chapter 22

Exploring Space

section 1 Radiation from Space

Before You Read

How do we learn about objects in space? What are some of the tools astronomers use?

_____

_____

_____

What You'll Learn

- what the electromagnetic spectrum is
- the differences between refracting and reflecting telescopes
- the differences between optical and radio telescopes

Read to Learn

Electromagnetic Waves

With the help of telescopes, we can see objects in our solar system and far into space. For now, this is the only way to learn about distant parts of the universe. Even if we could travel at the speed of light, it would take many years to travel to the closest star.

What do you see when you look at a star?

When you look at a star, the light that you see left the star many years ago. Although light travels fast, distances between objects in space are so great that it sometimes takes millions of years for the light to reach Earth.

What is electromagnetic radiation?

The light and other energy leaving a star are forms of radiation. Radiation is energy that moves from one place to another by electromagnetic waves. Since the radiation has both electric and magnetic properties, it is called electromagnetic radiation. Electromagnetic waves carry energy through empty space as well as through matter. There are electromagnetic waves everywhere around you. When you turn on the radio, the TV, or the microwave, different types of electromagnetic waves surround you.

Study Coach

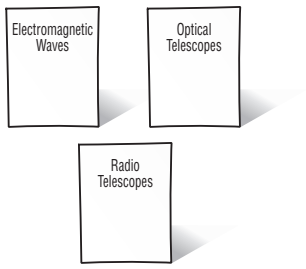
Create a Quiz Strategy

As you read, create a five-question quiz about different kinds of telescopes in this section. Switch papers with a classmate and answer each other's questions.

FOLDABLES™

A Organize Information

Make quarter sheet Foldables to organize information from this section.



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Where is electromagnetic radiation found?

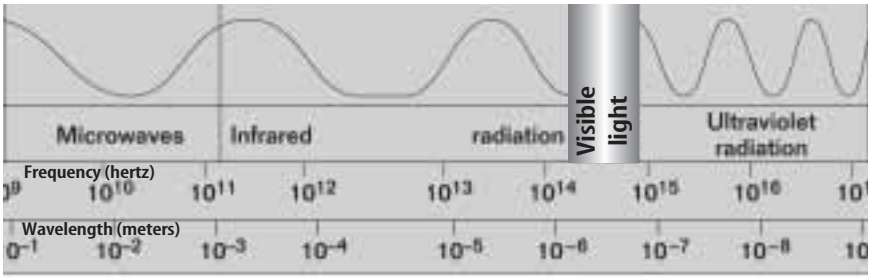
Electromagnetic radiation is all around you. Two types of electromagnetic waves are radio waves that carry signals to your radio and the light that travels to Earth from the Sun. Other types of electromagnetic waves are gamma rays, X rays, ultraviolet waves, infrared waves, and microwaves. Each of these forms of electromagnetic radiation has a different wavelength.

What is the electromagnetic spectrum?

The different types of electromagnetic radiation are shown in the electromagnetic spectrum in the figure below. The **electromagnetic spectrum** is the arrangement of the different kinds of electromagnetic radiation according to their wavelengths. Forms of electromagnetic radiation also differ in their frequencies. Frequency is the number of wave crests that pass a given point per unit of time. The shorter the wavelength is, the higher the frequency. The figure below shows the wavelengths and frequencies of some types of electromagnetic radiation.

Picture This

1. **Interpret Scientific Illustrations** Which type of electromagnetic radiation has a longer wavelength: infrared or ultraviolet?



How fast do electromagnetic waves travel?

Even though electromagnetic waves have different wavelengths, they all travel at the same speed. All electromagnetic waves travel at the speed of light, or 300,000 km/s. Stars give off visible light and other electromagnetic waves. It can take millions of years for some stars' light waves to reach Earth because the universe is so large. The light you see when you look at a star left the star many years ago.

Scientists can learn about the source of the electromagnetic radiation by studying a star's light waves. One tool that scientists use to study electromagnetic radiation in space is a telescope. A telescope is an instrument that magnifies, or enlarges, images of distant objects. There are different kinds of telescopes.

Think it Over

2. **Identify** Which type of electromagnetic wave travels fastest?

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Optical Telescopes

An optical telescope collects visible light, which is a form of electromagnetic radiation, to produce magnified images of objects. The telescope collects light using either an objective lens or mirror. The objective lens or mirror then forms an image at the focal point of the telescope. The focal point is where light that is bent by the lens or reflected by the mirror comes together to form an image. The image is magnified by another lens, the eyepiece. There are two types of optical telescopes.

Refracting Telescope A **refracting telescope** collects light using convex lenses. Convex lenses curve outward, like the surface of a ball. Light from an object passes through the convex objective lens. The lens bends the light to form an image at the focal point. The eyepiece magnifies the image. The illustration below on the left shows how a refracting telescope works.

Reflecting Telescope A **reflecting telescope** collects light using a concave mirror. The concave mirror is curved inward, like the inside of a bowl. When light strikes the mirror, the mirror reflects, or bounces, light to the focal point where it forms an image. Sometimes a smaller mirror is used to reflect light into the eyepiece lens, where it is magnified for viewing. The illustration below on the right shows how a reflecting telescope works.

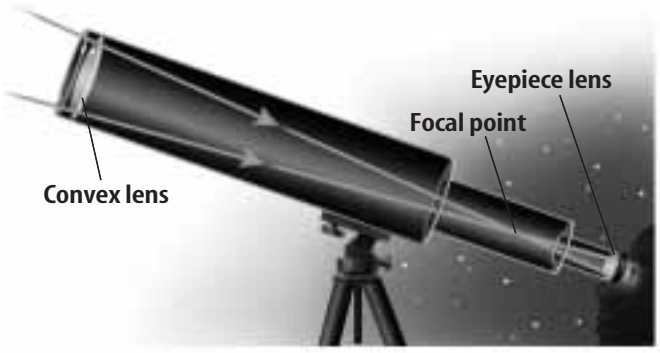
Picture This

3. **Compare and Contrast** Name one difference between a refracting telescope and a reflecting telescope.

_____

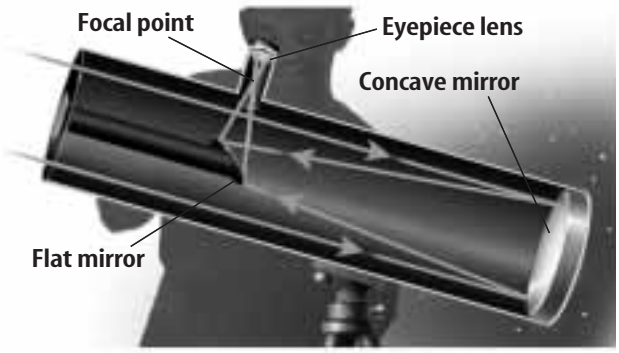
_____

Refracting Telescope



In a refracting telescope, a convex lens focuses light to form an image at the focal point.

Reflecting Telescope



In a reflecting telescope, a concave mirror focuses light to form an image at the focal point.

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How are optical telescopes used?

Most optical telescopes used by astronomers—scientists who study space—are housed in buildings called **observatories.** Observatories have dome-shaped roofs that open. This allows astronomers to view the night sky.

Reading Check

4. **Describe** What is an observatory?

What is the *Hubble Space Telescope?*

Not all optical telescopes are housed in observatories. The *Hubble Space Telescope* is a large reflecting telescope that orbits Earth. It was launched in 1990 by the space shuttle *Discovery*. Earth's atmosphere can absorb and distort energy received from space. Since *Hubble* was placed outside this atmosphere, scientists expected it to produce clear pictures. However, a mistake was made when the telescope's largest mirror was shaped. It did not produce clear images. In 1993, a set of small mirrors was installed to correct the faulty images. Two more missions to service *Hubble* happened in 1997 and 1999—as shown in the photograph. In 1999, *Hubble* sent back clear images of a large cluster of galaxies known as Abell 2218.

NASA

Picture This

5. **Explain** Why does the *Hubble Space Telescope* produce better images of space than telescopes on Earth?

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How do reflecting telescopes work?

In the early 1600s, the Italian scientist Galileo Galilei aimed a small telescope at the stars. Since then, telescopes have been greatly improved. Today, large reflecting telescopes use mirrors to direct light and to magnify images. These mirrors are several meters wide and are extremely hard to build. Instead of constructing one large mirror, some telescopes have mirrors that are constructed out of many small mirrors that are pieced together. The mirrors of the twin Keck telescopes in Hawaii are 10 meters wide and were made in this way.

How do optical telescopes work?

The most recent advances in optical telescopes involve active and adaptive optics. Active optics use a computer to correct for changes in temperature, mirror distortions, and bad viewing conditions. Adaptive optics are even more advanced. Adaptive optics use lasers to probe the atmosphere for air turbulence and send back information to a computer. The computer then makes adjustments to the telescope's mirror. Telescope images are clearer when corrections for air turbulence, temperature changes, and mirror-shape changes are made.

Radio Telescopes

Stars and other objects in space give off different kinds of electromagnetic energy. One example of that energy is the radio wave. Radio waves are a kind of long-wavelength energy in the electromagnetic spectrum. A **radio telescope** is used to collect and record radio waves that travel through space. Unlike visible light, radio waves pass freely through Earth's atmosphere. Because of this, radio telescopes are useful 24 hours a day under most weather conditions.

Radio waves reaching Earth's surface strike the large, concave dish of a radio telescope. This dish reflects the waves to a focal point where a receiver is located. The information gathered allows scientists to detect objects in space, to map the universe, and to search for signs of intelligent life on other planets.

Think it Over

6. Think Critically Why should scientists continue to try to improve telescopes?

_____

_____

Reading Check

7. Explain Why don't radio telescopes need to be above Earth's atmosphere in order to collect data from space?

_____

_____

_____

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After You Read

Mini Glossary

electromagnetic spectrum: arrangement of electromagnetic waves according to their wavelengths

observatory: building that can house an optical telescope; often has a dome-shaped roof that can open for viewing

radio telescope: telescope that collects and records radio waves that travel through space; can be used day or night and in most weather conditions

reflecting telescope: optical telescope that collects light using a concave mirror to reflect light and form an image at the focal point

refracting telescope: optical telescope that collects light using convex lenses to bend light and form an image at the focal point

1. Review the terms and their definitions above. Choose a term and write a sentence that shows you understand the meaning of that term.

_____

_____

_____

2. Fill in the missing information in the table.

	Optical Telescope	Radio Telescope
Type of electromagnetic radiation collected	_____	Radio Waves
Parts used to collect electromagnetic radiation	_____ and mirrors, eyepieces	Curved dish and _____
Affected by atmosphere?	_____	_____

3. Did you answer all the questions on the quiz you took? How did the *Create a Quiz* strategy help you remember what you read?

_____

_____

_____

End of Section

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chapter 22 Exploring Space

section 2 Early Space Missions

What You'll Learn

- about natural and artificial satellites
- the difference between artificial satellites and space probes
- about the history of the race to the moon

Before You Read

What have humans sent into space? Why were those things sent into space?

_____

_____

_____

Read to Learn

The First Missions into Space

Astronomers have used telescopes to learn a lot about the Moon and the planets. However, astronomers want to gain more knowledge by sending humans to these places or by sending spacecraft where humans can't go.

How do spacecraft travel?

Spacecraft must travel faster than 11 km/s to break free of Earth's gravity and enter Earth's orbit. They can do this with special engines called rockets. **Rockets** are engines that carry their own fuel and have everything they need for the burning of fuel. They don't require air to carry out the process. Therefore, they can work in space, which has no air.

What are the different types of rockets?

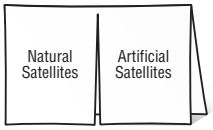
The simplest rocket engine is made of a burning chamber and a nozzle. A more complicated rocket has more than one burning chamber. There are two types of rockets. The difference between them is what fuel, or propellant, they burn.

Solid-Propellant Rockets Solid-propellant rockets are simpler in design. However, they cannot be shut down and restarted after they are ignited.

Identify the Main Point
Highlight the main point in each paragraph. Use a different color to highlight a detail or an example that helps explain the main point.

FOLDABLES™

B Organizing Information Make a two-tab Foldable to help you organize information about satellites.



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Liquid-Propellant Rockets Liquid-propellant rockets can be shut down after they are ignited and restarted. For this reason, they are used for long-term space missions. Scientists on Earth send signals to stop and restart the spacecraft's engines in order to change the spacecraft's direction. Liquid propellant rockets powered many space probes, including the two *Voyagers* and *Galileo*. In the photograph below, a liquid-propellant rocket stands on the launchpad.

Reading Check

1. **Identify** What kind of rocket was used to power the two *Voyager* space probes?

NASA

Picture This

2. **Describe** What is the advantage of the liquid-propellant rocket in the photo over a solid-propellant rocket?

How are fuels used to launch rockets?

Solid-propellant rockets use a rubber-like fuel. The fuel contains its own oxidizer. The burning chamber of a rocket is a tube that has a nozzle at one end. As the solid propellant burns, hot gases exert pressure on all inner surfaces of the tube. The tube pushes back on the gas except at the nozzle where hot gases escape. Thrust builds up and pushes the rocket forward.

Liquid-propellant rockets use a liquid fuel and an oxidizer, such as liquid oxygen stored in separate tanks. To ignite the rocket, the oxidizer is mixed with the liquid fuel in the burning chamber. As the mixture burns, forces are exerted and the rocket is propelled forward.

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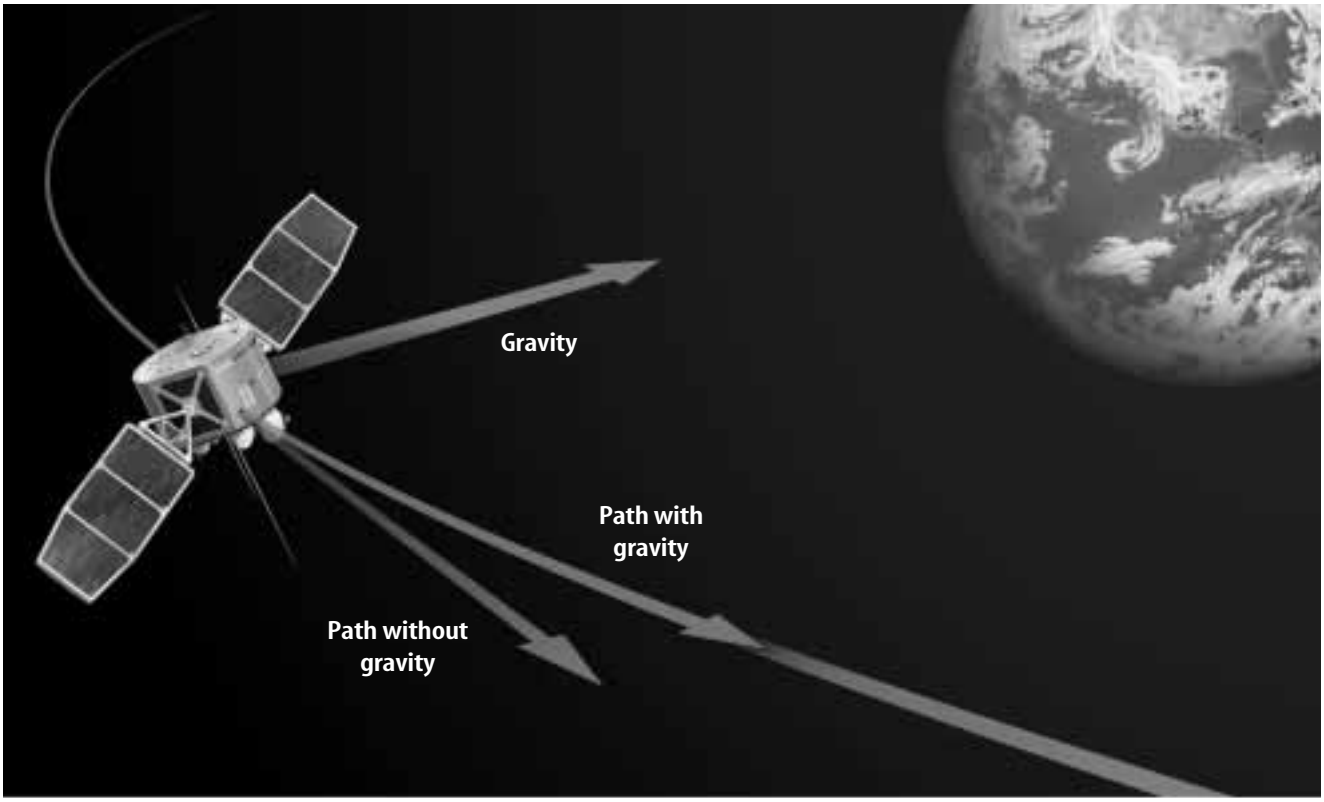

What are satellites?

The space age began in 1957 when the former Soviet Union used a rocket to send *Sputnik I* into space. *Sputnik I* was the first artificial satellite. A **satellite** is any object that revolves around another object. The Moon, which circles Earth, is an example of a natural satellite.

When an object enters space, it travels in a straight line unless a force makes it change direction. Earth's gravity is such a force. Earth's gravity pulls a satellite toward Earth. The illustration above shows the effect of gravity on a satellite's path. The result of the satellite traveling forward while at the same time being pulled toward Earth is a curved path. This curved path is called an **orbit.** *Sputnik I* orbited Earth for 57 days before gravity pulled it back into Earth's atmosphere, where it burned up.

What are satellites used for?

Today, thousands of artificial satellites orbit Earth. They have many uses. Communications satellites transmit radio and television programs to locations around the world. Other satellites collect scientific data. Weather satellites constantly monitor Earth's global weather patterns.

Picture This

3. **Interpret Scientific Illustrations** Where would the satellite go if Earth's gravity did not exist?

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Space Probes

Rockets also carry instruments into space to collect data. A **space probe** is an instrument that gathers information and sends it back to Earth. Space probes travel into and beyond the solar system, carrying cameras and other equipment to collect data. They carry radio transmitters and receivers to communicate with scientists on Earth. The table shows some of the space probes launched by the National Aeronautics and Space Administration (NASA).

Think it Over

4. **Compare** What did the *Mariner 2* and *Magellan* space missions have in common?

_____

_____

Some Early Space Missions

Mission Name	Date Launched	Destination	Data Obtained
Mariner 2	August 1962	Venus	verified high temperatures in Venus's atmosphere
Pioneer 10	March 1972	Jupiter	sent back photos of Jupiter—first probe to encounter an outer planet
Viking 1	August 1975	Mars	orbiter mapped the surface of Mars; lander searched for life on Mars
Magellan	May 1989	Venus	mapped Venus's surface and returned data on the composition of Venus's atmosphere

Where are other important space probes?

Voyager 1 and *Voyager 2* were launched in 1977. *Voyager I* flew past Jupiter and Saturn. *Voyager 2* flew past Jupiter, Saturn, Uranus, and Neptune. The objective of both probes is to explore beyond the solar system. Scientists expect both probes to send data back to Earth for at least 20 more years.

Galileo, launched in 1989, reached Jupiter in 1995. A smaller probe was released from *Galileo* into Jupiter's violent atmosphere. The small probe collected information about Jupiter's makeup, temperature, and pressure. *Galileo* also gathered information about Jupiter's moons, rings, and magnetic fields. The data from *Galileo* show that there may be an ocean of water under the surface of Europa, one of Jupiter's moons. *Galileo* also took photographs of a powerful volcanic vent on Io, another one of Jupiter's moons.

Applying Math

5. **Calculate** How many years did it take the probe *Galileo* to reach Jupiter?

_____

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Moon Quest

Sputnik I only sent out a beeping sound as it orbited Earth. But people soon realized that sending a human into space was not far off.

The former Soviet Union sent the first human into space in 1961. Cosmonaut Yuri A. Gagarin orbited Earth and returned safely. President John F. Kennedy called for the United States to send humans to the Moon and return them safely to Earth. He wanted to do this by the end of the 1960s. The race for space had begun.

The U.S. program to reach the Moon began with **Project Mercury.** The goal of *Project Mercury* was to orbit a piloted spacecraft and to bring it back safely. On May 5, 1961, Alan B. Shepard became the first U.S. citizen in space. In 1962, John Glenn became the first U.S. citizen to orbit Earth.

What was Project Gemini?

The next step in reaching the Moon was **Project Gemini.** There were two astronauts on every *Gemini* mission. *Gemini* spacecraft were larger than *Mercury* spacecraft. On one mission, astronauts met and connected with another spacecraft that was in orbit. The *Gemini* program also studied the effects of space travel on the human body.

Scientists also sent robotic probes to learn about the Moon. These probes did not carry humans. The probe *Ranger* proved that a spacecraft could be sent to the Moon. In 1966, *Surveyor* landed on the Moon's surface, proving that the surface could support spacecraft and humans. *Lunar Orbiter* took pictures of the Moon's surface to help choose future landing sites.

When did humans first walk on the Moon?

The final stage of the U.S. program to reach the Moon was **Project Apollo.** On July 20, 1969, the spacecraft *Apollo 11* landed on the Moon's surface. Neil Armstrong was the first human to set foot on the Moon. Edwin Aldrin walked on the Moon with Armstrong while Michael Collins remained in the Command Module. There were a total of six *Apollo* landings. Astronauts brought more than 2,000 samples of Moon rock and soil back to Earth before the program ended in 1972.

Reading Check

6. Summarize What was the goal of *Project Mercury*?

_____

_____

_____

Think it Over

7. Sequence Write the year in which each event occurred.

_____ The first human is sent into space.

_____ The first human orbits Earth.

_____ The first human walks on the Moon.

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After You Read

Mini Glossary

orbit: a curved path around a star or planet

Project Apollo: the final stage in the U.S. program to reach the Moon; the first person walked on the Moon on July 20, 1969

Project Gemini: the second stage in the U.S. program to reach the Moon in which an astronaut team connected with another spacecraft that was in orbit

Project Mercury: the first stage in the U.S. program to reach the Moon, in which a spacecraft with an astronaut orbited Earth and returned safely

rocket: engine that can work in space and burns liquid or solid fuel

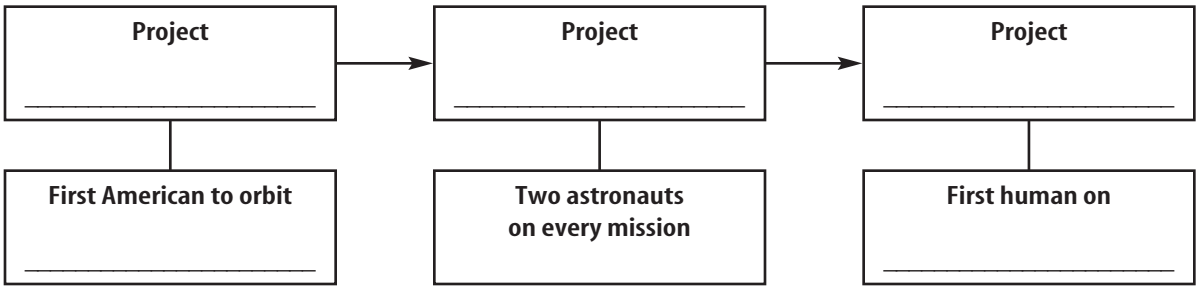
satellite: any object that revolves around another object

space probe: an instrument that is carried into space, collects data, and sends the data back to Earth

1. Review the terms and their definitions in the Mini Glossary. Use the term *orbit* to describe a satellite.

_____

2. Complete the following diagram to describe early U.S. space missions. Use the terms: *Earth, Gemini, Apollo, Mercury,* and *the Moon.*



3. Choose one of the question headings in the Read to Learn section. Write the question in the box. Then answer it in your own words.

Write your question here.

_____

_____

End of Section

ScienceOnline Visit **earth.msscience.com** to access your textbook, interactive games, and projects to help you learn more about early space missions.

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chapter 22 Exploring Space

section 3 Current and Future Space Missions

What You'll Learn

- about the space shuttle
- about orbital space stations
- about plans for future space missions
- about the application of space technology to everyday life

Before You Read

Do you have questions about the other planets? Write three questions about the planets on the lines below.

_____

_____

_____

Read to Learn

The Space Shuttle

NASA's early rockets cost millions of dollars and could be used only once. They were used to launch a small capsule holding astronauts into orbit.

NASA realized it would be less expensive and less wasteful to reuse resources. The space shuttle was created. The **space shuttle** is a reusable spacecraft that carries astronauts, satellites, and other materials to and from space.

At launch, the space shuttle stands on end and is connected to an external liquid-fuel tank and two solid-fuel booster rockets. When the shuttle reaches an altitude of about 45 km, the emptied, solid-fuel booster rockets drop off and parachute back to Earth. The rockets are recovered and reused. The liquid-fuel tank also separates and falls to Earth but is not recovered.

What happens on the space shuttle?

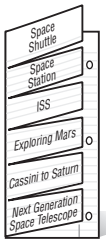
In space, the shuttle orbits Earth. Astronauts conduct scientific experiments, such as how space flight affects the human body. They also launch, repair, and retrieve satellites. When the mission is complete, the shuttle glides back to Earth and lands like an airplane.

Study Coach

Outline Outline the facts you learn about current and future space missions. For each mission, include a question that scientists hope to answer.

FOLDABLES™

Find Main Ideas Create a six-tab Foldable to summarize the main ideas from the section.



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Space Stations

Astronauts can spend only a short time living in the space shuttle. Its living area is small, and the crew needs more room to live, exercise, and work. A **space station** has living quarters, work and exercise areas, and all the equipment and life support systems that humans need in order to live and work in space.

In 1973, the United States launched the space station *Skylab*. Crews of astronauts spent up to 84 days there. They performed scientific experiments and collected data on the effects on humans of living in space. In 1979, the empty *Skylab* fell out of orbit and burned up as it entered Earth's atmosphere.

The former Soviet Union launched the space station *Mir*. Crews from the former Soviet Union spent more time on board *Mir* than crews from any other country.

Think it Over

1. **Infer** Why can't long-term projects be done on the space shuttle?

Cooperation in Space

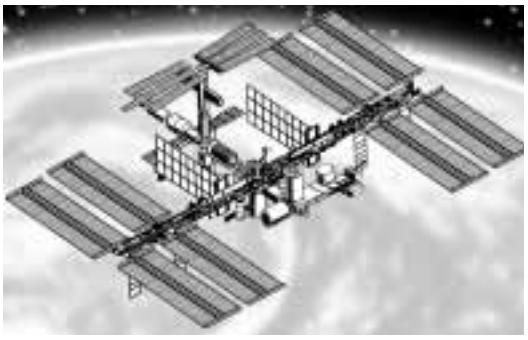
In 1995, the United States and Russia began an era of cooperation and trust in exploring space. One American and two Russians were launched into space together on a Russian spacecraft. Then a Russian traveled into space on an American shuttle. There were many missions involving space shuttles docking at *Mir*. Each was an important step toward building and operating the new *International Space Station*.

What is the *International Space Station*?

The *International Space Station (ISS)* will be a permanent laboratory in space designed for long-term research projects. Some of the research will be used to improve medicines and the treatment of many diseases. More than 15 nations are working together to build sections of the *ISS*. The sections will then be carried into space where the *ISS* will be constructed. The illustration below shows the proposed design for the *ISS*.

Reading Check

2. **Identify** What are some ways that the *ISS* will be used?



Proposed *International Space Station*

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How is the *ISS* being constructed?

The *ISS* is being built in phases. Phase One involved the space shuttle *Mir* docking missions. Phase Two began in 1998 when the first *ISS* module, or unit, was put into orbit. Another unit was attached, and the first crew of three people went to live and work on the station. Phase Two ended in 2001 when a U.S. laboratory was added. Labs from Japan, Europe, and Russia will follow. It will take 47 launches to finish the *ISS* by 2010, its scheduled completion date. NASA plans to station seven-person crews onboard for several months at a time.

Exploring Mars

In 1996, two Mars missions were launched, *Mars Global Surveyor* and *Mars Pathfinder*. *Surveyor* orbited Mars. It took high-quality photos of the planet's surface. *Pathfinder* landed on Mars. Rockets and a parachute slowed its fall. *Pathfinder* carried scientific instruments to study the surface, including a remote-controlled robot rover called *Sojourner*.

In 2002, the spacecraft *Mars Odyssey* began to map Mars. The information it gathered proved that soil contained frozen water on one part of Mars. In 2003, the twin robot rovers *Spirit* and *Opportunity* were launched from Earth to explore the surface of Mars. They will study the rocks, soils, and water on Mars. In 2008, a rover called *Phoenix* will be sent to dig over a meter into the surface.

New Millennium Program

NASA has plans for future space missions. The New Millennium Program (NMP) will develop equipment to be sent into the solar system.

Exploring the Moon

The *Lunar Prospector* spacecraft was launched in 1998. For one year it orbited the Moon, mapped it, and collected data. The data showed that there might be ice in craters at the Moon's poles. At the end of the mission, *Prospector* was crashed, on purpose, into a lunar crater. Scientists used special telescopes to look for water vapor that might have been tossed up when the spacecraft hit. They didn't find any water. But they believe that water ice is there. This water would be useful if a colony is ever built on the Moon.

Reading Check

3. Identify What was the name of the probe launched in 1996 that landed on Mars?

_____

Think it Over

4. Infer How could digging in Martian soil help scientists learn about Mars?

_____

_____

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Cassini

In October 1997, NASA launched the space probe *Cassini*. This probe's destination is Saturn. When it lands, the space probe will explore Saturn and surrounding areas for four years. One part of its mission is to deliver the European Space Agency's *Huygens* probe to Saturn's largest moon, Titan. Some scientists theorize that Titan's atmosphere may be similar to the atmosphere of early Earth.

Reading Check

5. **Describe** What do scientists hope to learn about Saturn's moon Titan from *Huygens*?

What will the new space telescopes be like?

Not all missions involve sending astronauts or probes into space. Plans are being made to launch a new space telescope that is capable of observing the first stars and galaxies in the universe. The *James Webb Space Telescope*, shown in the figure below, will be the successor to the *Hubble Space Telescope*. As part of the Origins project, it will provide scientists with the chance to study how galaxies evolved, how stars produce elements, and how stars and planets are formed. To accomplish these tasks, the telescope will have to see objects that are 400 times fainter than any objects seen by telescopes on Earth. NASA intends to launch the *James Webb Space Telescope* no earlier than 2013.

NASA

Picture This

6. **Think Critically** Why might scientists want to learn how galaxies evolved?

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What are some benefits of space technology?

Research done for the space programs is also used to solve problems on Earth. It has led to better ways to detect and treat heart disease. It has helped doctors create a way to find eye problems in infants. Knowledge gained from shuttle research has helped scientists develop cochlear implants. These tiny ear devices have helped thousands of deaf people hear.

Space technology can even help catch criminals and prevent accidents. Scientists developed a way to sharpen images they got from space. Now police use this same method to read blurry photos of license plates, as shown in the picture below.

Police cars and ambulances use an instrument developed in space research. As an emergency vehicle approaches a traffic light, the instrument changes the signal so other cars have time to stop safely. Global Positioning System (GPS) technology uses satellites to determine location on Earth's surface.

The Cover Story/CORBIS

Think it Over

7. Think Critically What are some ways space technology benefits people on Earth?

Picture This

8. Draw Conclusions How might the use of space technology help police enforce the law?

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After You Read

Mini Glossary

space shuttle: reusable spacecraft that carries astronauts, satellites, and other materials to and from space

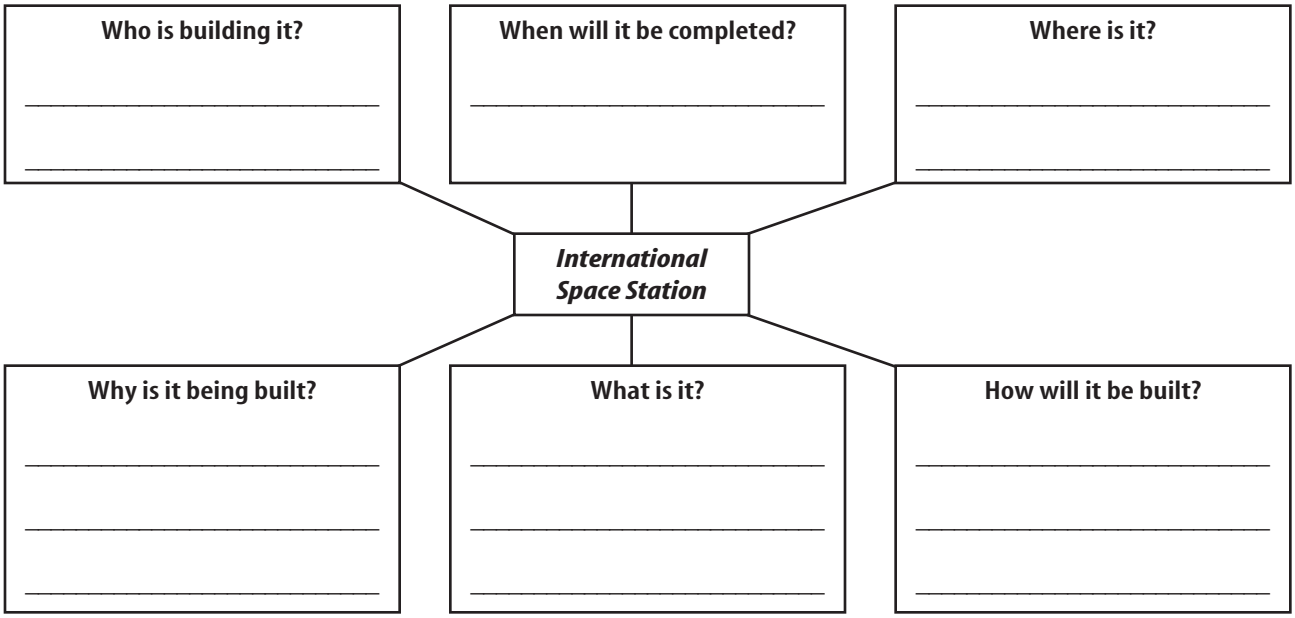
space station: a structure with living quarters, work and exercise areas, and equipment and life support systems for humans to live and work in space

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain how the space shuttle is used to build the space station.

_____

_____

2. Complete the diagram to review what you learned about the *International Space Station.*



3. Describe two ways that space research has helped people on Earth.

_____

_____

End of Section

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chapter 23

The Sun-Earth-Moon System

section 1 Earth

What You'll Learn

- Earth's shape, size, and movements
- the difference between rotation and revolution
- what causes the seasons

Before You Read

What do you already know about Earth's shape, its size, and how it moves? Write what you know on the lines below.

_____

_____

_____

Read to Learn

Properties of Earth

In the morning, the Sun rises in the east. It moves across the sky during the day. Finally, the Sun sets in the west. Is the Sun moving—or are you?

People once thought that Earth was a flat object at the center of the universe. They believed that the Sun went around Earth in a big circle each day. Now, most people know that Earth is not flat, and the Sun only looks like it is moving around Earth. Scientists have discovered that Earth spins and that Earth moves around the Sun. It is the spinning motion of Earth that makes it look like the Sun is moving across the sky.

What is Earth's shape?

Basketballs, tennis balls, and Earth have something in common. They are all round, three-dimensional objects called **spheres** (SFIHRZ). The distance from the center of a sphere to any point on the surface is the same.

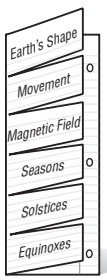
Aristotle, a Greek astronomer and philosopher who lived around 350 B.C., observed that Earth made a curved shadow on the Moon during an eclipse. His observations led him to think that Earth was a sphere.

Study Coach

Make a Sketch As you read, draw your own sketches to help you understand and remember new information.

FOLDABLES™

A Find Main Ideas Make the following six-tab Foldable to identify and record the main ideas about Earth.



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How do we know Earth is a sphere?

Today, we have observations from astronauts and pictures from artificial satellites and space probes to show us Earth's shape. Now we also know Earth is not a perfect sphere. It bulges at the equator and is somewhat flat at the poles. The table below shows the differences in Earth's diameter at the equator and from pole to pole.

Applying Math

1. **Solve a One-Step Equation** On the table, find the numbers for Diameter (equator) and for Diameter (pole to pole). Subtract the number for Diameter (pole to pole) from the number for Diameter (equator). What does this tell you about Earth's shape?

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

Does Earth spin?

Earth spins like a top. The imaginary center line around which Earth spins is called Earth's **axis.** The poles are at the north and the south ends of Earth's axis. The spinning of Earth on its axis is called **rotation.**

Earth's rotation causes day and night. As Earth rotates, your area of Earth faces toward the Sun in the morning and away from the Sun at night. Earth rotates once each day. A rotation takes about 24 hours.

Magnetic Field

Reading Check

2. **Explain** How is Earth like a bar magnet?

Scientists hypothesize that the movement of material inside Earth's core, along with Earth's rotation, generates a magnetic field. Like a bar magnet, Earth has opposite north and south magnetic poles. Earth's magnetic field protects you from harmful radiation. It does this by trapping many charged particles that reach Earth from the Sun.

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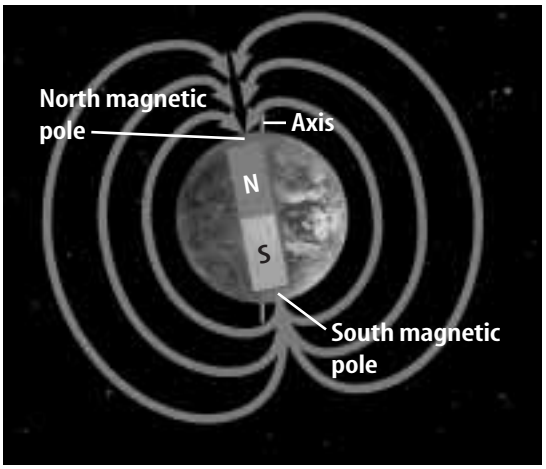

Picture This

3. **Draw** lines through Earth's magnetic axis and Earth's rotational axis to show they do not line up.

What is Earth's magnetic axis?

When a compass needle points north, you are seeing proof of Earth's magnetic field. The line that joins Earth's north and south magnetic poles is called its magnetic axis. As shown in the figure above, the magnetic axis does not line up with Earth's rotational axis. In fact, the location of the magnetic axis changes slowly over time. A compass whose needle points north will lead you to Earth's magnetic north pole, not the rotational north pole.

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 changes?

Does Earth's orbit cause seasons?

Recall that Earth's rotation causes day and night. Another movement of Earth is called revolution. **Revolution** is Earth's orbit, or the path of Earth, as it goes around the Sun. It takes a year for Earth to orbit the Sun.

Reading Check

4. **Define** What is Earth's revolution?

The shape of Earth's path around the Sun is an **ellipse** (ee LIHPS)—a long, curved shape, similar to a stretched-out circle. The Sun is not located in the center of the ellipse but is a little toward one end. Earth is closest to the Sun around January 3, and farthest from the Sun around July 4.

Although Earth's orbit takes it nearer and farther from the Sun, the change in distance is small and does not cause seasons. If Earth's distance from the Sun caused the seasons, January—when the Earth is nearest to the Sun—would have the warmest days. This is not the case, however, in the northern hemisphere.

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Does Earth's tilted axis cause seasons?

Earth's axis is tilted 23.5 degrees from a line drawn perpendicular to the plane of its orbit. It is this tilt that causes seasons. The tilt explains why Earth receives such a different amount of solar energy from place to place during the year.

In the northern hemisphere, summer begins in June and ends in September. This is when the northern hemisphere is tilted toward the Sun. During summer, there are more hours of sunlight—or solar energy. Longer periods of sunlight are one reason that summer is warmer than winter, but this is not the only reason.

Think it Over

5. Infer In the winter, are daylight hours longer or shorter than in summer?

How does Earth's tilt affect solar radiation?

Earth's tilt causes the Sun's radiation to strike the hemispheres at different angles. Sunlight strikes the hemisphere tilted toward the Sun at an angle closer to 90 degrees than the hemisphere tilted away. Thus the hemisphere tilted toward the Sun receives more solar radiation than the hemisphere tilted away from the Sun.

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

Think it Over

6. Infer If it is winter in the northern hemisphere, which hemisphere is getting more of the Sun's radiation?

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. The position of Earth in relation to the Sun at different times of the year is shown in the figure on the next page. In the southern hemisphere, the winter solstice is in June and the summer solstice is in December.

Summer solstice is the longest period of daylight of the year. From the summer solstice to the winter solstice, the number of daylight hours keeps decreasing. The winter solstice is the shortest period of daylight of the year. Then the number of daylight hours begins increasing again.

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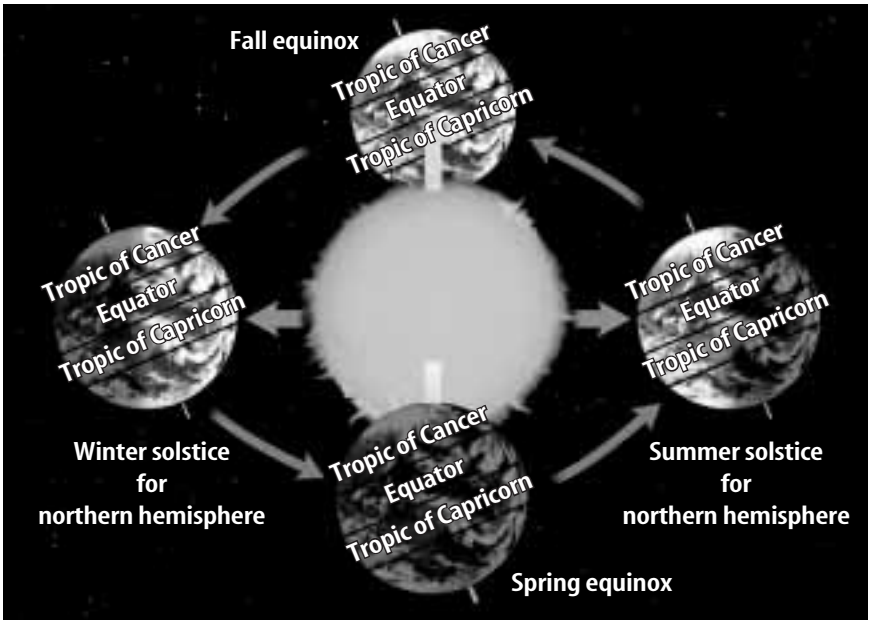

Equinoxes

An **equinox** (EE kwuh nahks) occurs when the Sun is directly above Earth's equator. The tilt of Earth's axis means that the Sun's position relative to the equator is constantly changing. Most of the time, the Sun is either north or south of the equator. But two times a year the Sun is directly over the equator. This results in the spring and fall equinoxes. At an equinox, the Sun strikes the equator at the highest possible angle, 90 degrees. This can be seen in the figure above.

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

In the northern hemisphere, the spring equinox occurs on March 20 or 21, and the fall equinox occurs on September 22 or 23. In the southern hemisphere, the spring equinox occurs in September, while the fall equinox occurs in March.

Picture This

7. Explain Use the figure to explain over which part of Earth the Sun is located during the winter solstice in the northern hemisphere.

_____

_____

Reading Check

8. Define When does an equinox occur?

_____

_____

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After You Read

Mini Glossary

axis: imaginary center line around which Earth spins

ellipse (ee LIHPS): elongated, closed curve that described Earth's yearlong orbit around the sun

equinox (EE kwuh nahks): twice-yearly time—each spring and fall—when the Sun is directly over the equator and the number of daylight and nighttime hours are equal worldwide

revolution: Earth's yearlong elliptical orbit around the Sun

rotation: spinning of Earth on its axis

solstice: twice-yearly point at which the Sun reaches its greatest distance north or south of the equator

sphere (SFIHR): a round, three-dimensional object whose surface is the same distance from its center at all points

1. Review the terms and their definitions in the Mini Glossary. Write a sentence or two about the effects of Earth's rotation and its tilted axis.

_____

_____

_____

2. Complete the table by labeling the statements true or false.

Earth's Properties and Seasons	True or False?
Earth's shape is a slightly flattened sphere.	_____
Earth's seasons are caused by its tilt.	_____
The shape of Earth's orbit is a circle.	_____
The shape of Earth's orbit is an ellipse.	_____
After the summer solstice, daylight hours increase.	_____
During a solstice, the Sun is at its farthest point north or south of the equator.	_____

End of Section

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chapter 23 The Sun-Earth-Moon System

section 2 The Moon—Earth's Satellite

What You'll Learn

- the phases of the Moon
- why solar and lunar eclipses occur
- the Moon's physical characteristics

Before You Read

What do you already know about the moon? List physical characteristics or phases of the moon on the lines below. Check your information as you read the section.

_____

_____

_____

Read to Learn

Motions of the Moon

The Moon's movements are similar to Earth's movements. Just as Earth rotates on its axis, the Moon rotates on its axis. Earth revolves around the Sun, while the Moon revolves around Earth. The Moon's revolution around Earth is responsible for the changes in the Moon's appearance.

If the Moon rotates on its axis, why can't you see it spin around in space? 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. So, even though the Moon rotates on its axis, the same side is always visible from Earth.

What lights the Moon?

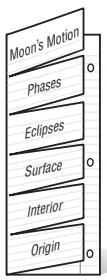
The surface of the Moon reflects the light of the Sun. Just as half of Earth experiences day as the other half experiences night, half of the Moon is lighted while the other half is dark. As the Moon revolves around Earth, different portions of its lighted side can be seen. This is why the Moon appears to change form or shape.

Study Coach

Create a Quiz As you read the text, create a quiz question for each subject. When you have finished reading, see if you can answer your own questions correctly.

FOLDABLES™

B Classify Make the following six-tab Foldable to identify the main ideas about Earth's Moon.



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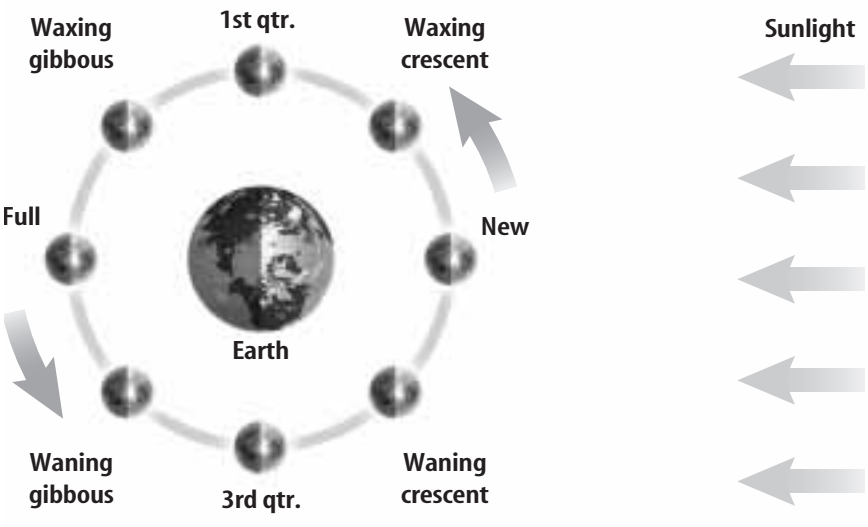
Phases of the Moon

Moon phases are the different ways the Moon appears from Earth. The phase of the Moon depends on the relative positions of the Moon, Earth, and the Sun, as shown in the figure below.

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 of the Moon faces Earth. Even though the Moon is in the sky, it cannot be seen. A new moon rises and sets in the sky at the same time as the Sun.

Moon Phases



Picture This

1. **Identify** Highlight the lighted side of each figure of the Moon.

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

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

Reading Check

2. **Apply** What is happening when the moon is in its waxing phases?

_____

_____

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Waning Phases After the full moon, the phases are said to be waning. **Waning** means that you can see less and less of the lighted half of the Moon each night. About 24 h after a full moon, you begin to see the waning gibbous moon. About a week after a full moon, you can again see half of the lighted side of the Moon, or one quarter of the Moon's surface. This is the third-quarter phase. As the waning phases continue, you see less and less of the Moon. The last of the waning phases is the waning crescent, when just a small slice of the Moon is visible. This takes place just before another new 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 difference in the numbers is due to Earth's revolution. It takes about two extra days for the Sun, Earth, and the Moon to return to their same relative positions.

Applying Math

3. Calculate About how many times does the moon complete its cycle of phases around Earth in one year?

Eclipses

Imagine living 10,000 years ago. You are gathering nuts and berries when, without warning, the Sun disappears. 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 or how. 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). Today, most people know what causes eclipses. What causes the day to become night and then change back into day?

What causes an eclipse?

The revolution of the Moon around Earth causes eclipses. Eclipses take place when Earth blocks light from reaching the Moon, or when the Moon blocks light from reaching a part of Earth. Sometimes, during a new moon, the Moon's shadow falls on Earth. This causes a solar eclipse. During a full moon, Earth may cast a shadow on the Moon. This causes a lunar eclipse.

An eclipse can take place 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 take place only a few times each year.

Think it Over

4. Infer What is between the Sun and the Moon during a lunar eclipse?

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What is an eclipse 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. A solar eclipse is shown in the figure below. Depending on where you are on Earth, you may be in a total eclipse or a partial eclipse. Only a small area of Earth is part of the total solar eclipse during the eclipse event.

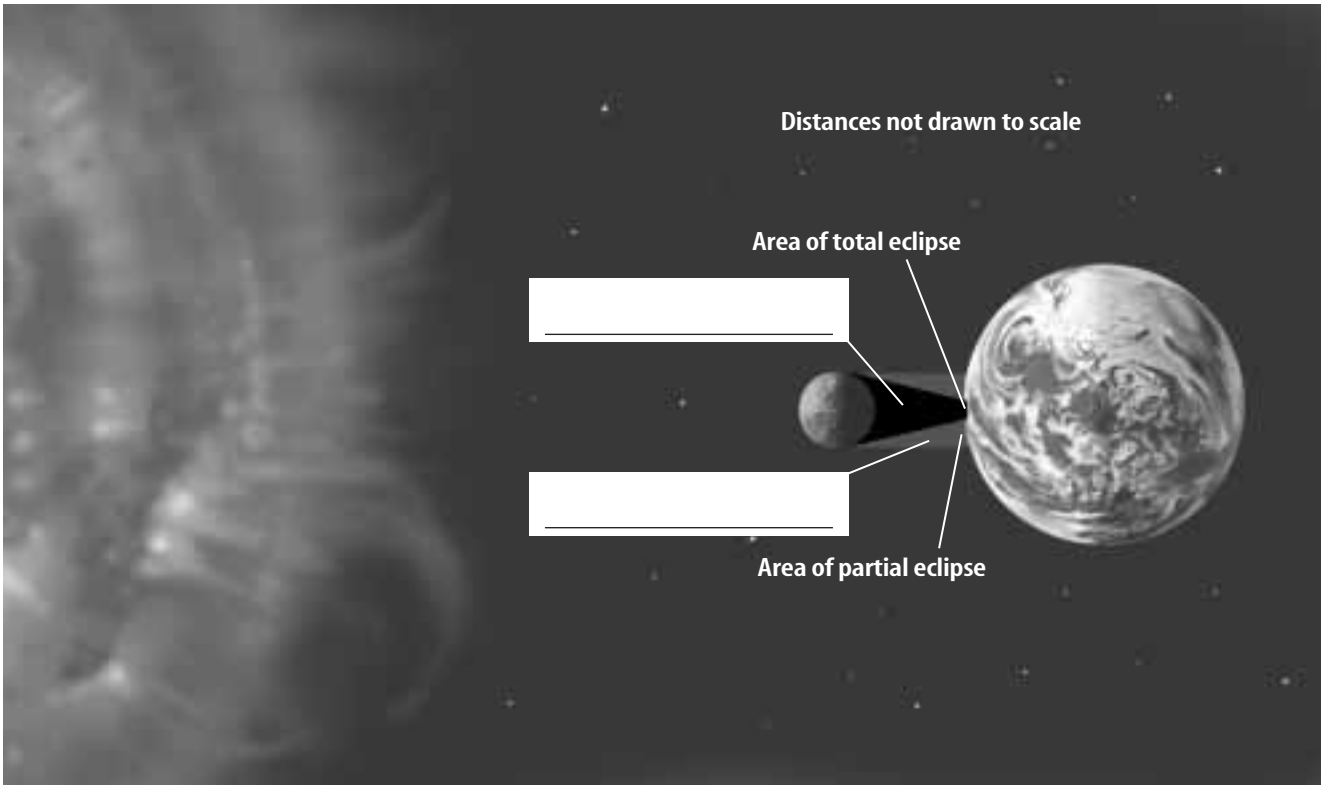
The darkest portion of the Moon's shadow on Earth is called the umbra (UM bruh). A person standing within the umbra experiences a total solar eclipse. During a total solar eclipse, the only part of the Sun that is visible is a white glow around the edge of the eclipsing Moon.

Surrounding the umbra is a lighter shadow on Earth's surface. This lighter shadow is called the penumbra (puh NUM bruh). Those who are 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.*

Picture This

5. Label On the diagram, label the umbra and the penumbra.

Solar Eclipse



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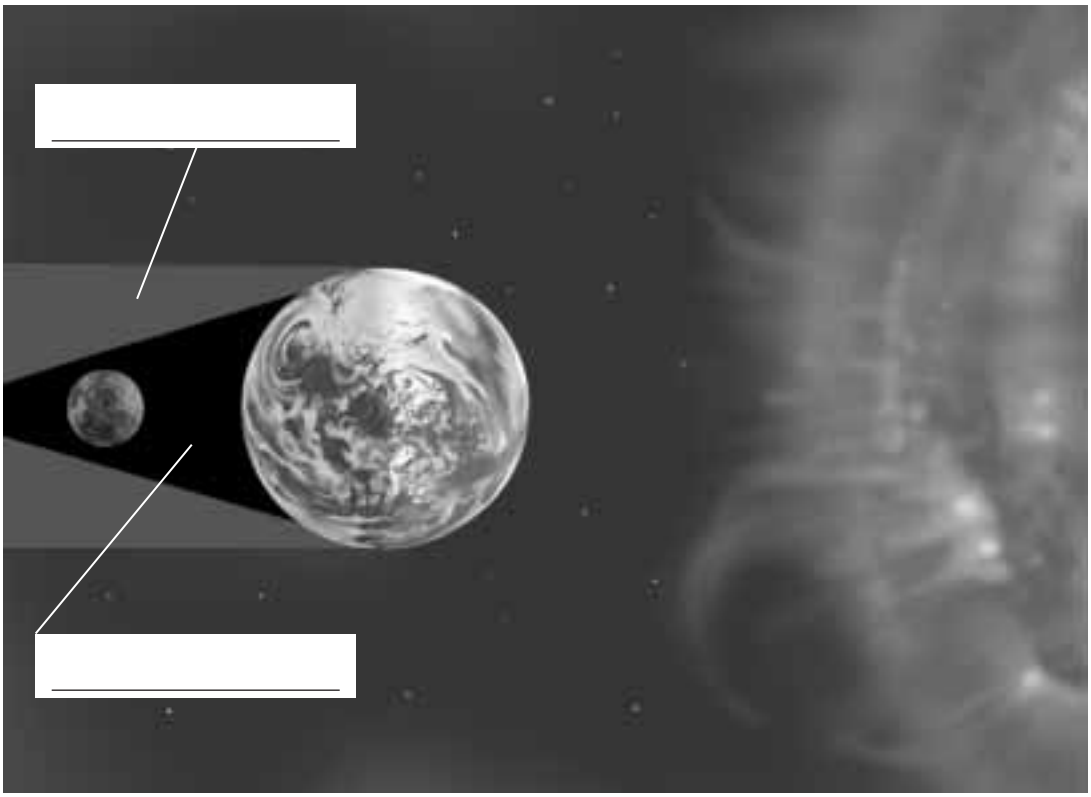
Lunar Eclipse



What is an eclipse of the Moon?

When Earth moves directly between the Sun and the Moon and its 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 can see a curved shadow on the Moon's surface. As the Moon moves completely into Earth's umbra, it goes dark. This is a total lunar eclipse. A total lunar eclipse is shown in the figure above. Sometimes sunlight bent through Earth's atmosphere will cause the eclipsed Moon to have a reddish appearance.

A partial lunar eclipse occurs when only a portion of the Moon moves into Earth's shadow. Then, the rest of the Moon is in Earth's penumbra and still gets some direct sunlight. When the Moon is totally within Earth's penumbra, it is called a penumbral lunar eclipse. It is difficult to tell when a penumbral lunar eclipse happens because some sunlight continues to fall on the side of the Moon facing Earth.

Picture This

6. Label On the diagram, label the umbra and penumbra.

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During which lunar phase do eclipses occur?

Lunar eclipses do not happen every month. Lunar eclipses happen only during the full moon phase.

A total lunar eclipse can be seen by anyone on the nighttime side of Earth as long as the Moon is not hidden by clouds. Only a few people get to witness a total solar eclipse, however. Only those in the small area where the Moon's umbra strikes Earth can witness it.

Reading Check

7. Explain When do lunar eclipses occur?

The Moon's Surface

When you look at the Moon, you can see many depressions called craters. Meteorites, asteroids, and comets striking the Moon's surface created most of these craters. When the objects struck the Moon, cracks may have formed in the Moon's crust, allowing lava to reach the surface and fill up the large craters. Dark, flat regions formed as the lava spread. These regions are called **maria** (MAHR ee uh).

Reading Check

8. Define What are maria?

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 shows that craters formed after the Moon's surface had cooled. The maria formed early while molten rock still remained in the Moon's interior. The Moon must once have been as geologically active as Earth is today. As the Moon cooled, the interior separated into distinct layers.

The Moon's Origin

Before the Apollo space missions in the 1960s and 1970s, there were three leading theories about the origin of the Moon. One theory was that the Moon was captured by Earth's gravity. Another stated 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.

What is the impact theory?

The data gathered by the Apollo missions led many scientists to support a new theory. This theory, called the impact theory, states that the Moon formed billions of years ago from condensing gas and debris thrown off when Earth collided with a Mars-sized object. The blast that resulted ejected material from both objects into space. A ring of gas and debris formed around Earth. Finally, particles in that ring joined together to form the Moon.

Think it Over

9. Recognize Cause and Effect What was a result of the data gathered in the Apollo missions?

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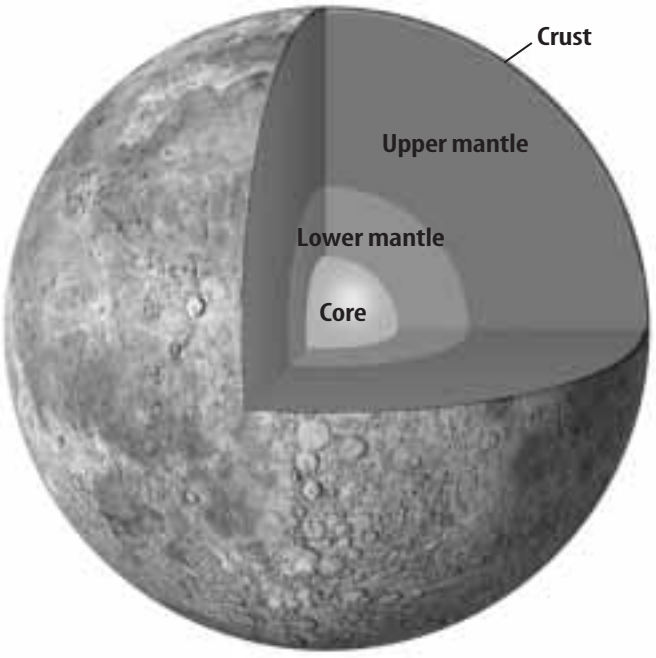
Inside the Moon

Just as scientists study earthquakes to gather information about Earth's interior, scientists study moonquakes to understand the structure of the Moon. The information scientists gather from moonquakes has helped them make several possible models of the Moon' interior. One model is shown in the figure below. In it, the Moon's crust is about 60 km thick on the side facing Earth. On the side facing away from Earth, the Moon's crust is thought to be about 150 km thick. Under the crust, another solid layer, the mantle, may be 1,000 km deep. A zone of the mantle where the rock is partly melted may extend even farther down. Below this mantle, there may be a solid, iron-rich core.



What has been learned about the Moon in history?

Much has been learned about the Moon and Earth by studying the Moon's phases and eclipses. Earth and the Moon are in motion around the Sun. From studying the curved shadow that Earth casts on the Moon, early scientists learned that Earth is a sphere. When Galileo first used his telescope to look at the Moon, he saw that it was not smooth but had craters and maria. Today, scientists study rocks collected from the Moon. By doing so, they hope to learn more about Earth.

Applying Math

10. Calculate About what is the difference in thickness between the Moon's crust on the side facing Earth and the crust facing away from Earth?

_____

Picture This

11. Interpret Scientific Illustrations List the layers of the Moon in order from the interior to the surface.

_____

_____

_____

_____

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After You Read

Mini Glossary

full moon: phase that occurs when all of the Moon's surface facing Earth reflects light

lunar eclipse: occurs when Earth passes directly between the Sun and the Moon and Earth's shadow falls on the Moon

maria (MAHR ee uh): dark-colored, relatively flat regions of the Moon formed when ancient lava reached the surface and filled craters on the Moon's surface

moon phase: change in appearance of the Moon as viewed from the Earth, due to the relative positions of the Moon, Earth, and the Sun

new moon: moon phase that occurs when the Moon is between Earth and the Sun, at which point the Moon cannot be seen because its lighted half is facing the Sun and its dark side faces Earth

solar eclipse: occurs when the Moon passes directly between the Sun and Earth and casts a shadow over part of Earth

waning: describes phases that occur after a full moon, as the visible lighted side of the Moon grows smaller

waxing: describes phases following a new moon, as more of the Moon's lighted side becomes visible

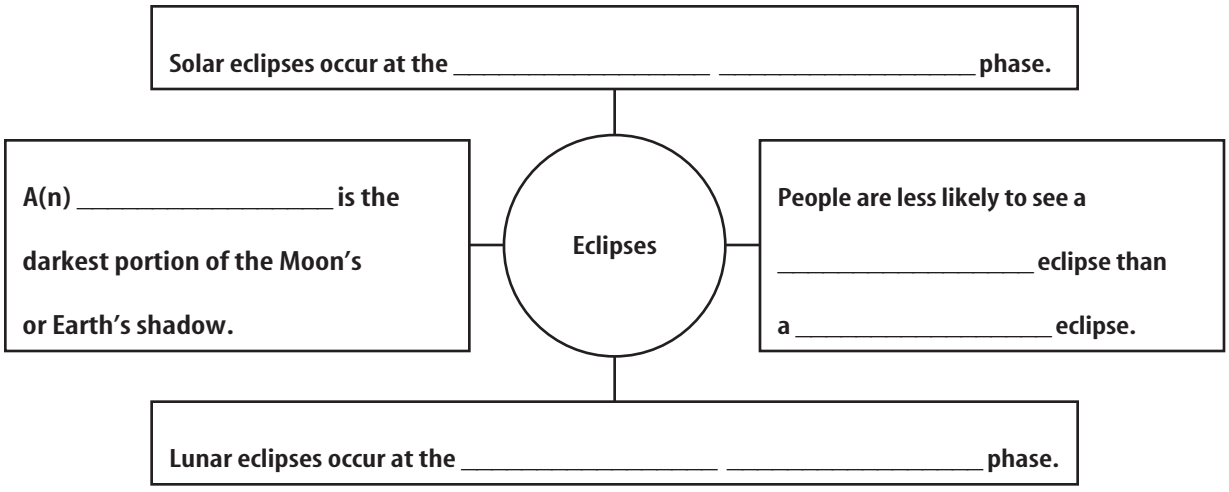
1. Review the terms and their definitions in the Mini Glossary. Write two sentences explaining different phases of the Moon.

_____

_____

_____

2. Fill in the concept map with what you know about eclipses.



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End of Section

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chapter 23 The Sun-Earth-Moon System

section 3 Exploring Earth's Moon

Before You Read

People have always been curious about the Moon. What would you like to know about the Moon? In the space below, write some questions you have about the Moon.

_____

_____

_____

What You'll Learn

- recent discoveries about the Moon
- facts that might affect future space travel to the Moon

Read to Learn

Missions to the Moon

For centuries, scientists have tried to discover what the Moon is made of and how it formed. In 1959, the former Soviet Union launched the first *Luna* spacecraft. This spacecraft made it possible to study the Moon up close.

Two years later, the United States began a similar space program. The United States launched the first *Ranger* spacecraft and a series of *Lunar Orbiters.* The spacecraft in these early missions took detailed photographs of the Moon.

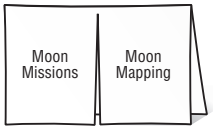
The *Surveyor* spacecraft were the next step. The *Surveyor* spacecraft were designed to take more detailed photographs and to actually land on the Moon. Five of these spacecraft landed on the Moon's surface and analyzed lunar soil. The goal of the *Surveyor* program was to gather information about the Moon that would allow astronauts to land there one day.

In 1969, the astronauts of *Apollo 11* landed on the Moon. Between 1969 and 1972, when the *Apollo* missions ended, 12 U.S. astronauts had walked on the Moon.

Identify the Main Point
Highlight the main point in each paragraph. Using a different color, highlight an example that helps explain the main point.

FOLDABLES™

Organize Information
Make the following 2-tab Foldable to organize information about Moon missions and Moon mapping.



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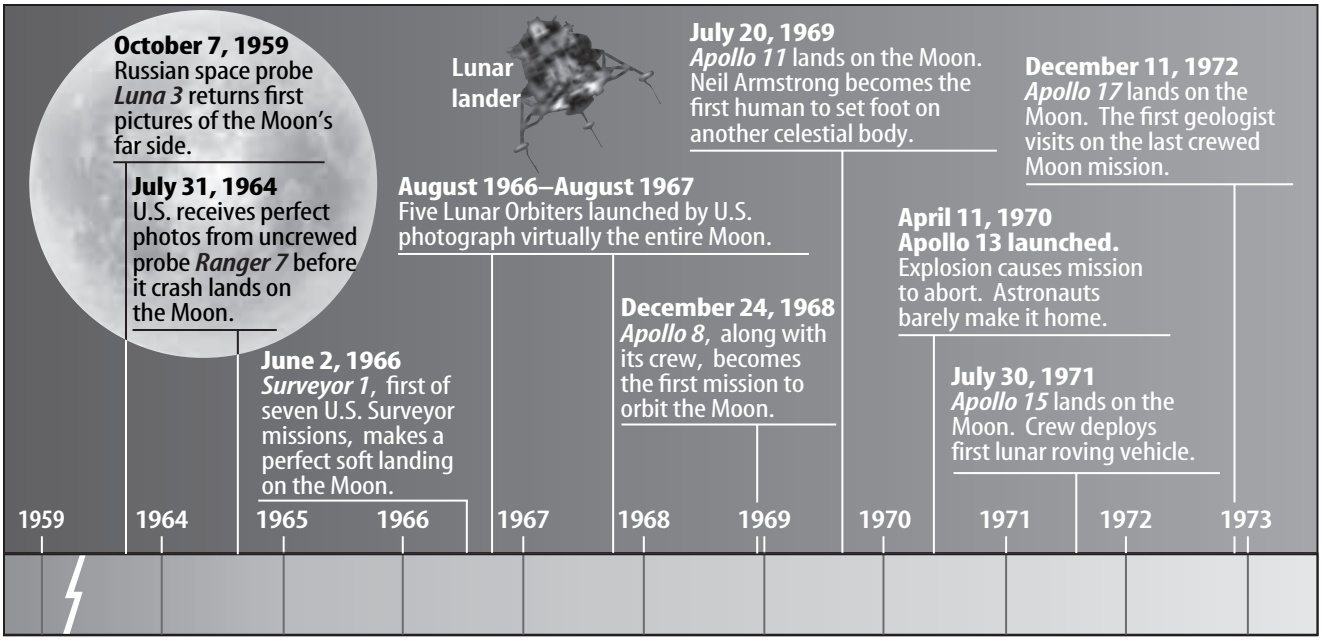
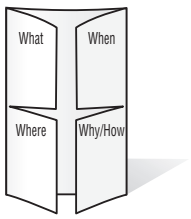


Picture This

1. **Use Tables** Which Apollo mission deployed the first lunar roving vehicle?

FOLDABLES™

Ⓓ Ask Questions Make the following Foldable to identify what you already know and what you want to know about the *Clementine* and *Lunar Prospector* missions.



Is the Moon being studied today?

The time line above shows important events in the exploration of the Moon. But, there is still much to learn about the Moon. The United States has started to study the Moon again. In 1994, the spacecraft *Clementine* was placed into lunar orbit. *Clementine's* purpose was to conduct a survey of the Moon's surface. An important part of the study was to collect data on the mineral content of Moon rocks. While in orbit around the Moon, *Clementine* also mapped features on the Moon's surface, including huge impact basins.

What is an impact basin?

An **impact basin,** or impact crater, is a depression left behind when a meteorite or other object strikes the Moon. The South Pole-Aitken Basin is the oldest impact basin that has been identified so far.

Impact basins like the South Pole-Aitken Basin are very interesting to scientists. Because this deep crater is located at one of the poles, the Sun's rays never reach the bottom of the crater. Therefore, the bottom of the crater is always in shadow. The temperatures there are extremely cold. Scientists hypothesize that if a comet collided with the Moon, ice could have been deposited there. Some of that ice might still be found in the shadows at the bottom of the crater. In fact, *Clementine* sent information that showed the presence of water, just as scientists had hypothesized.

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Mapping the Moon

Photographs taken by *Clementine* were used to create detailed maps of the Moon's surface. Data from *Clementine* showed that the Moon's crust did not have the same thickness all over the Moon. The crust on the side of the Moon that faces Earth is much thinner than the crust on the far side. Additional information showed that the Moon's crust is thinnest under impact basins.

What is the *Lunar Prospector?*

In 1998, NASA sent the small *Lunar Prospector* spacecraft into orbit around the Moon. For one year the spacecraft circled the Moon from one pole to the other. It flew around the Moon once every two hours.

The *Lunar Prospector* collected data that confirmed that the Moon has a small, iron-rich core at its center. This finding supports the impact theory of how the Moon was formed. The small core is a result of a small amount of iron that could have blasted away from Earth.

Reading Check

2. Describe What is in Moon's core that supports the impact theory?

_____

Where is there ice on the Moon?

In addition to photographing the surface, *Lunar Prospector* carried instruments that gathered information for mapping the Moon. The maps were of the Moon's gravity, its magnetic field, and how much and where certain elements were found in the Moon's crust. Scientists finally had data from the entire surface of the Moon, rather than just the areas around the Moon's equator.

The *Lunar Prospector* confirmed that ice was present in deep craters at both poles of the Moon. Using data from *Lunar Prospector*, scientists made maps that show the location of ice at each pole. At first scientists thought that ice crystals were mixed with lunar soil. More recent information suggests that the ice deposit may be in the form of more compact deposits.

Reading Check

3. Identify Where is there ice on the Moon's surface?

_____

_____

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After You Read

Mini Glossary

impact basin: a depression left on the surface of the Moon caused by an object striking its surface

1. Review the term and its definition in the Mini Glossary. Write a sentence explaining what causes impact basins to form.

2. Complete the chart to review missions that gathered information about the Moon.

Spacecraft	Mission
Ranger and Lunar Orbiters	**To photograph the Moon**
Surveyor	
Clementine	
Lunar Prospector	

3. How did highlighting help you read this section? Reread the sentences you highlighted in the text. Now that you have read the entire section, do you think you highlighted the right sentences? Make any corrections you think would help you.

End of Section

ScienceOnline Visit **earth.msscience.com** to access your textbook, interactive games, and projects to help you learn more about exploring Earth's moon.

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chapter 24 The Solar System

section 1 The Solar System

What You'll Learn

- past and present ideas about the solar system
- how the solar system formed
- how the Sun's gravity holds planets in orbit

Before You Read

Name the planets in the solar system that you already know.

_____

_____

Read to Learn

Ideas About the Solar System

Based on their observations, early humans believed the Sun and planets moved around Earth. Today, people understand that Earth and the other planets and objects in the solar system orbit, or move around, the Sun.

Earth-Centered Model Early Greek scientists thought the planets, the Sun, the Moon, and the stars rotated around Earth. This is called the Earth-centered model of the solar system. It included Earth, the Moon, the Sun, five planets—Mercury, Venus, Mars, Jupiter, and Saturn—and the stars.

Sun-Centered Model In 1543, Nicholas Copernicus published his model of the solar system. He stated that Earth and the other planets revolved around the Sun and that the Moon revolved around Earth. He explained that the Sun and the planets only looked like they were moving around Earth because Earth rotates. This is the Sun-centered model of the solar system.

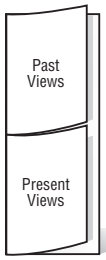
Galileo Galilei used his telescope to observe that Venus went through a full cycle of phases like the Moon's. Also, Venus looked smaller when its phase was near full. This could only be explained if Venus were orbiting the Sun, not Earth. Galileo concluded that the Sun is the center of the solar system.

Study Coach

Ask Questions As you read, write down your questions. Use the questions to find out more about topics that are not clear, or topics that are particularly interesting.

FOLDABLES™

A Find Main Ideas Make the following two-tab Foldable to help you identify the main ideas about past and present views on the solar system.



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What is the modern view of the solar system?

Today, we know that the **solar system** is made up of eight planets, including Earth, and many smaller objects that orbit the Sun. The Sun and the position of the eight planets relative to the Sun are shown in the figure on this page and the next page. The solar system also includes a huge amount of space that stretches out in all directions from the Sun.

The Sun contains 99.86 percent of the mass in the solar system. Therefore, the Sun has a lot of gravity. The Sun's gravity is strong enough to hold the planets and other objects in their orbits.

Reading Check

1. **Explain** What force holds the planets in their orbits?

_____

_____

How the Solar System Formed

Scientists hypothesize that the solar system formed more than 4.6 billion years ago. They have found clues that it may have formed from a cloud of gas, ice, and dust. Over time, this cloud pulled together to form a large, tightly packed, spinning disk. The center of the disk heated up to about 10 million degrees Celsius, and the reaction known as nuclear fusion began. That is how the star, the Sun, formed at the center of the solar system.

How did the planets form?

Not all of the gas, ice, and dust was pulled into the center of the spinning disk to form the Sun. Some matter collided and stuck together to form planets and asteroids. The eight planets of the solar system are divided into two groups, the inner planets and the outer planets.

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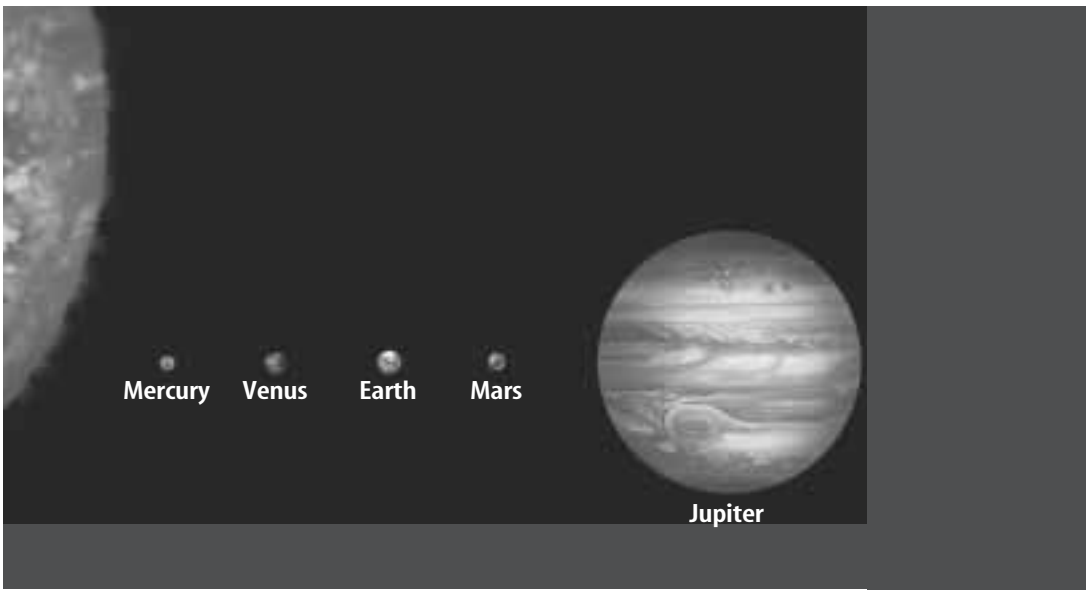
Picture This

2. **Interpret Scientific Illustrations** Which planet is closest to the Sun? Which planet is farthest from the Sun? Which is the third planet from the Sun?

_____

_____

_____



What are the eight planets?

The inner planets of the solar system—Mercury, Venus, Earth, and Mars—are small, rocky planets with iron cores. The outer planets are Jupiter, Saturn, Uranus, and Neptune. The outer planets are much larger than the inner planets. They are made up mostly of lighter substances, including hydrogen, helium, methane, and ammonia.

These light substances are not found in great quantities in the inner planets. The high temperatures closer to the Sun turned these substances to gas. They could not cool enough to form solids.

Motions of the Planets

When Nicholas Copernicus developed his Sun-centered model of the solar system, he thought the orbits of the planets were circles. In the early 1600s, Johannes Kepler discovered that the orbits of the planets are oval shaped, or elliptical. He also found that the Sun's position in the orbits is slightly off-center.

Kepler discovered that the planets orbit the Sun at different speeds. Planets closer to the Sun travel faster than planets farther away from the Sun. The outer planets also have longer distances to travel and take much longer to orbit the Sun than the inner planets.

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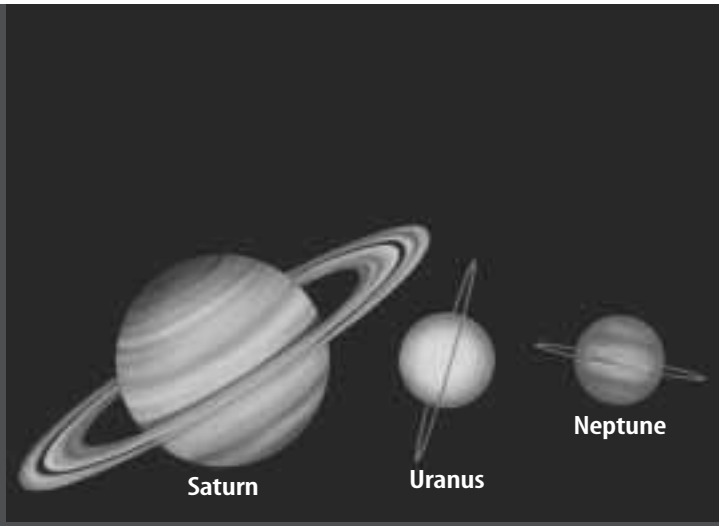

Reading Check

3. **Identify** Name the inner planets.

Think it Over

4. **Infer** Which planet takes longer to orbit the Sun—Mars or Neptune?

After You Read

Mini Glossary

solar system: system of eight planets, including Earth, and many smaller objects that orbit the Sun

1. Review the term and its definition in the Mini Glossary. On the lines below, write something you have learned about the solar system.

_____

_____

_____

2. Complete the chart that shows how the solar system may have formed.

1. The solar system formed from a cloud of _____, _____, and _____.
2. The cloud condensed to form a(n) _____.
3. _____ formed first. It was at the center of the new solar system.
4. The other material in the solar system collided and formed _____ planets.
5. The inner planets are _____, _____, _____, and _____.

3. Review the questions you wrote as you read this section. What resources could you use to find answers to your questions? Did the questions you write help you understand the information?

_____

_____

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End of Section

ScienceOnline Visit **earth.msscience.com** to access your textbook, interactive games, and projects to help you learn more about the solar system.

chapter 24 The Solar System

section 2 The Inner Planets

What You'll Learn

- facts about the inner planets
- what each inner planet is like
- compare and contrast Venus and Earth

Before You Read

What do you know about Mercury and Venus? What would you like to know about these inner planets?

_____

_____

_____

Read to Learn

Inner Planets

Today, people know a great deal about the solar system. Scientists use telescopes to study the planets both from Earth and from space. They also use space probes to study the solar system. Much of the information you will read in this section was gathered by space probes.

Mercury

Mercury is the planet closest to the Sun. The spacecraft *Mariner 10* sent pictures of Mercury to Earth in 1974 and 1975. Scientists learned that Mercury, like Earth's Moon, has many craters. But unlike the Moon, Mercury has cliffs as high as 3 km on its surface. These cliffs might have formed when the crust of the planet broke as the core of the planet was cooling and shrinking.

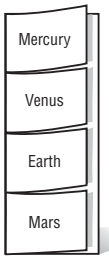
Scientists learned that Mercury has a weak magnetic field. This shows that Mercury has an iron core, the same as Earth. Some scientists think that Mercury's crust solidified while the iron core was still hot and liquid. As the core became more solid, it became smaller. The cliffs resulted from breaks in Mercury's crust caused by the shrinking of the core.

Study Coach

Make Flash Cards Make four flash cards to help you study this section. On one side of the card, write the name of an inner planet. On the other side, write facts about that planet.

FOLDABLES™

B Compare and Contrast Make the following Foldable to understand how the inner planets are similar and different.



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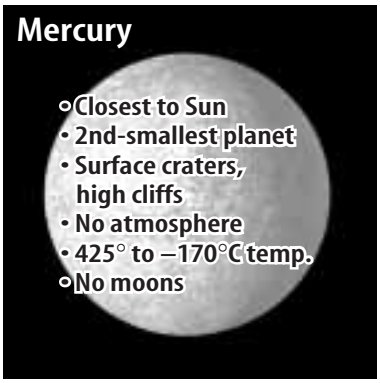
Does Mercury have an atmosphere?

Mercury has no true atmosphere. This is because Mercury has a low gravitational pull and high temperatures during the day. Most gases that could form an atmosphere escape into space. Messenger, launched in 2001, is the next mission to Mercury. This space probe will fly by the planet in 2008 and orbit it in 2011. The probe will photograph and map Mercury's entire surface. This lack of atmosphere and its nearness to the Sun cause Mercury to have great extremes in temperature. Mercury's temperature can reach as high as 425°C during the day, and it can fall to as low as −170°C at night. A picture of Mercury and some facts about the planet are shown below.

Reading Check

1. **Describe** What is the range in temperature on Mercury?

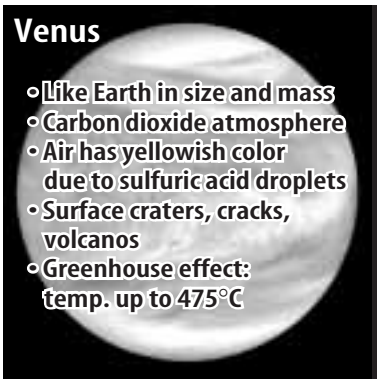


Venus

Venus is the second planet from the Sun. Venus is sometimes called Earth's twin because its size and mass are similar to Earth's. When *Mariner 2* flew past Venus in 1962, the satellite sent back information about Venus's atmosphere and rotation. From 1990 to 1994, the U.S. *Magellan* probe used radar to make detailed maps of Venus's surface. A picture of Venus and some facts about the planet are shown below.

Think it Over

2. **Identify** What are some physical characteristics of Venus?



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How hot is it on Venus?

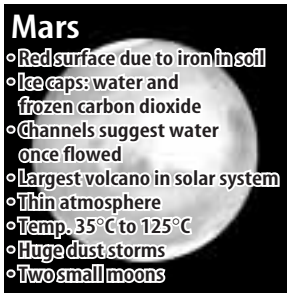
The thick clouds on Venus block most of the Sun's light from reaching the planet's surface. The clouds and carbon dioxide gas in the atmosphere trap heat from the Sun. Temperatures on the surface of Venus range from 450°C to 475°C.

Earth

Earth is the third planet from the Sun. It is about 150 million km from the Sun, or one astronomical unit (AU). Earth is the only planet in the solar system that has large amounts of liquid water. More than 70 percent of Earth's surface is covered by liquid water. Earth is also the only planet that supports life. Earth's atmosphere protects life forms from the Sun's harmful radiation. The atmosphere also causes most meteors to burn up before they reach the surface of the planet. A picture of Earth and some facts about the planet are shown below.

Mars

Mars is the fourth planet from the Sun. It is called the red planet. Its red color is caused by iron oxide in the soil. Polar ice caps on Mars can be seen through telescopes from Earth. The ice caps are made of frozen water covered by a layer of frozen carbon dioxide. A picture of Mars and some facts about the planet are shown below.



Reading Check

3. **Apply** How does Earth's atmosphere help support life?

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What have scientists learned from missions to Mars?

Reading Check

4. Infer Is the volcano Mt. Saint Helens on Earth larger than Olympus Mons on Mars?

Several spacecraft have made missions to Mars. From these missions, scientists have learned that there are long channels on the planet that might have been carved by flowing water. The largest known volcano in the solar system is on Mars. It is called Olympus Mons. It is probably not an active volcano. There are also large valleys in the Martian crust.

What did the *Viking* probes do?

Reading Check

5. Explain What were the Viking 1 and 2 probes looking for on Mars?

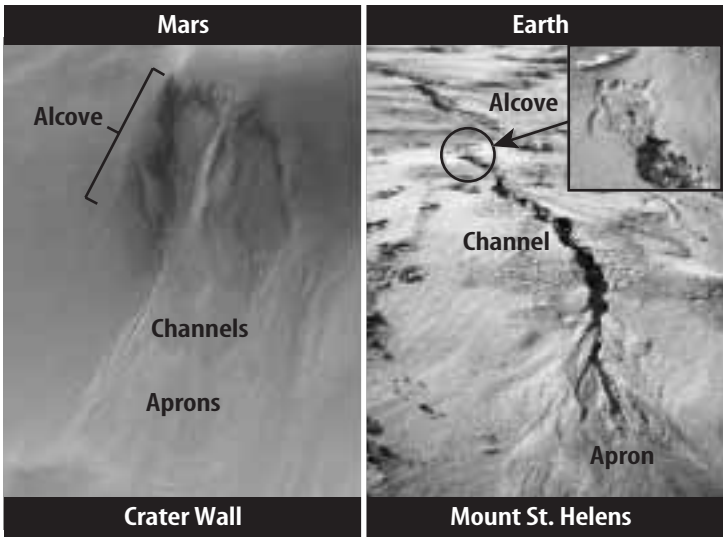
The *Viking 1* and *2* probes arrived at Mars in 1976. Each probe had two parts—an orbiter and a lander. The orbiters remained in space. They took photographs of the entire surface of Mars. The landers touched down on the surface of Mars. They carried equipment to search for signs of life on the planet. No conclusive evidence of life was found on Mars.

How were *Pathfinder, Global Surveyor,* and *Odyssey* used?

The *Mars Pathfinder* analyzed Martian rock and soil. These data indicated that iron might have reached the surface of Mars from underground. *Global Surveyor* took pictures that showed features like gullies that could have been formed by flowing water. *Mars Odyssey* had instruments that detected frozen water. The water forms a layer of frost under a thin layer of soil. It is possible that volcanic activity might melt frost beneath the Martian surface. The features look similar to those formed by flash floods on Earth, such as on Mount St. Helens. You can see how they compare in the figure below.

Picture This

6. List the features that the gullies on Mars and on Mount St. Helens have in common.



NASA/JPL/Malin Space Science Systems

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What makes up Mars's atmosphere?

Mars's atmosphere is much thinner than Earth's atmosphere. It is made up mostly of carbon dioxide with some nitrogen and argon. Temperatures on the surface of Mars can be as high as 35°C and as low as −125°C. The change in temperature between day and night causes strong winds, which in turn cause global dust storms. This information is important if humans ever explore Mars.

Are there seasons on Mars?

Mars's axis is tilted 25°, which is close to Earth's tilt of 23.5°. So, Mars has seasons as it orbits the Sun. The polar ice caps on Mars change with the season. During winter, carbon dioxide freezes at the poles. The polar ice caps get larger. During summer, the carbon dioxide ice changes to gas. The ice caps get smaller. It is winter at one pole when it is summer at the other pole. The color of the ice caps and other areas on Mars also changes with the seasons. This is due to the movement of dust and sand during dust storms.

Does Mars have moons?

Mars has two small moons—Phobos and Deimos. Phobos orbits Mars once every 7 hours. It has a large crater and chains of smaller craters. Deimos orbits Mars once every 31 hours. It is farther away from Mars's surface. Its surface looks smoother than that of Phobos. Its craters have partially filled with soil and rock.

Reading Check

7. **Recognize Cause and Effect** What is the result of extreme change in day and night temperatures on Mars?

Think it Over

8. **Compare** Why does Mars have seasons?

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After You Read

Mini Glossary

Earth: third planet from the Sun; has plenty of liquid water and an atmosphere that protects life

Mars: fourth planet from the Sun; has polar ice caps and a reddish appearance caused by iron oxide in the soil

Mercury: planet closest to the Sun; does not have a true atmosphere; has a surface with many craters and high cliffs

Venus: second planet from the Sun; similar to Earth in mass and size; has thick clouds

1. Review the terms and their definitions in the Mini Glossary. Write something interesting you learned about Mars, Venus, or Mercury.

_____

_____

2. Complete the table to organize the information from this section.

THE INNER PLANETS			
	ORDER FROM SUN	ATMOSPHERE	TEMPERATURES
MERCURY	Closest	_____	Highs: 425°C Lows: –170°C
VENUS	_____	Heavy clouds Carbon dioxide gas	Highs: _____ Lows: _____
EARTH	3rd	_____ _____	Not given
MARS	_____	Mostly carbon dioxide Some nitrogen and argon	_____

3. Review the flash cards you made. How did this help you learn the content of the section? How could you use the flash cards to prepare for a test on the inner planets?

_____

_____

End of Section

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chapter 24 The Solar System

section 3 The Outer Planets

What You'll Learn

- facts about the outer planets: Jupiter, Uranus, Saturn, and Neptune
- which are the dwarf planets

Before You Read

What do you know about the outer planets Jupiter, Uranus, Saturn, or Neptune? What would you like to learn?

_____

_____

_____

Read to Learn

Outer Planets

Voyager, Galileo, and *Cassini* were not the first space probes to explore the outer planets. However, much new information about the outer planets has come from these probes.

Jupiter

Jupiter is the fifth planet from the Sun. It is the largest planet in the solar system. Data from space probes show that Jupiter has faint rings around it made of dust. Io, one of Jupiter's moons, has active volcanoes.

What is Jupiter's atmosphere made of?

Jupiter is made up mostly of hydrogen and helium with some ammonia, methane, and water vapor. Scientists hypothesize that the atmosphere of hydrogen and helium gas changes to liquid hydrogen and helium toward the middle of the planet. Below this liquid layer may be a rocky core that is probably different from any rock on Earth.

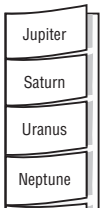
Jupiter's atmosphere has bands of white, red, brown, and tan clouds. Storms of swirling gas have been observed on the planet. The **Great Red Spot** is the most spectacular of these storms.

Study Coach

Make Flash Cards Make four flash cards to help you study this section. On one side of each card, write the name of one of the outer planets. On the other side, write facts about that planet.

FOLDABLES™

Compare and Contrast Make the following Foldable to help you understand how the outer planets are similar and different.



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How many moons orbit Jupiter?

At least 63 moons orbit Jupiter. In 1610, the astronomer Galileo Galilei was the first person to see the four largest moons. Io (I oh) is the large moon closest to Jupiter.

Jupiter's gravity and the gravity of the next large moon, Europa, pull on Io. This force heats up Io. The result is that Io has the most active volcanoes in the entire solar system.

Europa is made up mostly of rock. It has a thick crust of ice. Under the ice there might be a deep ocean. If this ocean does exist, it would be one of the few places in the solar system with large quantities of liquid water. The next moon is Ganymede. Ganymede is the largest moon in the solar system—larger than the planet Mercury. Callisto, the last of Jupiter's large moons, is made up mostly of ice and rock. Callisto is another place in the solar system where there may be a large quantity of water. Pictures of Jupiter and Callisto, as well as some facts about Jupiter, are shown below.

Reading Check

1. **Define** What are Io and Callisto?

_____

_____

Saturn

Saturn is the sixth planet from the Sun. It is the second-largest planet in the solar system. Saturn is the least dense planet in the solar system.

What is Saturn's atmosphere like?

Saturn is similar to Jupiter. Both planets are large and made up mostly of gas. Saturn has a thick outer atmosphere made up mostly of hydrogen and helium. Deeper within the atmosphere the gases change to liquid. Below its atmosphere and liquid layers, Saturn might have a small, rocky core.

Picture This

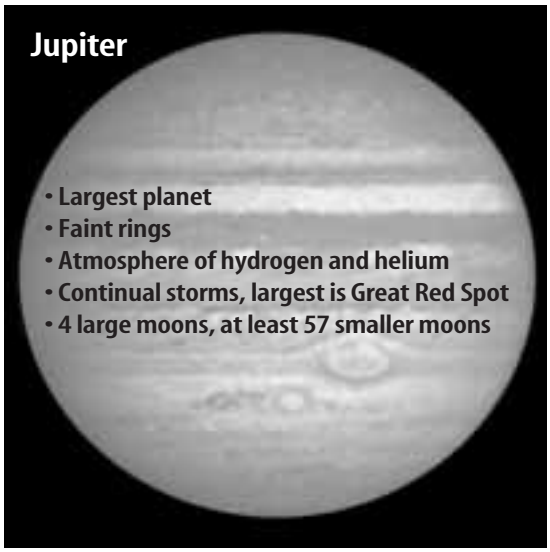
2. **Describe** List four facts that describe Jupiter.

_____

_____

_____

_____



Jupiter's moon Callisto

JPL

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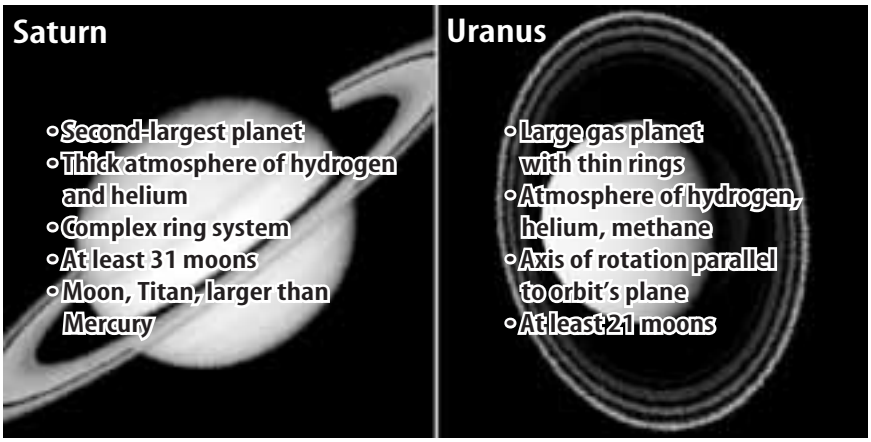
What are Saturn's rings and moons like?

Each of Saturn's large rings is made up of thousands of thin rings. These are made of ice and rock particles. Some particles are as tiny as a speck of dust, and some are tens of meters across. Saturn has the most complex ring system in the solar system.

At least 47 moons orbit Saturn. The planet's gravity holds them in their orbits. Titan is the largest of Saturn's moons. It is larger than the planet Mercury. A picture of Saturn and some facts about the planet are shown below.



Uranus

Uranus (YOOR uh nus) is the seventh planet from the Sun. It is a large planet and also is made up mostly of gas. Thin, dark rings surround the equator. Scientists know that Uranus has at least 27 moons. Its largest moon, Titania, has many craters and deep valleys.

What are the characteristics of Uranus?

The atmosphere of Uranus is made up of hydrogen, helium, and some methane. Methane gives the planet a bluish-green color. A few clouds and storms can be seen on Uranus. There may be liquid water under its atmosphere.

Uranus has an unusual rotation. It is tilted on its side. The axes of rotation of the other planets, except Pluto, are nearly perpendicular to the planes of their orbits. Uranus's axis of rotation is nearly parallel to the plane of its orbit. Some scientists believe that a collision may have caused Uranus to tip over in this way. A picture of Uranus and some facts about the planet are shown above.

Think it Over

3. **Compare and Contrast** Describe two ways that Saturn and Uranus are different.

Reading Check

4. **Recognize Cause and Effect** What do scientists believe may have caused Uranus to tilt on its axis?

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Neptune

Neptune is usually the eighth planet from the Sun. However, part of Pluto's orbit crosses inside Neptune's orbit. From 1979 until 1999, Pluto was closer to the Sun than Neptune was.

What characteristics does Neptune have?

Neptune's atmosphere is similar to Uranus's atmosphere. Methane gives the atmosphere of Neptune its bluish-green color, just as it does for Uranus. Neptune has dark-colored storms similar to the Great Red Spot on Jupiter. These storms and bright clouds form and disappear. This shows that Neptune's atmosphere is active and changes rapidly.

Under its atmosphere, Neptune has a uniform mixture of rock and various types of ices made from methane and ammonia. The planet probably has a rocky core. Neptune has at least 11 moons and several rings. Neptune's largest moon, Triton, has a thin atmosphere made up mostly of nitrogen and methane.

Think it Over

5. **Recognize Cause and Effect** What gas causes Uranus and Neptune to have a bluish-green color?

   a. hydrogen
   b. methane
   c. helium
   d. carbon dioxide

Dwarf Planets

In August, 2006, the International Astronomical Union (IAU) defined the term planet. With that definition, Pluto, which became the ninth planet in 1930, was no longer a planet. It is now known as a dwarf planet. Besides Pluto there are two other dwarf planets, Ceres and Eris.

What do we know about dwarf planets?

Ceres was discovered in 1801. It is located in the asteroid belt and is the largest asteroid. Ceres orbits the Sun about once every 4.6 years.

Pluto has a thin atmosphere and a solid, icy-rock surface. Pluto has three moons, Nix, Hydra, and Charon. Pluto orbits the Sun once every 248 years.

Eris, which is slightly larger than Pluto, was discovered in 2005 and originally named UB313. It has a moon named Dysnomia. Eris orbits the Sun once every 557 years.

Think it Over

6. **Infer** Could Pluto support life?

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After You Read

Mini Glossary

Great Red Spot: giant, high-pressure storm in Jupiter's atmosphere

Jupiter: largest planet, and fifth planet from the Sun; has an atmosphere made up mostly of hydrogen and helium

Neptune: the eighth planet from the Sun; is large, gaseous, and bluish-green in color

Pluto: dwarf planet; has a solid icy-rock surface and three single moons, Charon, Hydra, and Nix

Saturn: second-largest and sixth planet from the Sun; has a complex ring system, at least 31 moons, and a thick atmosphere made mostly of hydrogen and helium

Uranus (YOOR uh nus): seventh planet from the Sun; is large and gaseous, has a distinct bluish-green color.

1. Review the terms and their definitions in the Mini Glossary. Choose an outer planet and write a sentence that tells something you learned about it.

_____

_____

_____

2. Complete the table below to organize the information from this section.

THE OUTER PLANETS			
	ORDER FROM THE SUN	**ATMOSPHERE**	**MOONS**
Jupiter	**5th**	_____	_____, **including** _____
Saturn	_____	**Thick; hydrogen and helium**	**At least 31, including Titan**
Uranus	**7th**	_____	_____, **including** _____
Neptune	_____	**Thick methane**	_____, **including** _____

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ScienceOnline Visit **earth.msscience.com** to access your textbook, interactive games, and projects to help you learn more about the outer planets.

End of Section

chapter 24

The Solar System

section 4 Other Objects in the Solar System

What You'll Learn

- how comets change when they near the Sun
- the differences among comets, meteoroids, and asteroids

Before You Read

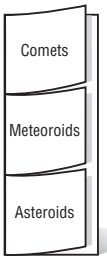
Look up into the sky on a clear night. There are many objects you can see in addition to the Moon. What do you think these objects are? What would you like to know about them?

Mark the Text

Highlight Highlight the descriptions of comets, meteors, and asteroids as you read about them in this section.

FOLDABLES™

D Organize Information
Make the following three-tab Foldable to help you organize information about comets, meteoroids, and asteroids.



Read to Learn

Comets

Planets and moons are not the only objects in the solar system. Comets, meteoroids, and asteroids are other important objects that orbit the Sun.

You may have heard of Halley's Comet. A **comet** is made up of dust and pieces of rock mixed with frozen water, methane, and ammonia. Halley's Comet was last seen from Earth in 1986. It takes Halley's Comet 76 years to orbit the Sun. Astronomer Jan Oort suggested that billions of comets surround the solar system. This cloud of comets, called the Oort Cloud, is located beyond the orbit of Neptune.

What is the structure of a comet?

A comet is a mass of frozen ice and rock. As a comet approaches the Sun, the Sun's heat turns the ice to gas. This releases dust and jets of gases which form a bright cloud, or coma, around the nucleus, or solid part, of the comet. The solar wind pushes on the gas and dust to form tails that point away from the Sun.

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Meteoroids, Meteors, and Meteorites

After many trips around the Sun, most of the ice in a comet's nucleus has evaporated. The comet is now just rocks and dust, spread out within the original comet's orbit. These objects are called meteoroids. A meteoroid that enters Earth's atmosphere and burns up is called a **meteor.** Another term for a meteor is a shooting star.

Whenever Earth passes through the old orbit of a comet, small pieces of rock and dust enter Earth's atmosphere. The event is called a meteor shower. A **meteorite** is a large meteoroid that does not burn up completely in Earth's atmosphere and strikes Earth. Most meteorites are probably the remains from asteroid collisions or broken-up comets. Others come from the Moon and Mars.

Reading Check

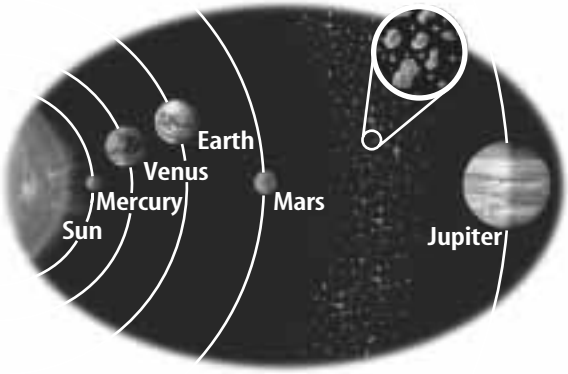
1. **Define** What is a meteor shower?

_____

_____

Asteroids

An **asteroid** is a piece of rock made up of material like that which formed the planets. Most asteroids are located in an area between the orbits of Mars and Jupiter called the asteroid belt as shown in the figure. Other asteroids are scattered throughout the solar system.



Picture This

2. **Interpret Scientific Illustrations** Between the orbits of which planets is the asteroid belt located?

_____

What else do we know about asteroids?

Some asteroids are tiny. Others measure hundreds of kilometers. The first asteroid ever discovered, Ceres, is the largest. It measures 940 km in diameter.

Comets, asteroids, and most meteorites were formed early in the history of the solar system. Scientists study these space objects to learn what the solar system might have been like long ago. Understanding this could help scientists better understand how Earth formed.

Think it Over

3. **Explain** What is important about studying objects in space?

_____

_____

_____

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After You Read

Mini Glossary

asteroid: a piece of rock made up of material similar to that which formed the planets

comet: space object made of dust and rock particles mixed with frozen water, methane, and ammonia

meteor: a meteoroid that burns up in Earth's atmosphere

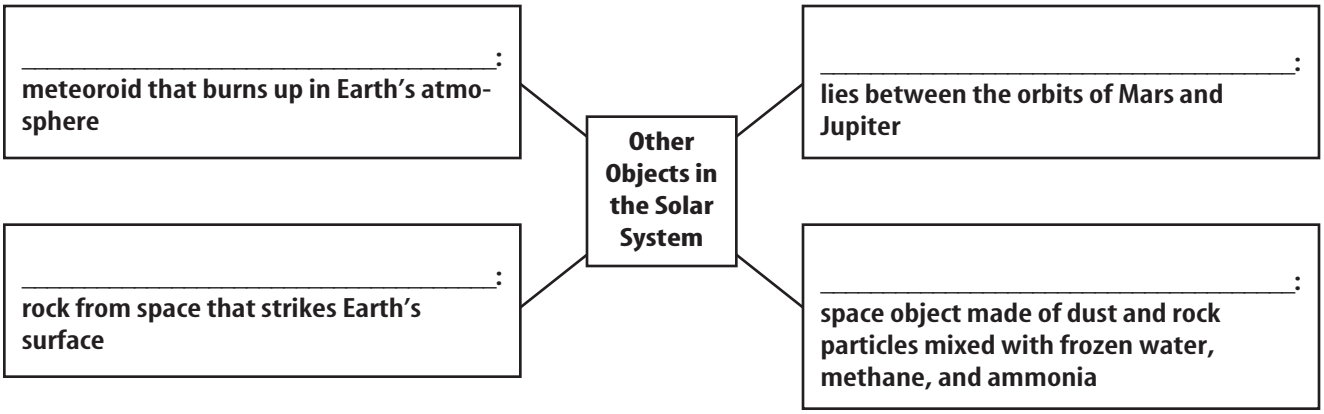
meteorite: a meteoroid that strikes Earth's surface

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to tell what the Oort cloud is.

_____

_____

2. Complete the concept chart with the correct words from the Mini Glossary.



3. Reread the sentences you highlighted in the text. Did this strategy help you describe comets, meteors, and asteroids? Work with a partner and take turns describing space objects to each other.

_____

_____

_____

End of Section

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chapter 25 Stars and Galaxies

section 1 Stars

What You'll Learn

- about constellations
- the difference between absolute magnitude and apparent magnitude

Before You Read

Describe the sky on a cloudless, moonless night. What would you see? Write the names of any stars you know about.

_____

_____

_____

Read to Learn

Constellations

It's fun to look at clouds and find animals, faces, and objects. It takes more imagination to play this game with stars. Ancient Greeks, Romans, and other people who lived long ago found patterns, or shapes, made by stars in the night sky. These star patterns are called **constellations** (kahn stuh LAY shuns). In these star patterns, they saw characters, animals, and objects from stories they knew well.

From Earth, a constellation looks like spots of light arranged in a particular shape against the night sky. However, the stars in a constellation often have no relationship to each other in space.

What are some common constellations?

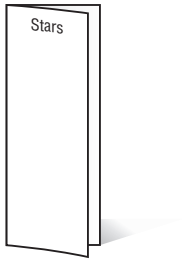
Modern astronomy divides the sky into 88 constellations. Many of these were named by early astronomers. The Big Dipper is part of the constellation Ursa Major. The two stars at the front of the Big Dipper point to the star Polaris. Polaris is often called the North Star. That is because Polaris is almost directly over Earth's north pole. Polaris is located at the end of the Little Dipper in the constellation Ursa Minor. See the figure on the next page for the locations of Polaris, the Big Dipper, and the Little Dipper.

Study Coach

Identify What You Know
Create a K-W-L chart for this chapter. Write what you already know about stars, what you want to know, and what you learn as you read this section.

FOLDABLES™

A Record Data For this section, create a Foldable to record important facts, notes, and new vocabulary about stars.



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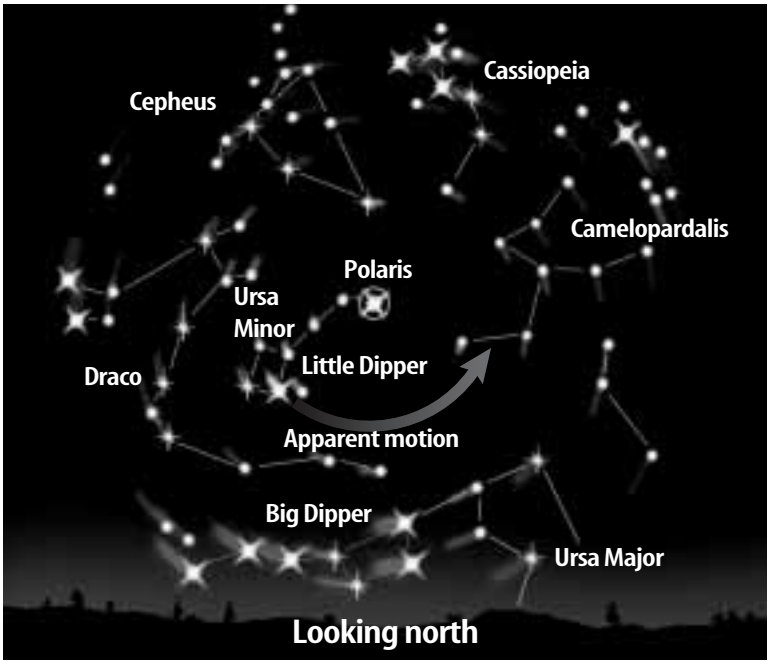
Picture This

1. **Interpret Diagram** Do the stars appear to rotate clockwise or counter-clockwise around Polaris?



Why do constellations appear to move?

You may have noticed that stars appear to move during the night. Constellations in the northern sky appear to circle around Polaris. Because of this, they are called circumpolar constellations. They appear to move because Earth is moving.

The figure above shows the circumpolar constellations rotating around Polaris. Because of their unique position, you can see the circumpolar constellations all year long. Other constellations, like Orion, can only be seen in certain seasons. In the summer, Orion can't be seen north of the equator because the northern hemisphere faces Orion during the day.

Reading Check

2. **Identify** Which constellations can be seen all year?

Absolute and Apparent Magnitudes

When you look at constellations, you'll notice that some stars are brighter than others. Sometimes stars look brighter than others because they're closer to Earth.

There are two ways to describe a star's brightness. The **absolute magnitude** (MAG nuh tewd) of a star is the amount of light it gives off. The **apparent magnitude** is the amount of light that reaches Earth, or how bright it looks. A star that is dim can look bright in the sky if it's close to Earth. A star that is bright can appear dim if it's far away. For example, Rigel is a brighter star than Sirius, but Sirius appears brighter because it is 100 times closer to Earth than Rigel is.

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Measurement In Space

One way scientists measure the distance between Earth and a nearby star is to measure parallax (PER uh laks). Parallax is what makes an object seem to change its position when you look at it from two different positions. Stretch your arm out in front of you and look at your thumb with one eye closed. Now open your eye and close your other eye and look at your thumb. Your thumb looks like it has moved, even though it has not. That apparent shift is parallax. Try it again, but with your thumb closer to your face. What did you see? Your thumb appears to move when it is closer to your eyes. The nearer an object is, the greater its parallax.

How is parallax measured?

Astronomers measure the parallax of a nearby star to see how far away it is from Earth. Astronomers observe the same star at two different times of the year. Astronomers look at how the star seems to change positions compared with stars that are farther away. Then they use the angle of the parallax and the size of Earth's orbit to calculate the distance of the star from Earth.

Space is so enormous that scientists need a special way to describe distances. Distances between stars and galaxies are measured in light-years. A **light-year** is the distance that light travels in one year. Light travels 300,000 km/s.

Reading Check

3. **Determine** Which would have a greater parallax—an object close to you or one that is far away?

Properties of Stars

The color of a star indicates its temperature. For example, hot stars are a blue-white color. Stars that have a medium temperature, like the Sun, are yellow. A cooler star looks orange or red.

Astronomers use an instrument called a spectroscope to learn what a star is made of. The spectroscope spreads light out into a band of colors which might include dark lines. These dark lines stand for elements in a star's atmosphere. These patterns of lines help astronomers identify the elements in a star's atmosphere.

Reading Check

4. **Identify** What do the dark lines in the band of colors produced by a spectroscope represent?

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After You Read

Mini Glossary

absolute magnitude (MAG nuh tewd): the amount of light that a star gives off

apparent magnitude: the amount of a star's light that reaches Earth

constellation (kahn stuh LAY shun): a group of stars that forms a pattern in the night sky

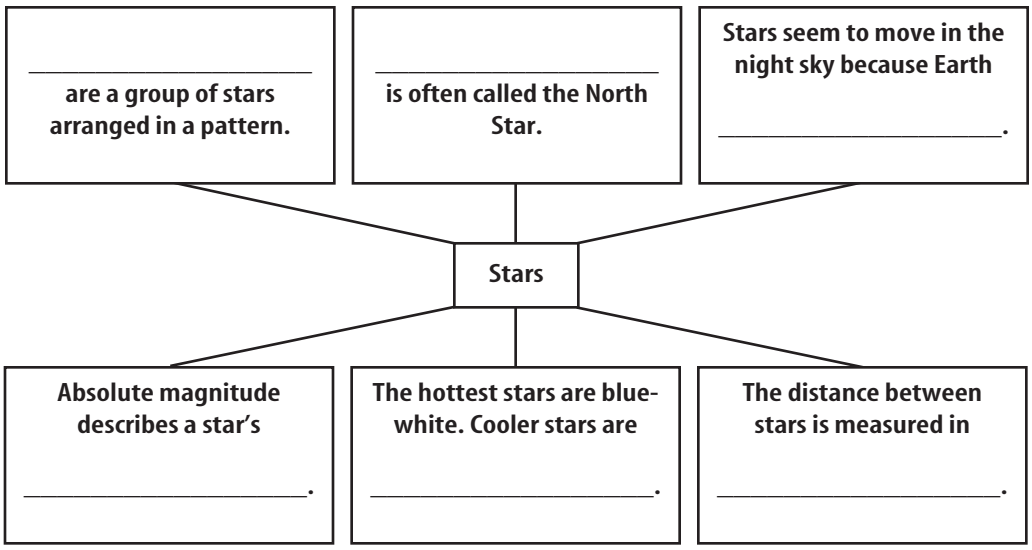
light-year: the distance that light travels in one year

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain why two stars can have the same absolute magnitude but may have different apparent magnitudes.

_____

_____

2. Complete the diagram to explain what you learned about stars.



3. Look back at the K-W-L chart you made as you read this section. Did you add to what you already knew? Did you learn what you wanted to know? Did the K-W-L chart help you to understand what you read?

_____

_____

_____

End of Section

ScienceOnline Visit **earth.msscience.com** to access your textbook, interactive games, and projects to help you learn more about stars.

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chapter 25

Stars and Galaxies

section 2 The Sun

Before You Read

What comes to mind when you think about the Sun? Brainstorm some words and write them below.

_____

_____

What You'll Learn

- the Sun is the closest star to Earth
- the structure of the Sun
- the features of the Sun, such as sunspots and solar flares

Read to Learn

Mark the Text

Underline the different properties of the Sun as you read.

The Sun's Layers

The Sun is an ordinary star and is the center of our solar system. It is also the closest star to Earth. Almost all life on Earth depends on energy from the Sun.

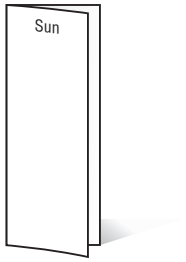
Like other stars, the Sun is an enormous ball of gas that produces energy in its core, or center. This energy is produced by fusing hydrogen into helium. This energy travels outward to the Sun's atmosphere. The energy is given off as light and heat.

The Sun's Atmosphere

The Sun is made up of different layers. The lowest layer of the Sun's atmosphere is the **photosphere** (FOH tuh sfihr). This is the layer that gives off the light we see from Earth. The photosphere is often called the surface of the Sun. Temperatures there are about 6,000 K. The layer above the photosphere is called the **chromosphere** (KROH muh sfihr). This layer is about 2,000 km thick. There is a change of zone between 2,000 km and 10,000 km above the photosphere. Above this zone is the outer layer of the Sun's atmosphere. This outer layer is called the **corona** (kuh ROH nuh). The corona is the largest layer of the Sun's atmosphere. It reaches millions of kilometers into space. The illustration on the next page shows the different layers of the Sun.

FOLDABLES™

B Take Notes Create a Foldable to record the main ideas about the Sun. Include information about the Sun's layers, atmosphere, and surface features.



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Think it Over

1. List Number the parts of the Sun's atmosphere shown below, with 1 being the innermost layer and 4 being the outermost layer.

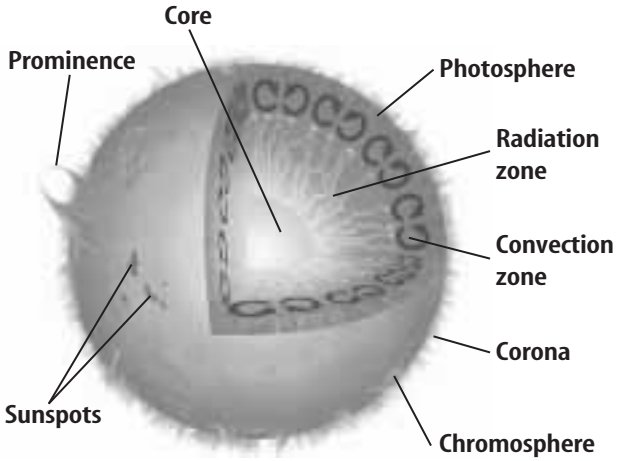
_____ chromosphere

_____ corona

_____ core

_____ photosphere

The Sun's Atmosphere



Surface Features

From our point of view on Earth, the Sun's surface looks smooth. But the Sun's surface has many features. Among them are sunspots, prominences, flares, and CMEs.

What is a sunspot?

Sunspots are areas of the Sun's surface that appear dark. Sunspots look this way because they are cooler than the area around them. Scientists have been studying sunspots for hundreds of years. They have observed the way that sunspots move. The fact that sunspots move has led scientists to determine that the Sun rotates. However, the Sun does not rotate like Earth does. The Sun rotates faster at its equator than at its poles. Sunspots near the equator take about 25 days to rotate once. Near the poles, sunspots take about 35 days.

Sunspots are not permanent features on the Sun. They appear and disappear over days, weeks, or months. The number of sunspots increases and decreases in a regular cycle of time. About every 10 or 11 years, there is a period of many large sunspots. In between those times, there are fewer sunspots.

Reading Check

2. Describe What happens in a solar flare?

_____

_____

_____

What are prominences and solar flares?

Sunspots are related to other features on the Sun's surface. Sunspots and strong magnetic fields are found together on the Sun. The magnetic fields might cause prominences, which are huge arching columns of gas.

The gases near a sunspot may suddenly brighten and rapidly shoot outward. This is called a solar flare.

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What is a CME?

When large amounts of electrically-charged gas shoot out from the Sun's corona, the event is called a CME. CME stands for coronal mass ejection.

CMEs present little danger to life on Earth, but they do affect our planet. CMEs can damage satellites. They can cause radio interference. Near the poles, they can produce a display of shifting colorful lights in the night sky. These displays tend to occur at Earth's poles. One such display of lights is called the Aurora borealis, or northern lights. The picture below shows the Aurora borealis.

The Sun—An Average Star

The Sun is an average star. It is middle-aged and its absolute magnitude is about average. The Sun shines with a yellow light. Although the Sun is an average star, it is much closer to Earth than other stars. Light from the Sun reaches Earth in about eight minutes. Light from other stars takes many years to reach Earth.

The Sun is unusual in one way. It is not close to any other stars. Most stars are found in groups of two or more stars that orbit each other. Stars can also be held together by each other's gravity. This kind of group is a star cluster. Most star clusters are far from the solar system. They might be visible as a fuzzy bright patch in the night sky.

Think it Over

3. **Infer** Why do you think the Aurora borealis is also known as the northern lights?

Reading Check

4. **Identify** How long does it take for the light from the Sun to reach Earth?

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After You Read

Mini Glossary

chromosphere (KROH muh sfihr): one of the middle layers of the Sun's atmosphere

corona (kuh ROH nuh): the top, largest layer of the Sun's atmosphere

photosphere (FOH tuh sfirh): the lowest layer of the Sun's atmosphere; gives off light

sunspot: an area on the Sun's surface that is cooler and less bright than surrounding areas

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using three terms to describe the Sun's atmosphere.

_____

_____

_____

2. Complete the chart to show how the Sun is like other stars and different from other stars.

The Sun vs. Other Stars	
Similarities	**Differences**
It is a huge ball of _____.	Its light reaches Earth in _____.
It produces energy in its _____.	Life on _____ depends on it.
It has an _____ that has different layers. One is the corona.	It is not close to other _____.

3. Look at the list of words you brainstormed to describe the Sun before you read this section. What words would you add to this list? Look at the text you underlined to describe the Sun. Now look at your new list. What was the most surprising thing you learned about the Sun?

_____

_____

_____

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End of Section

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chapter 25 Stars and Galaxies

section 3 Evolution of Stars

Before You Read

What makes one star different from another? Do you think the Sun is the same as other stars? Write your ideas on the lines below.

_____

_____

_____

What You'll Learn

- how stars are sorted into groups
- ways the Sun is the same as other types of stars
- ways the Sun is different from other types of stars
- how stars develop

Read to Learn

Classifying Stars

When you look at the night sky, all stars might look about the same. However, they're very different. They vary in age and size. They vary in temperature and brightness as well. These features led scientists to organize stars into categories, or groups.

How is a star's temperature related to its brightness?

In the early 1900s, two scientists named Ejnar Hertzsprung and Henry Russell noticed that hotter stars are usually brighter. In other words, stars with higher temperatures have brighter absolute magnitudes.

How do scientists show this relationship?

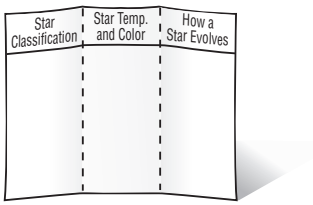
Hertzsprung and Russell developed a graph to show this relationship. You can see this graph on the next page. The temperatures are at the bottom. Absolute magnitude goes up the left side. A graph that shows this relationship between a star's temperature and its brightness is called a Hertzsprung-Russell diagram, or an H-R diagram.

Study Coach

Make Flash Cards to help you record new vocabulary words. Write the word on one side of the flash card and a brief definition on the other side.

FOLDABLES™

C Create a Foldable as shown below about evolution of stars. Label the three columns Star Classification, Star Temperature and Color, and How a Star Evolves.



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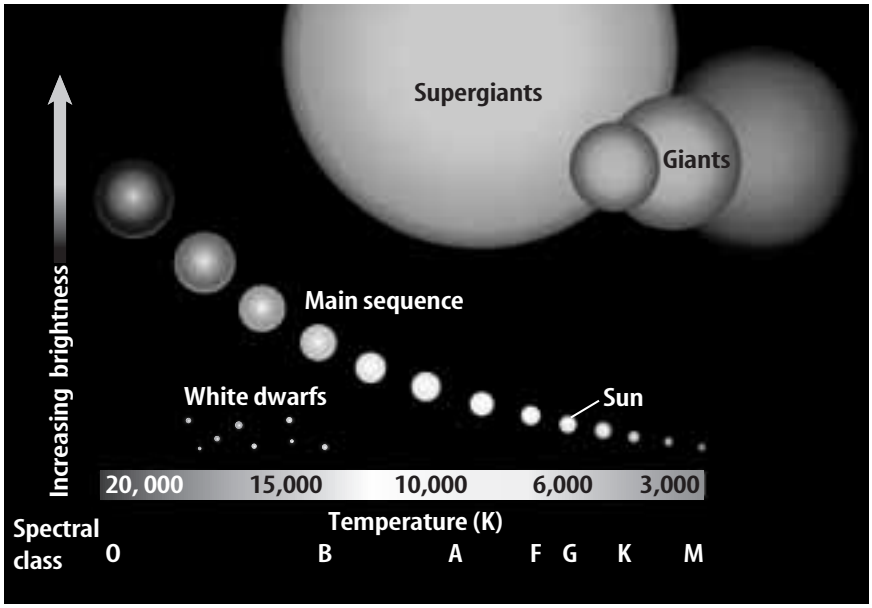
Picture This

1. **Complete the Diagram** Color hot, bright stars blue. Color cool, dim stars red. Color in-between stars yellow. Read to find out how to color dwarfs and giants.



What is the main sequence?

The H-R diagram above shows the connection between a star's temperature and its brightness. As you can see, most stars seem to fit into a band that runs from the upper left to the lower right. This band is called the main sequence. Hot, blue, bright stars begin at 20,000 K and continue to about 15,000 K. Cool, red, dim stars range from 5,000 K to 3,000 K. Yellow stars, like the Sun, are in between.

What are dwarfs?

About 90 percent of all stars are main sequence stars. Most of these are small, red stars found in the lower right of the H-R diagram. Some of the stars that are not in the main sequence are hot, but they are not bright. These small stars are called white dwarfs, although they are usually blue in color. White dwarfs are found on the lower left of the H-R diagram.

Reading Check

2. **Identify** What are small stars that are hot but not bright called?

What are giants?

Other stars are very bright, but they are not hot. These large stars are called giants or red giants, because they are usually red in color. They're found on the upper right of the H-R diagram. The largest giants are called supergiants. These stars can be hundreds of times bigger than the Sun and thousands of times brighter.

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How do stars shine?

For centuries, people have wondered what stars were made of and what made them shine. Over time, people realized the Sun had been shining for billions of years. What material could burn for so long?

What process creates the light that reaches Earth?

In the 1930s, scientists made an important discovery about atoms. Scientists observed that the nuclei, or centers, of atoms reacted with one another. They hypothesized that the center of the Sun was hot enough to cause hydrogen atoms to fuse, or link together, and form another kind of atom—helium atoms. This reaction, called fusion, releases huge amounts of energy. Much of this energy is released as different kinds of light. A very small part of this light comes to Earth.

Reading Check

3. **Identify** What is the name of the process in which hydrogen is converted to helium?

Evolution of Stars

The H-R diagram explained a lot about stars. However, scientists wondered why some stars didn't fit in the main sequence. Scientists also wondered what happened when a star used up its hydrogen fuel. Now, there are theories about how stars evolve, or change over time. These theories also explain what makes stars different from one another, and what happens when a star "dies."

When a star uses up its hydrogen, that star is no longer in the main sequence. This can take less than 1 million years for the brightest stars. It can take billions of years for the dimmest stars. The Sun has a main sequence life span of about 10 billion years. Half of its life is still in the future.

Applying Math

4. **Calculate** About how many years are left in the Sun's main sequence life span?

How are stars formed?

Stars begin as a large cloud of gas and dust called a **nebula** (NEB yuh luh). The pull of gravity between the particles of gas and dust causes the nebula to contract, or shrink. The nebula can break apart into smaller and smaller pieces. Each piece eventually might collapse to form a star.

The particles in the smaller pieces of nebula move closer together. This causes temperatures in each piece to rise. When the temperature in the core of a piece of nebula reaches 10 million K, fusion begins. Energy is released from the core and travels outward. Now the object is a star.

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What is a giant?

After a star is formed, the heat created by fusion creates outward pressure. Without this pressure, the star would collapse from its own gravity. The star becomes a main sequence star. It continues to use its hydrogen fuel. The different stages in the life of a star are shown in the illustration on this page and the next page.

When hydrogen in the core of the star runs out, the core contracts and temperatures inside the star increase. The outer layers of the star expand and cool. In this late stage in its life cycle, a star is called a **giant.**

As the core contracts, its temperature continues to rise. By the time it reaches 100 million K, the star is huge. Its outer layers are much cooler than when it was a main sequence star. In about 5 billion years, the Sun will become a giant.

Think it Over

5. Infer What is the relationship between how much hydrogen a star has and the star's temperature?

_____

_____

What is a white dwarf?

The star's core contracts even more after it uses much of its helium and the outer layers escape into space. This leaves only the hot, dense core. At this stage in a star's life cycle, it is about the size of Earth. It is called a **white dwarf.** In time, the white dwarf will cool and stop giving off light.

What are supergiants and supernovas?

The length time it takes for a star to go through its stages of life depends on its mass. The stages happen more quickly and more violently in stars that are more than eight times more massive than the Sun. In massive stars, the core heats up to much higher temperatures. Heavier and heavier elements form in the core. The star expands into a **supergiant.** Finally, iron forms in the core. Iron can't release energy through fusion. The core collapses violently. This sends a shock wave outward through the star. The outer part of the star explodes. This produces a kind of star called a supernova. A supernova can be millions of times brighter than the original star was.

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What is a neutron star?

What happens next depends on the size of the supernova's collapsed core. If the collapsed core is between 1.4 and 3 times as massive as the Sun, the core shrinks until it is only about 20 km in diameter. In this dense core, there are only neutrons. This kind of star is called a **neutron star.** Because the star is so dense, one teaspoonful of a neutron star would weigh more than 600 million metric tons on Earth.

What is a black hole?

The core of some supernovas is more than three times more massive than the Sun. Nothing can stop the core's collapse in these supernovas. All of the core's mass collapses to a point. The gravity near this point is so strong that not even light can escape from it. Because light cannot escape from this region, it is called a **black hole.** If you could shine a light into a black hole, the light would disappear into it. However, a black hole is not like a vacuum cleaner. It does not pull in faraway objects. Stars and planets can orbit around a black hole, as long as they are far enough away.

Where does a nebula's matter come from?

You learned that a star begins as a nebula. Where does the matter, or gas and dust, come from to form the nebula? Some of it was once in other stars. A star ejects large amounts of matter during the course of its life. Some of this matter becomes part of a nebula. It can develop into new stars. The matter in stars is recycled many times.

The matter that is created in the cores of stars and during supernova explosions is also recycled. Elements such as carbon and iron can become parts of new stars. Spectrographs of the Sun show that it contains some carbon, iron, and other heavy elements. However, the Sun is too young to have formed these elements itself. The Sun condensed from material that was created in stars that died long ago.

Some elements condense to form planets and other objects. In fact, your body contains many atoms that were formed in the cores of ancient stars.

Think it Over

6. Infer If the collapsed core of a supernova is 2.4 times as massive as the Sun, what will it become next?

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After You Read

Mini Glossary

black hole: the final stage in the evolution of a very massive star, where the core collapses to a point that its gravity is so strong that not even light can escape

giant: a late stage in the life of a low-mass star, when the core contracts but its outer layers expand and cool; a large, bright, cool star

nebula (NEB yuh luh): a large cloud of gas and dust where stars are formed

neutron star: a very dense core of a collapsed star that can shrink to about 20 km in diameter and contains only neutrons

supergiant: late stage in the life cycle of a massive star in which the core heats up and the star expands; a large, very bright star

white dwarf: a late stage in the life cycle of a low-mass star; formed when its outer layers escape into space, leaving behind a hot, dense core; a small, dim, hot star

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to compare a white dwarf and a giant.

_____

_____

_____

2. Fill in the blanks to review what you have learned about the life of a massive star.

A massive star forms in a _____. The star burns hydrogen fuel as a main _____ star. The core heats up. The star expands and cools into a _____. The star then explodes as a _____. Depending on its mass, it will then become either a _____ or a _____.

3. Could you use the flash cards you created to describe how the Sun developed? What information was helpful? What other information should have been on the cards?

_____

_____

_____

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End of Section

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chapter 25

Stars and Galaxies

section 4 Galaxies and the Universe

Before You Read

Imagine that someone on the other side of the universe wanted to send you mail. How might you give someone an address for Earth?

_____

_____

What You'll Learn

- the Sun's position in the Milky Way Galaxy
- what forces affect our solar system
- what forces affect other galaxies

Read to Learn

Galaxies

How can you describe the location of Earth? We are in the solar system. The solar system is in a galaxy called the Milky Way. A **galaxy** is a large group of stars, gas, and dust held together by gravity.

There are many other galaxies. Every galaxy has the same elements, forces, and types of energy that are found in our solar system.

You learned that stars are grouped together in galaxies. In the same way, galaxies are grouped into clusters. The Milky Way is part of a cluster called the Local Group. The Local Group is made up of about 45 galaxies in different sizes and shapes. There are three major types of galaxies.

What are the three major types of galaxies?

Spiral galaxies have spiral arms that wind outward from the center. The arms are made up of bright stars, dust, and gas. The Milky Way galaxy is a spiral galaxy.

Elliptical (ih LIHP tih kul) galaxies are a common type of galaxy. They are shaped like large, three-dimensional ellipses.

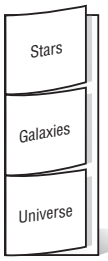
Irregular galaxies include all the galaxies that don't fit into the other two groups. These galaxies have many different shapes.

Mark the Text

Highlight the main point in each paragraph. Use a different color to highlight a detail or example that helps explain the main point.

FOLDABLES™

D Summarize Create a three-tab Foldable to summarize the main ideas from the section.



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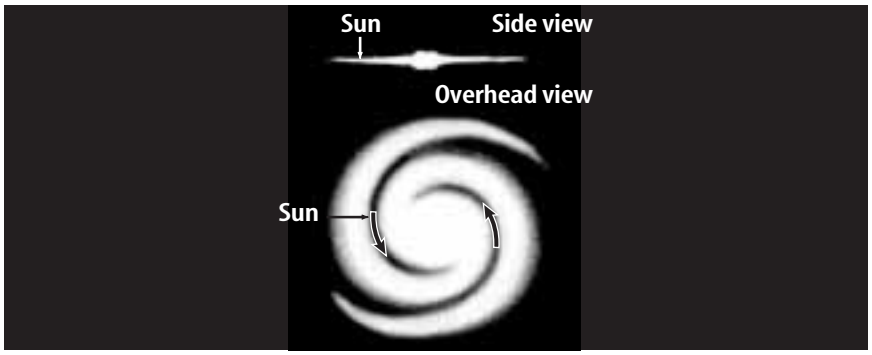
The Milky Way Galaxy

There might be one trillion stars in the Milky Way. It is about 100,000 light-years across. Find the Sun in the image of the Milky Way below. It is about 26,000 light-years from the galaxy's center in one of the spiral arms. In the galaxy, all stars orbit around a central region, or core. It takes about 225 million years for the Sun to orbit the center of the Milky Way.

Scientists put the Milky Way into the spiral galaxy group. However, it's difficult to know the exact shape because we can't look at the galaxy from the outside. You can't see the shape of the Milky Way because the location of our solar system is in one of its spiral arms. But you can see the Milky Way stretching across the sky. It looks like a dusty band of dim light. All the stars you can see in the night sky are part of the Milky Way. Like many other galaxies, the Milky Way has a black hole at its center.

Picture This

1. **Explain** Why can't you see the shape of the Milky Way?



Origin of the Universe

Scientists have offered different models, or ideas, for how the universe began. One model is the steady state theory. It suggests that the universe always has been the same as it is now. The universe expands and new matter is created. This keeps the density of the universe in a steady state.

A second model is the oscillating (AH sih lay ting) model. This model states that the universe formed and then it expanded, or grew larger. Over time, the rate of growth slowed down. Then the universe began to contract, or shrink. Then the whole process began again. In other words, it oscillates back and forth in size.

A third model is called the big bang theory. This theory states that the universe began with a big bang and has been expanding ever since.

Think it Over

2. **Compare** What do the three theories about the origin of the universe have in common?

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Expansion of the Universe

Think of the sound of a whistle on a passing train. The pitch of the whistle rises as the train moves closer. Then the pitch of the whistle drops as the train moves away. This happens because the sound waves coming from the whistle are compressed, or shortened, as the train gets closer. This effect is called the Doppler (DAH plur) shift.

Does the Doppler shift affect light?

The Doppler shift happens with light too. Like sound, light moves in waves. If a star is moving toward Earth, the light waves are shortened. If a star is moving away from Earth, the light waves are stretched out. Blue-violet light waves are shorter than red light waves. Scientists can identify blue-violet light from stars moving toward Earth. When a star is moving away from Earth, the light shifts toward red. This is called a red shift.

How do we know the universe is expanding?

In 1929, Edwin Hubble noticed a red shift in the light from galaxies outside the Local Group. This meant the galaxies are moving away. If all galaxies outside the Local Group are moving away from Earth, then the entire universe must be expanding.

The Big Bang Theory

The **big bang theory** is the leading theory about how the universe formed. It states that the universe began about 13.7 billion years ago. There was a huge explosion. In less than a second, the universe grew from the size of a pinhead to 2,000 times the size of the Sun. Even today, galaxies are still moving away from this explosion.

Scientists don't know if the universe will expand forever or stop expanding. If there is enough matter in the universe, gravity might stop the expansion. Then the universe would contract until everything came back to a single point. But studies show the universe is expanding faster, not slower. Scientists are still trying to figure out what will happen to the universe.

Reading Check

3. **Apply** You hear a police siren in the distance. If the siren's pitch is getting higher, is the police car coming closer or moving away?

Think it Over

4. **Draw Conclusions** Why do you think the leading theory about how the universe formed is called the big bang theory?

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After You Read

Mini Glossary

big bang theory: the theory that the universe began about 13.7 billion years ago with a huge explosion and has been expanding ever since

galaxy: a large group of stars, dust, and gas held together by gravity

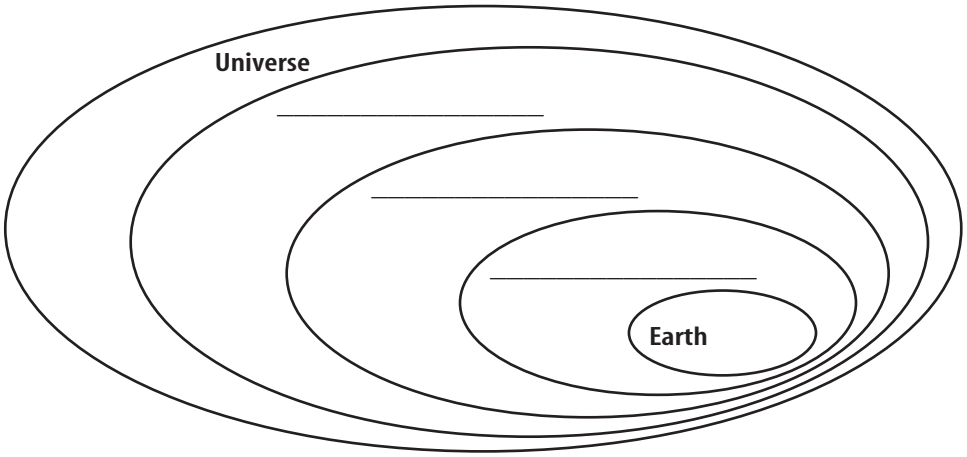
1. Review the terms and their definitions in the Mini Glossary. Write a sentence using the terms *big bang theory* and *galaxy.*

_____

_____

_____

2. Complete the diagram to show how Earth fits into the Universe. Use the following terms: Milky Way, Solar System, and Local Group.



3. Look at your highlighted text about the Milky Way. Write a short description of the Milky Way that includes three details. Did highlighted text help you write your description? What other strategy could have helped you keep track of details about the Milky Way?

_____

_____

_____

End of Section

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