Moon's surface could be compiled. *Clementine* carried cameras and other instruments to collect data at wavelengths ranging from infrared to ultraviolet. One camera could resolve features as small as 20 m across. One image resulting from *Clementine* data is shown in **Figure 17**. It shows that the crust on the side of the Moon that faces Earth is much thinner than the crust on the far side. Additional information shows that the Moon's crust is thinnest under impact basins. Based on analysis of the light data received from *Clementine*, a global map of the Moon also was created that shows its composition, as seen in **Figure 18**.



Reading Check

What information about the Moon did scientists learn from *Clementine*?

The Lunar Prospector The success of *Clementine* opened the door for further moon missions. In 1998, NASA launched the desk-sized *Lunar Prospector*, shown in **Figure 18**, into lunar orbit. The spacecraft spent a year orbiting the Moon from pole to pole, once every two hours. The resulting maps confirmed the *Clementine* data. Also, data from *Lunar Prospector* confirmed that the Moon has a small, iron-rich core about 600 km in diameter. A small core supports the impact theory of how the Moon formed—only a small amount of iron could be blasted away from Earth.

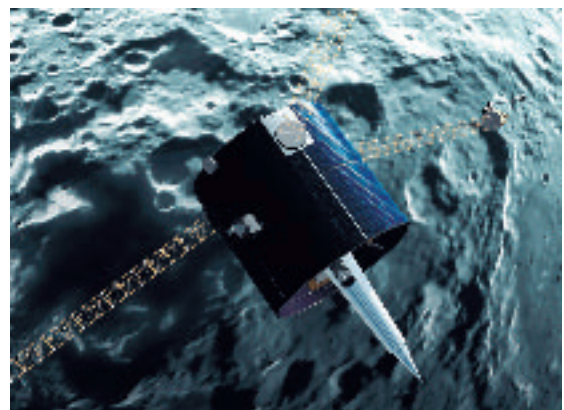


Figure 18 *Lunar Prospector* performed high-resolution mapping of the lunar surface and had instruments that detected water ice at the lunar poles.



Icy Poles In addition to photographing the surface, *Lunar Prospector* carried instruments designed to map the Moon's gravity, magnetic field, and the abundances of 11 elements in the lunar crust. This provided scientists with data from the entire lunar surface rather than just the areas around the Moon's equator, which had been gathered earlier. Also, *Lunar Prospector* confirmed the findings of *Clementine* that water ice was present in deep craters at both lunar poles.

Later estimates concluded that as much as 3 billion metric tons of water ice was present at the poles, with a bit more at the north pole. Using data from *Lunar Prospector*, scientists prepared maps showing the location of water ice at each pole. **Figure 19** shows how water may be distributed at the Moon's north pole. At first it was thought that ice crystals were mixed with lunar soil, but most recent results suggest that the ice may be in the form of more compact deposits.

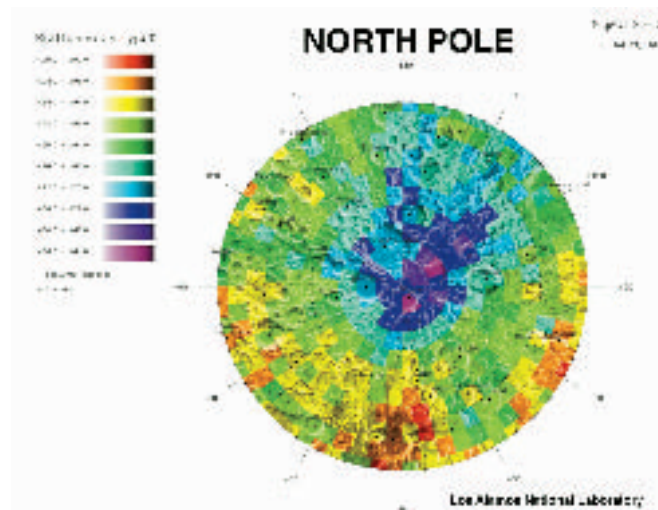


Figure 19 The *Lunar Prospector* data indicates that ice exists in crater shadows at the Moon's poles.

section 3 review

Summary

Missions to the Moon

- The first lunar surveys were done by *Luna*, launched by the former Soviet Union, and U.S.-launched *Ranger* and *Lunar Orbiters*.
- Five *Surveyor* probes landed on the Moon.
- U.S. Astronauts landed on and explored the Moon in the *Apollo* program.
- *Clementine*, a lunar orbiter, mapped the lunar surface and collected data on rocks.
- *Clementine* found that the lunar crust is thinner on the side facing Earth.
- Data from *Clementine* indicated that water ice could exist in shaded areas of impact basins.

Mapping the Moon

- *Lunar Prospector* orbited the Moon from pole to pole, collecting data that confirm *Clementine* results and that the Moon has a small iron-rich core.
- Data from *Lunar Prospector* indicate the presence of large quantities of water ice in craters at the lunar poles.

Self Check

1. **Name** the first U.S. spacecraft to successfully land on the Moon. What was the major purpose of this program?
2. **Explain** why scientists continue to study the Moon long after the *Apollo* program ended and list some of the types of data that have been collected.
3. **Explain** how water ice might be preserved in portions of deep impact craters.
4. **Describe** how the detection of a small iron-rich core supports the theory that the Moon was formed from a collision between Earth and a Mars-sized object.
5. **Think Critically** Why might the discovery of ice in impact basins at the Moon's poles be important to future space flights?

Applying Skills

6. **Infer** why it might be better to build a future moon base on a brightly lit plateau near a lunar pole in the vicinity of a deep crater. Why not build a base in the crater itself?

TILT AND TEMPERATURE

Goals

- **Measure** the temperature change in a surface after light strikes it at different angles.
- **Describe** how the angle of light relates to seasons on Earth.

Materials

tape
black construction paper
(one sheet)
gooseneck lamp
with 75-watt bulb
Celsius thermometer
watch
protractor

Safety Precautions

WARNING: Do not touch the lamp without safety gloves. The lightbulb and shade can be hot even when the lamp has been turned off. Handle the thermometer carefully. If it breaks, do not touch anything. Inform your teacher immediately.

If you walk on blacktop pavement at noon, you can feel the effect of solar energy. The Sun's rays hit at the highest angle at midday. Now consider the fact that Earth is tilted on its axis. How does this tilt affect the angle at which light rays strike an area on Earth? How is the angle of the light rays related to the amount of heat energy and the changing seasons?

Real-World Question

How does the angle at which light strikes Earth affect the amount of heat energy received by any area on Earth?

Procedure

1. Choose three angles that you will use to aim the light at the paper.
2. **Determine** how long you will shine the light at each angle before you measure the temperature. You will measure the temperature at two times for each angle. Use the same time periods for each angle.
3. Copy the following data table into your Science Journal to record the temperature the paper reaches at each angle and time.

Temperature Data

Angle of Lamp	Initial Temperature	Temperature at ____ Minutes/Seconds	Temperature at ____ Minutes/Seconds
First angle			
Second angle	Do not write in this book.		
Third angle			

4. Form a pocket out of a sheet of black construction paper and tape it to a desk or the floor.
5. Using the protractor, set the gooseneck lamp so that it will shine on the paper at one of the angles you chose.

Using Scientific Methods

6. Place the thermometer in the paper pocket. Turn on the lamp. Use the thermometer to measure the temperature of the paper at the end of the first time period. Continue shining the lamp on the paper until the second time period has passed. Measure the temperature again. Record your data in your data table.
7. Turn off the lamp until the paper cools to room temperature. Repeat steps 5 and 6 using your other two angles.

Conclude and Apply

1. **Describe** your experiment. Identify the variables in your experiment. Which were your independent and dependent variables?
2. **Graph** your data using a line graph. Describe what your graph tells you about the data.
3. **Describe** what happened to the temperature of the paper as you changed the angle of light.
4. **Predict** how your results might have been different if you used white paper. Explain why.
5. **Describe** how the results of this experiment apply to seasons on Earth.

Communicating Your Data

Compare your results with those of other students in your class. **Discuss** how the different angles and time periods affected the temperatures.



THE Mayan Calendar



Most people take for granted that a week is seven days, and that a year is 12 months. However there are other ways to divide time into useful units. Roughly 1,750 years ago, in what is now south Mexico and Central America, the Mayan people invented a calendar system based on careful observations of sun and moon cycles.



These glyphs represent four different days of the Tzolkin calendar.

In fact, the Maya had several calendars that they used at the same time.

Two calendars were most important—one was based on 260 days and the other on 365 days. The calendars were so accurate and useful that later civilizations, including the Aztecs, adopted them.



The Kukulcan, built around the year 1050 A.D., in what is now Chichén Itzá, Mexico, was used by the Maya as a calendar. It had four stairways, each with 91 steps, a total of 365 including the platform on top.

The 260-Day Calendar

This Mayan calendar, called the *Tzolkin* (tz uhl KIN), was used primarily to time planting, harvesting, drying, and storing of corn—their main crop. Each day of the *Tzolkin* had one of 20 names, as well as a number from 1 to 13 and a Mayan god associated with it.

The 365-Day Calendar

Another Mayan calendar, called the *Haab* (HAHB), was based on the orbit of Earth around the Sun. It was divided into 18 months with 20 days each, plus five extra days at the end of each year.

These calendars were used together making the Maya the most accurate reckoners of time before the modern period. In fact, they were only one day off every 6,000 years.

Drawing Symbols The Maya created picture symbols for each day of their week. Historians call these symbols glyphs. Collaborate with another student to invent seven glyphs—one for each weekday. Compare them with other glyphs at msscience.com/time.

Science online

For more information, visit blue.msscience.com/time

Reviewing Main Ideas

Section 1 Earth

1. Earth is spherical and bulges slightly at its equator.
2. Earth rotates once per day and orbits the Sun in a little more than 365 days.
3. Earth has a magnetic field.
4. Seasons on Earth are caused by the tilt of Earth's axis as it orbits the Sun.

**Section 2 The Moon—
Earth's Satellite**

1. Earth's Moon goes through phases that depend on the relative positions of the Sun, the Moon, and Earth.

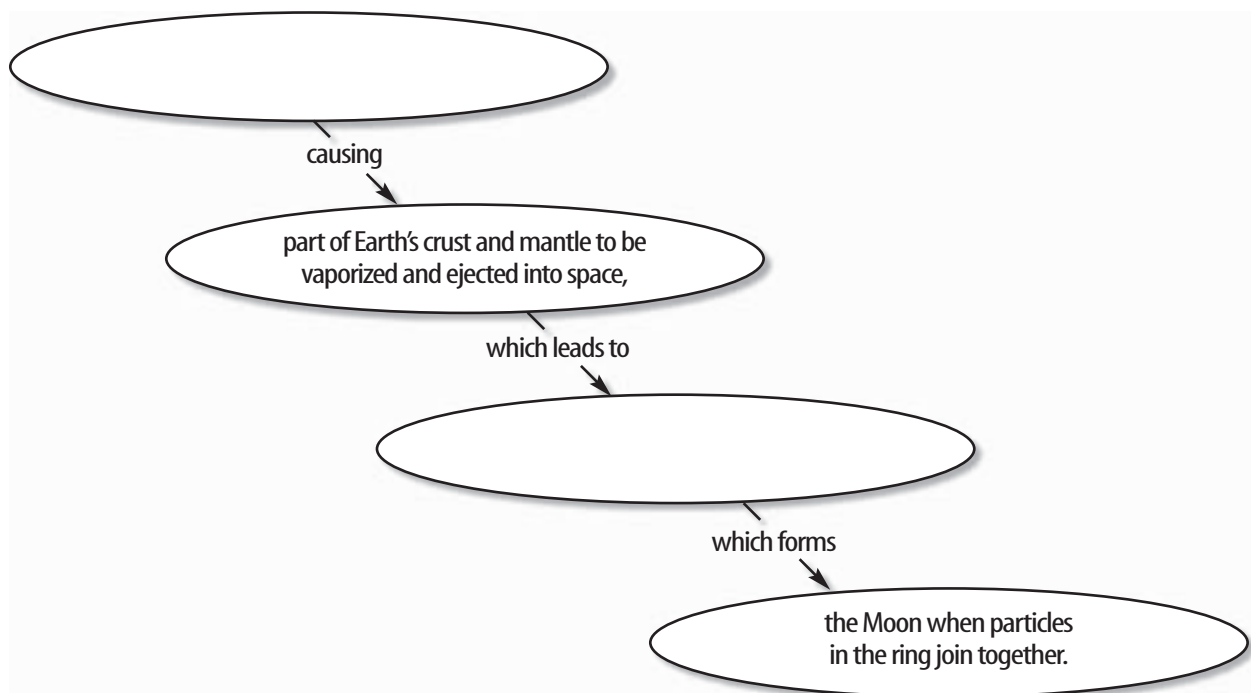
2. Eclipses occur when Earth or the Moon temporarily blocks sunlight from reaching the other.
3. The Moon's maria are the result of ancient lava flows. Craters on the Moon's surface formed from impacts with meteorites, asteroids, and comets.

Section 3 Exploring Earth's Moon

1. The *Clementine* spacecraft took detailed photographs of the Moon's surface and collected data indicating the presence of water in deep craters.
2. NASA's *Lunar Prospector* spacecraft found additional evidence of ice.

Visualizing Main Ideas

Copy and complete the following concept map on the impact theory of the Moon's formation.



Using Vocabulary

axis p.307	new moon p.313
ellipse p.309	revolution p.309
equinox p.311	rotation p.307
full moon p.313	solar eclipse p.315
impact basin p.323	solstice p.310
lunar eclipse p.316	sphere p.306
maria p.317	waning p.313
moon phase p.313	waxing p.313

Fill in the blanks with the correct vocabulary word or words.

- The spinning of Earth around its axis is called _____.
- The _____ is the point at which the Sun reaches its greatest distance north or south of the equator.
- The Moon is said to be _____ when less and less of the side facing Earth is lighted.
- The depression left behind by an object striking the Moon is called a(n) _____.
- Earth's orbit is a(n) _____.

Checking Concepts

Choose the word or phrase that best answers the question.

- How long does it take for the Moon to rotate once?
A) 24 hours C) 27.3 hours
B) 365 days D) 27.3 days
- Where is Earth's circumference greatest?
A) equator C) poles
B) mantle D) axis
- Earth is closest to the Sun during which season in the northern hemisphere?
A) spring C) winter
B) summer D) fall

- What causes the Sun to appear to rise and set?
A) Earth's revolution
B) the Sun's revolution
C) Earth's rotation
D) the Sun's rotation

Use the photo below to answer question 10.



- What phase of the Moon is shown in the photo above?
A) waning crescent C) third quarter
B) waxing gibbous D) waning gibbous
- How long does it take for the Moon to revolve once around Earth?
A) 24 hours C) 27.3 hours
B) 365 days D) 27.3 days
- What is it called when the phases of the Moon appear to get larger?
A) waning C) rotating
B) waxing D) revolving
- What kind of eclipse occurs when the Moon blocks sunlight from reaching Earth?
A) solar C) full
B) new D) lunar
- What is the darkest part of the shadow during an eclipse?
A) waxing gibbous C) waning gibbous
B) umbra D) penumbra
- What is the name for a depression on the Moon caused by an object striking its surface?
A) eclipse C) phase
B) moonquake D) impact basin

Thinking Critically

16. **Predict** how the Moon would appear to an observer in space during its revolution. Would phases be observable? Explain.
17. **Predict** what the effect would be on Earth's seasons if the axis were tilted at 28.5° instead of 23.5° .
18. **Infer** Seasons in the two hemispheres are opposite. Explain how this supports the statement that seasons are NOT caused by Earth's changing distance from the Sun.
19. **Draw Conclusions** How would solar eclipses be different if the Moon were twice as far from Earth? Explain.
20. **Predict** how the information gathered by moon missions could be helpful in the future for people wanting to establish a colony on the Moon.
21. **Use Variables, Constants, and Controls** Describe a simple activity to show how the Moon's rotation and revolution work to keep the same side facing Earth at all times.
22. **Draw Conclusions** Gravity is weaker on the Moon than it is on Earth. Why might more craters be present on the far side of the Moon than on the side of the Moon facing Earth?
23. **Recognize Cause and Effect** During a new phase of the Moon, we cannot see it because no sunlight reaches the side facing Earth. Yet sometimes when there is a thin crescent visible, we do see a faint image of the rest of the Moon. Explain what might cause this to happen.
24. **Describe** Earth's magnetic field. Include an explanation of how scientists believe it is generated and two ways in which it helps people on Earth.

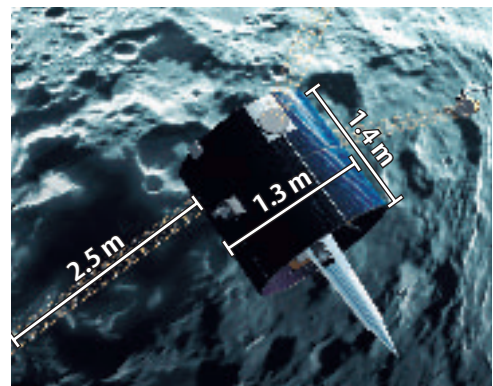
Performance Activities

25. **Display** Draw a cross section of the Moon. Include the crust, outer and inner mantles, and possible core based on the information in this chapter. Indicate the presence of impact craters and show how the thickness of the crust varies from one side of the Moon to the other.
26. **Poem** Write a poem in which you describe the various surface features of the Moon. Be sure to include information on how these features formed.

Applying Math

27. **Orbital Tilt** The Moon's orbit is tilted at an angle of 5° to Earth's orbit around the sun. Using a protractor, draw the Moon's orbit around Earth. What fraction of a full circle (360°) is 5° ?

Use the illustration below to answer question 28.



28. **Model to Scale** You are planning to make a scale model of the *Lunar Prospector* spacecraft, shown above. Assuming that the three instrument masts are of equal length, draw a labeled diagram of your model using a scale of 1 cm equals 30 cm.
29. **Spacecraft Velocity** The *Lunar Prospector* spacecraft shown above took 105 hours to reach the Moon. Assuming that the average distance from Earth to Moon is 384,000 km, calculate its average velocity on the trip.

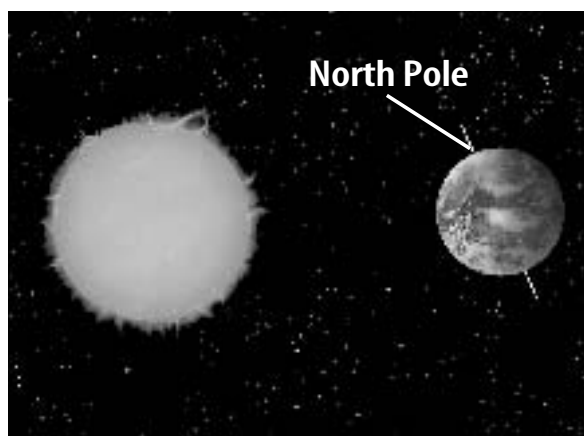
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following terms would you use to describe the spinning of Earth on its axis?

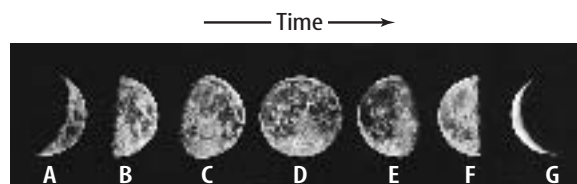
A. revolution C. rotation
B. ellipse D. solstice

Use the illustration below to answer questions 2 and 3.



2. Which season is beginning for the southern hemisphere when Earth is in this position?
- A. spring C. fall
B. summer D. winter
3. Which part of Earth receives the greatest total amount of solar radiation when Earth is in this position?
- A. northern hemisphere
B. South Pole
C. southern hemisphere
D. equator
4. Which term describes the dark, flat areas on the Moon's surface which are made of cooled, hardened lava?
- A. spheres C. highlands
B. moonquakes D. maria

Use the illustration below to answer questions 5 and 6.



5. Which letter corresponds to the moon phase waning gibbous?
- A. G C. E
B. C D. A
6. The Moon phase cycle lasts about 29.5 days. Given this information, about how long does it take the Moon to wax from new moon to full moon?
- A. about 3 days C. about 2 weeks
B. about 1 week D. about 4 weeks
7. Where have large amounts of water been detected on the Moon?
- A. highlands C. maria
B. lunar equator D. lunar poles
8. In what month is Earth closest to the Sun?
- A. March C. July
B. September D. January
9. So far, where on the Moon have the youngest rocks been found?
- A. lunar highlands C. lunar poles
B. maria D. lunar equator

Test-Taking Tip

Eliminate Choices If you don't know the answer to a multiple-choice question, eliminate as many incorrect choices as possible. Mark your best guess from the remaining answers before moving to the next question.

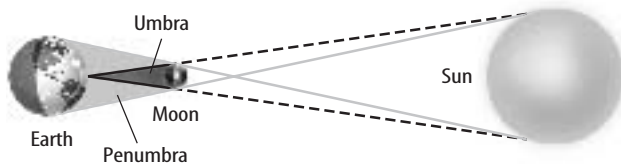
Question 5 Eliminate those phases that you know are not gibbous.

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. Explain why the North Pole is always in sunlight during summer in the northern hemisphere.
11. Describe one positive effect of Earth's magnetic field.
12. Explain the difference between a solstice and an equinox. Give the dates of these events on Earth.
13. Explain how scientists know that the Moon was once geologically active.

Use the illustration below to answer questions 14 and 15.



14. What type of eclipse is shown above?
15. Describe what a person standing in the Moon's umbra would see if he or she looked at the sky wearing protective eyewear.
16. The tilt of Earth on its axis causes seasons. Give two reasons why this tilt causes summer to be warmer than winter.
17. When the Apollo missions ended in 1972, 12 astronauts had visited the Moon and brought back samples of moon soil and rock. Explain why we continue to send orbiting spacecraft to study the Moon.
18. Define the term *impact basin*, and name the largest one known in the solar system.

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the illustrations below to answer questions 19 and 20.



19. As a ship comes into view over the horizon, the top appears before the rest of the ship. How does this demonstrate that Earth is spherical?
20. If Earth were flat, how would an approaching ship appear differently?
21. Explain why eclipses of the Sun occur only occasionally despite the fact that the Moon's rotation causes it to pass between Earth and the Sun every month.
22. Recent data from the spacecraft *Lunar Prospector* indicate the presence of large quantities of water in shadowed areas of lunar impact basins. Describe the hypothesis that scientists have developed to explain how this water reached the moon and how it might be preserved.
23. Compare the impact theory of lunar formation with one of the older theories proposed before the *Apollo* mission.
24. Describe how scientists study the interior of the Moon and what they have learned so far.
25. Explain why Earth's magnetic north poles must be mapped and why these maps must be kept up-to-date.