Name _____ Class _____ Date _____

CHAPTER 18 Studying Space

SECTION 1

Astronomy: The Original Science

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do astronomers define a day, a month, and a year?
- What is the difference between the Ptolemaic and Copernican theories about the universe?
- What contributions did Brahe, Kepler, Newton, Galileo, and Hubble make to astronomy?

National Science Education Standards

ES 3a, ES 3b, ES 3c

How Does Astronomy Affect Our Calendar?

Imagine that it is 5,000 years ago. You do not have a modern clock or calendar. How can you know what day it is? How can you know what month it is? One way is to study the movement of the moon, the planets, and the stars.

People in ancient cultures used the movements of the stars, planets, and moon to mark the passage of time. People observed that the objects in the solar system move in regular and predictable ways. Farmers used these cycles to figure out the best time of year to plant and harvest. Sailors used the stars to navigate their ships. ☑

The early observations of the night sky led to the first calendars. Our modern calendar is also based on the movements of the bodies in our solar system. In our modern calendar, a **year** is the amount of time it takes the Earth to orbit the sun once. A **month** is about the same amount of time that the moon takes to orbit the Earth once. A **day** is the time it takes for the Earth to rotate once on its axis.

Unit	Description
Day	
Month	
	the time it takes the Earth to orbit the sun once

Over time, the study of the night sky became the science of astronomy. **Astronomy** is the study of the universe. Scientists who study astronomy are called *astronomers*. Modern astronomy is based partly on the work of early astronomers.

STUDY TIP

Compare As you read, make a chart comparing the different scientists that are mentioned in this section. In your chart, describe each scientist's contributions to astronomy.

READING CHECK

1. Explain How did people in ancient cultures mark the passage of time?

_____

_____

_____

TAKE A LOOK

2. Identify Fill in the blank spaces in the table.

How Did Early Astronomers Affect Astronomy?

Almost everything that early astronomers knew came from what they could observe with their eyes. Therefore, most early astronomers thought the universe was made only of the moon, the planets, and the sun. They thought that all the stars were at the edge of the universe.

Early theories about the universe were incorrect in many ways. However, over time, more data became available to astronomers. As a result, theories about the universe began to change. ☑

READING CHECK

3. Explain Why have astronomers changed their theories about the universe over time?

_____

_____

_____

PTOLEMY: AN EARTH-CENTERED UNIVERSE

Claudius Ptolemy was a Greek astronomer. In 140 CE, he wrote a book that brought together many ancient astronomical observations. He used these observations, together with careful calculations, to develop what is known as the *Ptolemaic theory*. According to this theory, the Earth is the center of the universe. The Ptolemaic theory also states that all other objects in the universe orbit the Earth.

Today, we know that the Ptolemaic theory is incorrect. However, Ptolemy's calculations predicted the motions of the planets better than any other theory at the time. The predictions fit the observations that other astronomers made. Therefore, the Ptolemaic theory was accepted as correct for more than 1,500 years.

COPERNICUS: A SUN-CENTERED UNIVERSE

In 1543, a Polish astronomer named Nicolaus Copernicus published a new theory. His theory stated that the sun is the center of the universe and that the planets revolve around the sun.

Scientists did not accept Copernicus's theory immediately. However, when it was accepted, it caused major changes in science and society. These changes were called the *Copernican revolution*.

Critical Thinking

4. Compare Today, scientists know that only part of Copernicus's theory is correct. Which part of Copernicus's theory is not correct?

_____

_____

TAKE A LOOK

5. Describe Fill in the blank spaces in the table.

Astronomer	Description of theory
Ptolemy	
	The sun is the center of the universe, and the planets orbit the sun.

TYCHO BRAHE: A WEALTH OF DATA

In the late 1500s, a Danish astronomer, Tycho Brahe, made the most detailed astronomical observations so far. Brahe thought the sun and moon revolved around the Earth, and the other planets revolved around the sun. Although his theory was incorrect, his precise observations helped future astronomers. ☑

READING CHECK

6. Explain How did Tycho Brahe's work help astronomers?

_____

_____

JOHANNES KEPLER: LAWS OF PLANETARY MOTION

Johannes Kepler was Brahe's assistant. He continued to analyze Brahe's data after Brahe died. Kepler determined that the planets revolve around the sun in *elliptical*, or oval-shaped, orbits. He also developed three laws that describe planetary motion. These laws are still used today.

GALILEO: TURNING A TELESCOPE TO THE SKY

Galileo Galilei was one of the first people to use a telescope to observe objects in space. Before his time, astronomers observed space using only their eyes. Galileo made many important observations about the solar system. Some of these observations are listed below.

- There are craters and mountains on the surface of the Earth's moon.
- Jupiter has at least four moons.
- Dark spots sometimes appear on the surface of the sun.

These discoveries were important because they showed that the planets are physical bodies like the Earth. Until Galileo, people thought that the planets were stars that moved quickly through the sky.

STANDARDS CHECK

ES 3a The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

7. Identify What is the most massive object in the solar system?

_____

ISAAC NEWTON: THE LAWS OF GRAVITY

In 1687, Sir Isaac Newton showed that all objects in the universe attract each other through a force called gravity. Heavy objects and objects that are close together have the strongest force of gravity. This explains why all the planets orbit the sun. The sun has more mass than any other object in the solar system.

EDWIN HUBBLE: BEYOND THE MILKY WAY

In 1924, Edwin Hubble used detailed observations to prove that other galaxies existed beyond the edge of our galaxy. His data confirmed that the universe is much larger than our own galaxy, the Milky Way.

Name _____ Class _____ Date _____

Section 1 Review

NSES ES 3a, ES 3b, ES 3c

SECTION VOCABULARY

astronomy the scientific study of the universe **day** the time required for Earth to rotate once on its axis	**month** a division of the year that is based on the orbit of the moon around the Earth **year** the time required for the Earth to orbit once around the sun

1. **Compare** What is the difference between a day, a month, and a year in terms of astronomy?

2. **Describe** What did people in ancient cultures observe about the motions of the planets, the moon, and the sun?

3. **Explain** Why was the Ptolemaic theory accepted for a long time?

4. **Infer** How did Tycho Brahe's work help Kepler develop his laws of planetary motion?

5. **Evaluate** What advantage did Galileo have over other, earlier astronomers?

6. **Identify** What did Edwin Hubble prove about the size of the universe?

Name _____ Class _____ Date _____

CHAPTER 18 Studying Space

SECTION 2

Telescopes

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

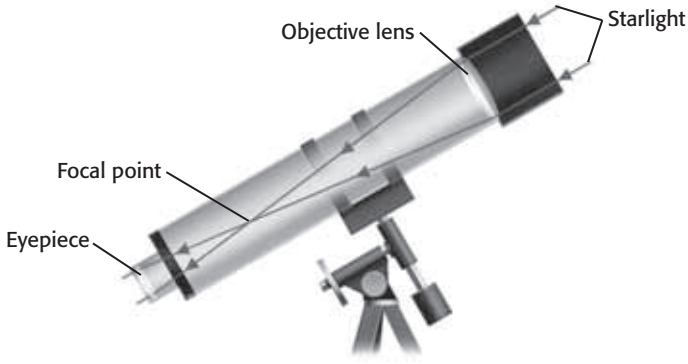
- What are telescopes?
- How can telescopes help scientists study space?

How Can a Telescope Help Us Make Observations?

How much of the sky can you see when you gaze up at night? At most, you can see 3,000 stars. With a telescope, you can see millions of stars, as well as many other objects. A **telescope** is a tool that scientists use to study objects, such as stars, that are far away. A telescope collects light and other kinds of radiation from the sky and makes it brighter. In this way, telescopes make distant objects more visible.

An *optical telescope* is used to study visible light from objects in the universe. Simple optical telescopes, such as the one in the figure below, have two lenses. The *objective lens* collects light from distant objects. The objective lens focuses the light and forms an image at a focal point. A *focal point* is where rays of light that pass through a lens or reflect from a mirror come together. ☑

The second lens in a simple optical telescope is in the eyepiece. This lens *magnifies*, or makes bigger, the image that forms at the focal point.



This simple refracting telescope has an objective lens that collects light and a lens in the eyepiece to magnify the image.

STUDY TIP

Learn New Words As you read, underline words you don't know. When you figure out what they mean, write the words and their definitions in your notebook.

READING CHECK

1. Define What is a focal point?

_____

_____

_____

TAKE A LOOK

2. Compare How is the objective lens different from the lens in the eyepiece?

_____

_____

_____

_____

REFRACTING TELESCOPES

Refracting telescopes are simple optical telescopes that use lenses to gather and focus light. The figure on the previous page shows a drawing of a refracting telescope. Refracting telescopes are the simplest telescopes, so they are usually easy to use. ☑

READING CHECK

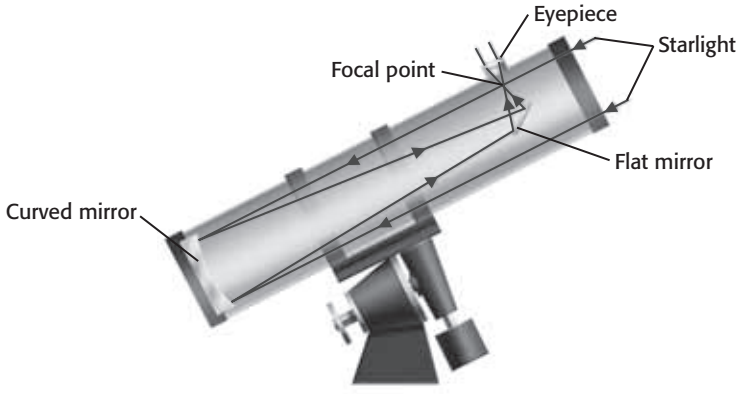
3. Explain How do refracting telescopes gather and focus light?

_____

There are two disadvantages to refracting telescopes. First, lenses focus different colors of light at slightly different distances. This means that images cannot be focused well. Second, refracting telescopes cannot be very large. Large telescopes have large objective lenses. The bigger the objective lens, the more light the telescope can gather. However, if the lens is too large, it can bend under its own weight. This causes the image to look fuzzy.

REFLECTING TELESCOPES

Reflecting telescopes use curved mirrors to gather and focus light. Light enters the telescope and reflects off a large, curved mirror. The light then travels to a flat mirror near the eyepiece. The flat mirror focuses the image and reflects it to the eyepiece.



This reflecting telescope uses mirrors to collect and focus light.

TAKE A LOOK

4. Describe What does the flat mirror in a reflecting telescope do?

_____

_____

_____

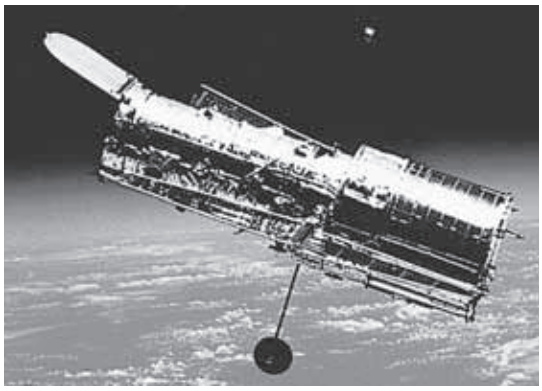
There are some advantages to reflecting telescopes. First, the mirrors can be large. This allows the reflecting telescope to gather a lot of light. Second, the light reflects off the mirrors instead of passing through them. This means that problems with the glass in the mirrors do not affect the image. Third, mirrors can focus all colors of light to the same focal point. Therefore, the images can be better focused than with refracting telescopes.

LARGE TELESCOPES AND CLEAR IMAGES

Some very large reflecting telescopes use several mirrors to collect and focus light. For example, the Keck Telescopes in Hawaii each use 36 mirrors to collect and focus light. However, even very large reflecting telescopes must be in a good location if they are to form clear images.

The light gathered by telescopes on the Earth is affected by the atmosphere. The motion of the air in the Earth's atmosphere causes starlight to shimmer and blur. Therefore, astronomers may place telescopes on mountain tops, where the air is thinner. There may also be less air and light pollution in these areas.

In order to avoid interference from the atmosphere, scientists have put telescopes in space. These telescopes can detect very faint objects because there is no air to blur the image.



The mirrors in the Hubble Space Telescope are smaller than the mirrors in many telescopes on the Earth. However, the Hubble Telescope can produce images of very faint objects because the Earth's atmosphere does not blur the images.

What Is Light?

Optical telescopes make the visible light from objects in space easier for us to see. Visible light is a form of electromagnetic radiation. However, visible light is not the only form of electromagnetic radiation. Other examples of electromagnetic radiation are gamma rays, X rays, and radio waves. The **electromagnetic spectrum** is made up of all the kinds of electromagnetic radiation.

Electromagnetic radiation travels in waves. Each kind of radiation has a different wavelength. Gamma rays have the shortest wavelengths. Radio waves have the longest wavelengths. ☑

Most of the electromagnetic spectrum is invisible. For example, we cannot see gamma rays or radio waves. The figure on the top of the next page shows some of the different kinds of electromagnetic radiation.

Critical Thinking

5. Apply Concepts Scientists may place telescopes in deserts or other areas where the air is dry. This is because dry air often produces less blurry images than moist air. What is the most likely reason that dry air produces less blurry images than moist air?

_____

_____

_____

_____

READING CHECK

6. Identify Which kind of electromagnetic radiation has the shortest wavelength?

_____

Say It

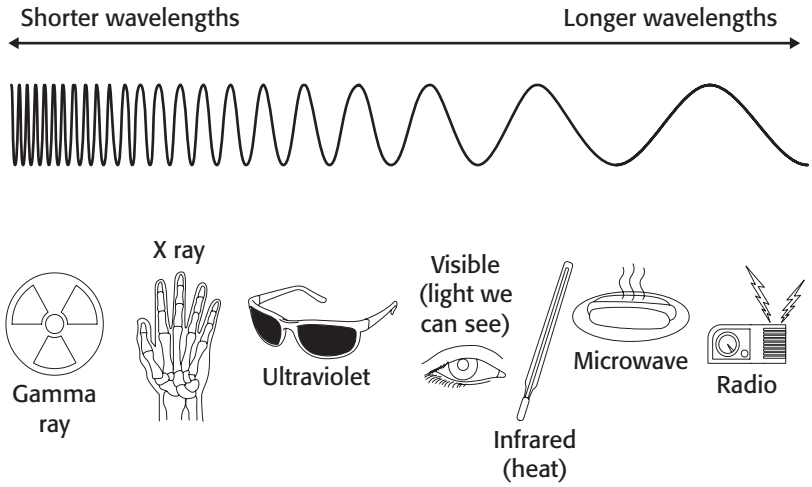
Discuss You may have heard or seen the terms "X ray," "infrared," and "ultraviolet" in other places. In a small group, talk about the ways that these words are used in other situations.

TAKE A LOOK

7. Identify Give two kinds of electromagnetic radiation that are invisible.

_____

_____



The electromagnetic spectrum is made up of all the kinds of electromagnetic radiation. Visible light is light that we can see. However, most electromagnetic radiation is invisible.

DETECTING ELECTROMAGNETIC RADIATION

The atmosphere acts as a shield around the Earth. It blocks most kinds of invisible radiation that come from objects in space. However, some types of radiation, such as radio waves and microwaves, can pass through the atmosphere.

Scientists can study invisible radiation using *nonoptical telescopes*. These telescopes can detect invisible radiation and focus it to produce an image. Astronomers study the entire electromagnetic spectrum because each type of radiation reveals different clues about an object. ☑

READING CHECK

8. Explain How do scientists study invisible radiation from objects in space?

_____

_____

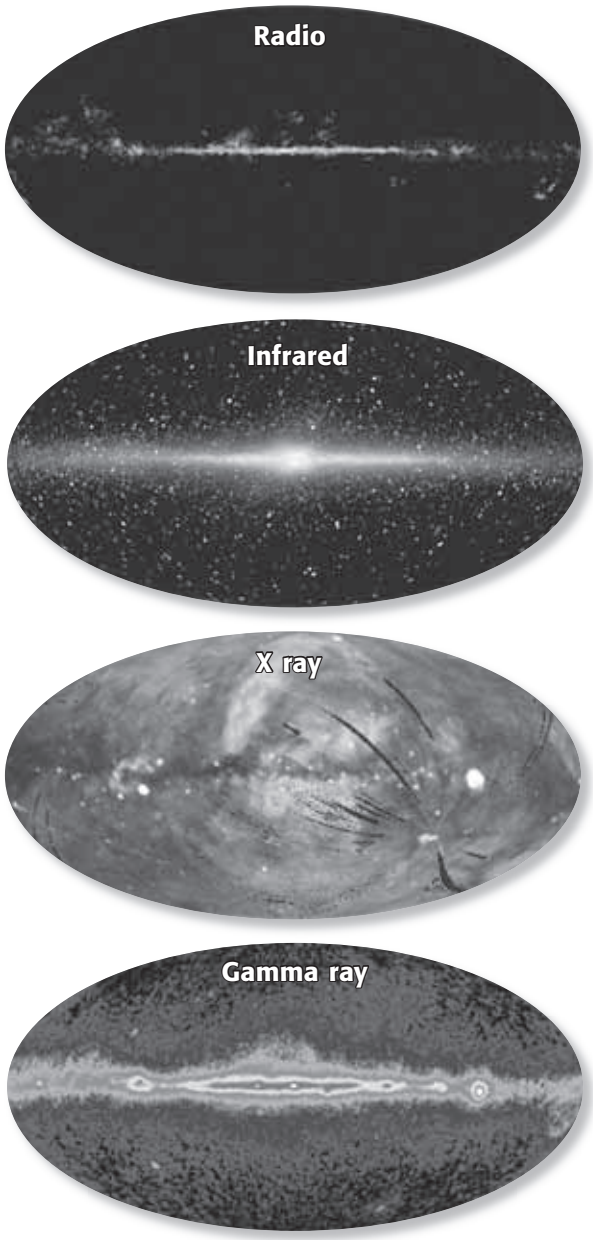
RADIO TELESCOPES

Radio telescopes detect radio waves. Radio wavelengths are much longer than visible wavelengths. Therefore, radio telescopes have to be much larger than optical telescopes. However, the reflecting surfaces of radio telescopes do not have to be as smooth as those in optical telescopes. In addition, radio waves can be detected at night and during the day. Therefore, radio telescopes can be very useful, even though they are large.

Astronomers can use many radio telescopes together to get more detailed images. When radio telescopes are linked together, they work like a single giant telescope. The Very Large Array (VLA) consists of 27 radio telescopes spread over 30 km. Together, the VLA telescopes act as a single telescope that is 30 km across.

NONOPTICAL TELESCOPES IN SPACE

Most electromagnetic waves are blocked by the Earth's atmosphere. Therefore, scientists have placed some kinds of nonoptical telescopes in space. These telescopes produce images of objects in space using different kinds of electromagnetic radiation. For example, each figure below shows an image of our galaxy. The images look different because they were recorded from different types of electromagnetic radiation. ☑



Each of these images shows our galaxy, the Milky Way. Different features of the galaxy are visible at different wavelengths of electromagnetic radiation.

READING CHECK

9. Explain Why have scientists placed some nonoptical telescopes in space?

_____

_____

_____

_____

TAKE A LOOK

10. Compare On each image, circle a feature that is not found in any of the other images.

Name _____ Class _____ Date _____

Section 2 Review

SECTION VOCABULARY

electromagnetic spectrum all of the frequencies or wavelengths of electromagnetic radiation **reflecting telescope** a telescope that uses a curved mirror to gather and focus light from distant objects	**refracting telescope** a telescope that uses a set of lenses to gather and focus light from distant objects **telescope** an instrument that collects electromagnetic radiation from the sky and concentrates it for better observation

1. Compare What is the main difference between a refracting telescope and a reflecting telescope?

2. Describe What limits the size of a refracting telescope? Explain your answer.

3. Identify List five types of electromagnetic radiation. Put them in order, from the longest wavelengths to the shortest.

4. Explain Why do radio telescopes have to be larger than optical telescopes?

5. Explain Why do astronomers place telescopes in space? Give two reasons.

Name _____ Class _____ Date _____

CHAPTER 18 Studying Space

SECTION 3

Mapping the Stars

BEFORE YOU READ

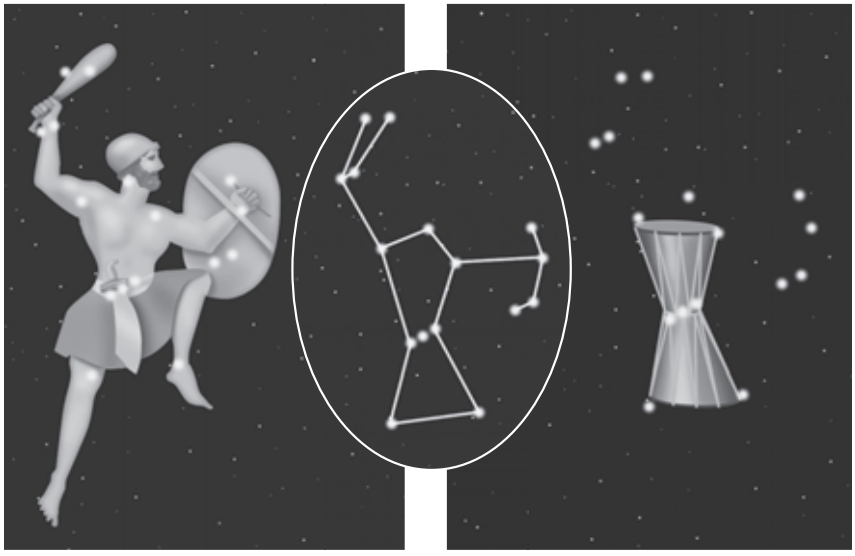
After you read this section, you should be able to answer these questions:

- What are constellations?
- How can we precisely locate stars in the night sky?

What Are Constellations?

People in ancient cultures grouped stars into patterns and named sections of the sky based on those patterns. **Constellations** are sections of the sky that contain recognizable star patterns.

Different civilizations had different names for the same constellations. For example, the Greeks saw a hunter (Orion) in the northern sky, but the Japanese saw a drum. Today, different cultures still see different shapes in the stars in the sky. However, astronomers have agreed on the names and locations of the constellations.



The ancient Greeks saw a hunter in this set of stars. The Japanese saw the same set of stars as a drum.

STUDY TIP

Summarize in Pairs Read this section quietly to yourself. With a partner, talk about what you learned. Together, try to figure out things that you don't understand.

Say It

Infer Why is it important for modern astronomers to agree on the names and locations of the constellations? In a small group, talk about what might happen if astronomers did not agree on these things. How might the science of astronomy be different?

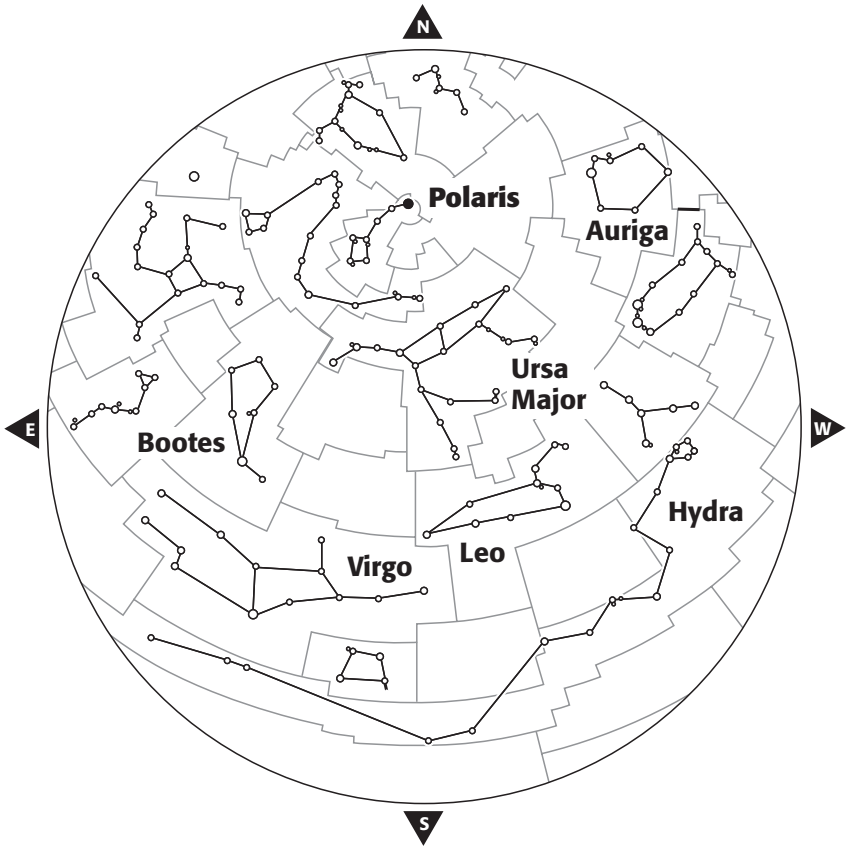
CONSTELLATIONS: ORGANIZING THE SKY

Many people think of constellations as stick figures made by connecting bright stars with imaginary lines. However, to an astronomer, a constellation is an entire section of the sky. Just as Texas is a region of the United States, Ursa Major is a region of the sky. Each constellation shares a border with a neighboring constellation. Every star or galaxy in the sky is located within one of 88 constellations. ☑

READING CHECK

1. Identify How many regions do astronomers break the sky into?

_____



This sky map shows some of the constellations that are visible in the Northern Hemisphere at midnight in the spring.

TAKE A LOOK

2. Identify Which constellation takes up a large part of the southern and southwestern sky in the spring in the Northern Hemisphere?

_____

SEASONAL CHANGES

READING CHECK

3. Explain Why can't you use the same star map to show all of the stars that are visible to everyone on the Earth?

_____

_____

_____

The figure above shows what the midnight sky in the Northern Hemisphere looks like in the spring. However, as the Earth travels around the sun, different areas of the universe are visible. In addition, different constellations are visible from different points on the Earth. Therefore, this map is not accurate for the Northern Hemisphere during seasons other than spring, or for the Southern Hemisphere. ☑

THE PATH OF STARS ACROSS THE SKY

You know that the sun seems to move across the sky during the day. In the same way, the stars and planets rise and set during the night. This apparent motion is caused by Earth's rotation. As the Earth rotates, different parts of the universe become visible to people on the Earth. ☑

Near the poles, some stars can be seen at all times of year and all times of night. These stars are called *circumpolar stars*. *Circum* means "around" or "circling." Circumpolar stars seem to move through the sky in circles around the poles.

READING CHECK

4. Identify Why do the stars seem to move across the sky?

_____

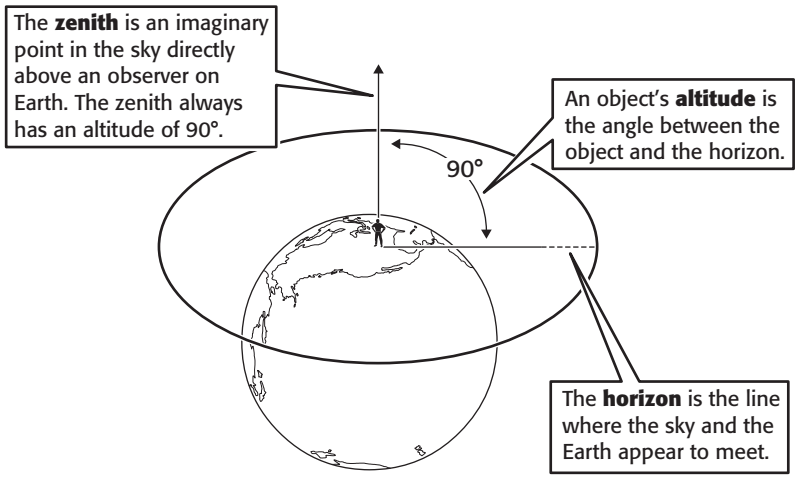
_____

_____

How Can You Describe the Location of a Star?

Have you ever tried to point out a star to someone? It can be very difficult to describe the exact location of an object in the sky. You can use a tool called an *astrolabe* to help you describe the location of such an object.

To use an astrolabe, you need to understand the differences between horizon, altitude, and zenith. The **horizon** is the line where the Earth and the sky seem to meet. An object's **altitude** is the angle between the object and the horizon. The **zenith** is an imaginary point in the sky that is directly above your head. The zenith always has an altitude of 90°. The figure below shows these three reference points.



Math Focus

5. Estimate Angles On the figure, draw a star to show the location of an object with an altitude of about 45°.

THE CELESTIAL SPHERE

To talk to each other about a star, astronomers must have a common method of describing the star's location. The method that astronomers use is based on the celestial sphere. The *celestial sphere* is an imaginary sphere that surrounds the Earth. Remember that we use latitude and longitude to describe the location of objects on the Earth's surface. In the same way, astronomers use declination and right ascension to plot positions in the sky.

Remember that latitude is a measure of the distance north or south of the equator. *Declination* is the distance of an object north or south of the celestial equator. The *celestial equator* is an imaginary circle formed by extending the Earth's equator into space, as shown in the figure below.

Remember that longitude is a measure of the distance east or west of the prime meridian. *Right ascension* is a measure of how far east an object is from the vernal equinox. The *vernal equinox* is the position of the sun on the first day of spring.

Critical Thinking

6. Compare How is latitude similar to declination? How are they different?

_____

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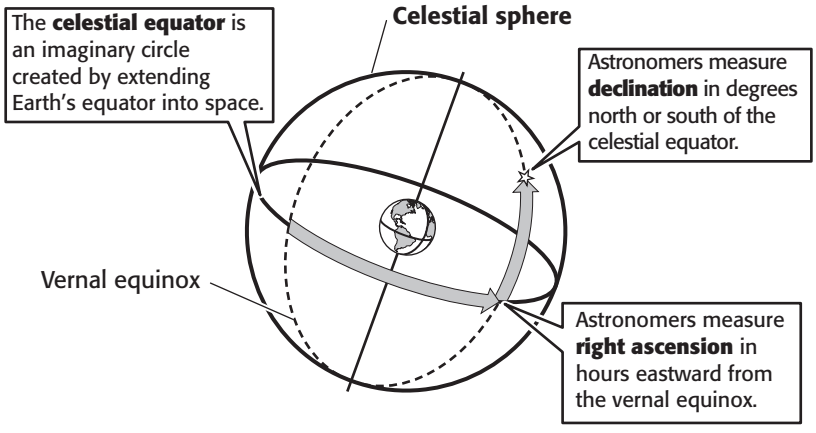
The Celestial Sphere



TAKE A LOOK

7. Define What is the celestial equator?

_____

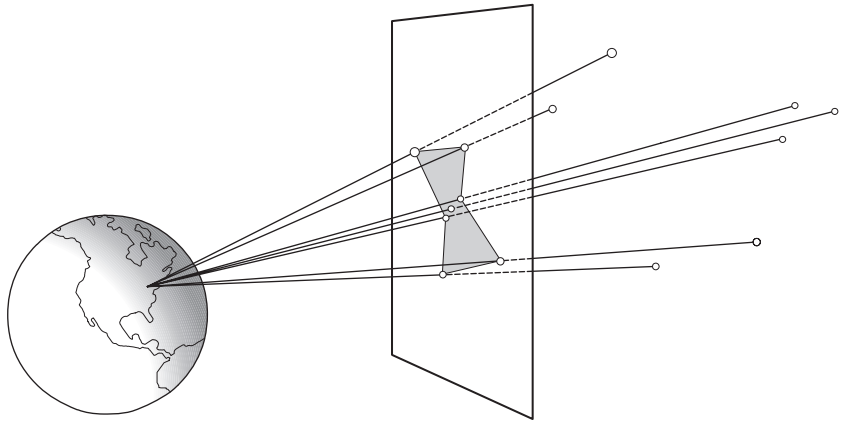
_____

_____

How Big Is the Universe?

In the 1500s, Nicolaus Copernicus noticed that the planets appeared to move, but the stars did not. He thought the stars must be farther away than the planets. Stars are so distant that a new unit of length, the light-year, was invented to measure their distance. A **light-year** is the distance that light travels in 1 year. One light-year is equal to 9.46 trillion kilometers. The farthest objects we can observe are more than 10 billion light-years away! ☑

Many of the stars in the sky look the same. For example, the stars in Orion all seem to be about the same size in the sky. However, some stars are much closer than others. The figure below shows how stars that are very far apart can look the same to people on the Earth.



The stars in Orion seem to be very close together. However, they are actually very far apart.

READING CHECK

8. Define What is a light-year?

_____

_____

TAKE A LOOK

9. Infer How might the pattern of stars that we see in Orion change if the Earth were further away from the stars than it is?

_____

_____

THE SCALE OF THE UNIVERSE

When you think about the universe, it is important to think about scale. For example, stars appear to be very small when you see them in the sky. However, we know that most stars are much larger than the Earth. They look small in the sky because they are very far away. The figure on the next page shows how distance can affect the apparent size of objects. ☑

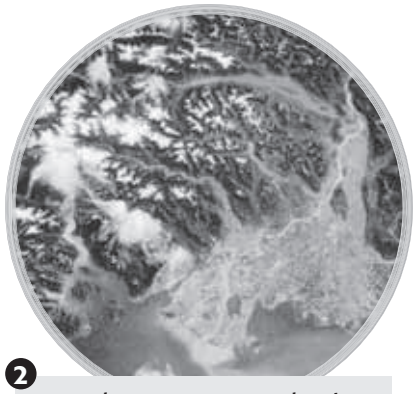
READING CHECK

10. Explain Why do stars look very small, even though they are actually larger than the Earth?

_____

_____

1 Let's start with home plate in a baseball stadium. You are looking down from a distance of about 10 m.



2 At 100 km away, you see the city that contains the stadium and the countryside around the city.

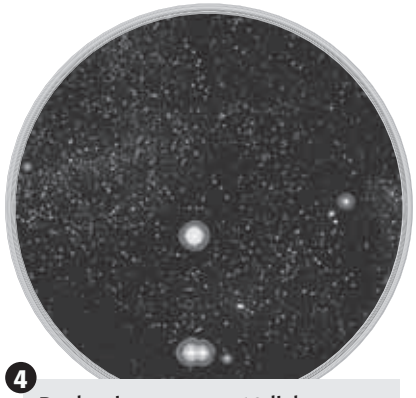
TAKE A LOOK

11. Infer What is a light-minute?

_____

_____

3 At 1,500,000,000 km (83 light-minutes) away, you can look back at the sun and the inner planets.



4 By the time you are 10 light-years away, the sun looks like any other star in space.

TAKE A LOOK

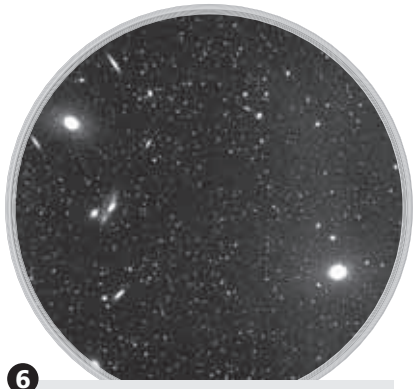
12. Identify What is the local group?

_____

_____

_____

5 At 1 million light-years away, our galaxy looks like the Andromeda galaxy, a cloud of stars set in the blackness of space.



6 At 10 million light-years away, you can see a handful of galaxies called the *Local Group*.

How Do Scientists Know That the Universe Is Expanding?

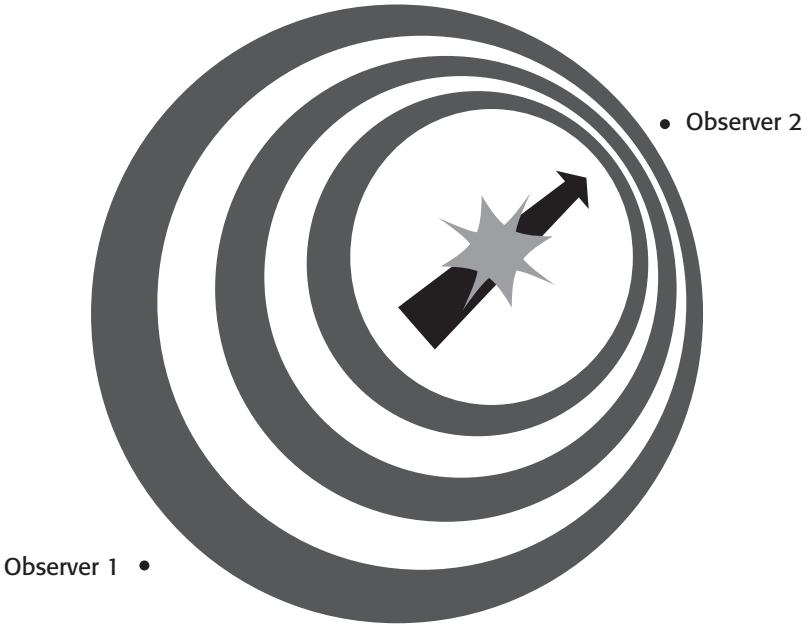
We see stars and galaxies because they *emit*, or give off, visible light. The color of light that we see from stars can change if the stars are moving compared to the Earth. When stars or galaxies are moving away from the Earth, the light from them looks redder than normal. This effect is called *redshift*. When stars or galaxies are moving toward the Earth, the light from them looks bluer than normal. This effect is called *blueshift*. ☑

READING CHECK

13. Explain Why do we see stars and galaxies?

_____

_____



The galaxy is moving away from Observer 1 and toward Observer 2. To Observer 1, the light from the galaxy looks redder than normal. The waves of light are more spread out, so the wavelength is longer. To Observer 2, the light from the galaxy looks bluer than normal. The waves of light are closer together, so the wavelength is shorter.

TAKE A LOOK

14. Identify Which observer is seeing light that is affected by redshift?

_____

Redshift and blueshift affect light only from objects that are moving very quickly. This is why cars and airplanes do not look redder or bluer when they pass by you. They are not traveling fast enough for you to see redshift or blueshift effects.

The astronomer Edwin Hubble studied the light from stars and galaxies in the universe. He discovered that light from all of these objects, except the ones closest to the Earth, is affected by redshift. This means that the stars and galaxies in the universe are moving away from each other and from the Earth. In other words, the universe is expanding. ☑

READING CHECK

15. Explain How did Edwin Hubble show that the universe is expanding?

_____

_____

_____

_____

Name _____ Class _____ Date _____

Section 3 Review

SECTION VOCABULARY

altitude the angle between an object in the sky and the horizon

constellation a region of the sky that contains a recognizable star pattern and that is used to describe the location of objects in space

horizon the line where the sky and the Earth appear to meet

light-year the distance that light travels in one year; about 9.46 trillion kilometers

zenith the point in the sky directly above an observer on Earth

1. Define Write your own definition for *constellation*.

2. Explain Why can we see different constellations in the fall than in the spring?

3. Identify Fill in the spaces in the table below.

Term	Description
Declination	
Right ascension	
Celestial sphere	

4. Calculate About how many kilometers are in 0.5 light-years? Show your work.

5. Apply Concepts Suppose that Edwin Hubble had observed that light from most stars and galaxies was affected by blueshift. What conclusion about the universe could be drawn from this observation? Explain your answer.

Name _____ Class _____ Date _____

CHAPTER 19 Stars, Galaxies, and the Universe

SECTION 1

Stars

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Why are stars different colors?
- How can scientists learn what stars are made of?
- How can we measure the distance between stars?
- Why do stars seem to move across the sky?

Why Are Stars Different Colors?

Stars look like tiny points of light in the sky. However, they are actually huge, bright balls of burning gas. If you look closely at the night sky, you might see that stars are different colors. Scientists can tell how much heat a star gives off by studying its color.

Compare the yellow flame of a candle to the blue flame of a Bunsen burner. A blue flame is much hotter. Stars are similar: blue stars burn hotter than yellow ones. Red stars are coolest.

A blue flame is hotter than a yellow one.

STUDY TIP

Ask Questions Read this section quietly to yourself. Write down questions that you have about this section. Discuss your questions in a small group.

TAKE A LOOK

1. Color Use colored pencils to make these flames the correct color.

2. Identify Which of the flames is cooler?

_____

What Are Stars Made Of?

Stars are made of gas. Hydrogen and helium are the two main elements that make up a star. Stars also contain small amounts of other elements, such as carbon, nitrogen, and oxygen. Each star is made up of a different mix of elements.

Most stars are trillions of miles away from Earth. Because scientists cannot visit the stars, they need to study stars from Earth. To find out what a star is made of, scientists study the light from the stars. ☑

READING CHECK

3. Explain How do scientists learn about stars?

_____

_____

_____

How Can Scientists Learn About Stars from Their Light?

Light takes time to travel through space. Stars are so far away that their light takes millions of years to travel to Earth! When scientists look through telescopes, it is as if they are looking back in time. The light we see from stars today was made millions of years ago. Some stars that we see might have already burned out. However, we can still see them because their light is just reaching Earth.

Critical Thinking

4. Apply Concepts When we look at the night sky, are we seeing the universe exactly as it is?

_____

_____

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_____

What Can Scientists Learn from a Star's Light?

Scientists use the light from stars to find out what the stars are made of. When you look at white light through a glass prism, you can see a rainbow of colors. This rainbow is called a **spectrum** (plural, *spectra*). Millions of colors make up a spectrum, including red, orange, yellow, green, blue, indigo, and violet. Scientists use a machine called a *spectrograph* to break up a star's light into a spectrum.

Each element has a particular pattern of lines that appear in an *emission spectrum*. The emission spectrum shows scientists what elements are in the star.

Hydrogen

Helium

These are the emission spectra for the elements hydrogen and helium. These two elements make up most stars. Each line represents a different color of visible light.

TAKE A LOOK

5. Compare Which emission spectrum contains more colors of visible light, hydrogen or helium?

_____

How Do Scientists Classify Stars?

Stars can be classified in several ways. Scientists classify stars most commonly by temperature and brightness.

TEMPERATURE

In the past, scientists classified stars by the elements they contained. Today, stars are classified by temperature. Each group of stars is named with a letter of the alphabet. The table on the next page shows the features of different groups of stars.

Class	Color	Temperature (°C)	Elements detected
O	blue	above 30,000	helium
B	blue-white	10,000 to 30,000	hydrogen, helium
A	blue-white	7,500 to 10,000	hydrogen
F	yellow-white	6,000 to 7,500	hydrogen and heavier elements
G	yellow	5,000 to 6,000	calcium and heavier elements
K	orange	3,500 to 5,000	calcium and iron
M	red	less than 3,500	molecules, such as titanium dioxide

TAKE A LOOK

6. Identify A scientist discovers a star that is blue-white and is made of hydrogen. Which class should the scientist put the star in?

7. Identify Which class has hotter stars—G or B?

BRIGHTNESS

Before telescopes were invented, scientists judged the brightness of the stars with their naked eyes. They called the brightest stars they could see first-magnitude stars, and the dimmest stars, sixth-magnitude stars.

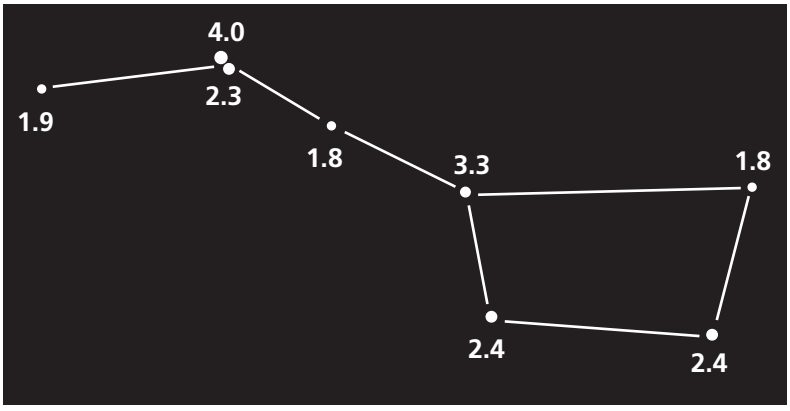
When telescopes were developed, scientists discovered this system had flaws. They could see more stars with the telescope than with the naked eye. They could also see the differences in brightness more clearly. The old system for classifying brightness was too general to include the dimmest stars that scientists were finding. A new system had to be created.

Today, scientists give each star a number to show its brightness, or *magnitude*. The dimmest stars have the largest numbers. The brightest stars have the smallest numbers. The magnitude of a very bright star can even be a negative number!

Critical Thinking

8. Apply Concepts Which star is brighter: one with a magnitude of 6.3 or one with a magnitude of −1.4?

Magnitudes of Stars in the Big Dipper



TAKE A LOOK

9. Identify Circle the brightest stars in the Big Dipper. What is their magnitude?

Does Distance Change a Star's Brightness?

If you look at a row of street lights, do all of the lights look the same? The nearest lights look brightest, and the farthest ones look dimmest.

The closer a light is, the brighter it looks.

TAKE A LOOK

10. Identify Circle the dimmest light in the picture. Put a box around the brightest light.

11. Explain The street lights are all equally bright. Why do they appear different?

_____

_____

The brightness of a star as we see it from Earth is the star's **apparent magnitude**. A bright star can look very dim if it is very far away from Earth. A dim star can appear bright if it is closer to Earth.

A star's **absolute magnitude** is the actual brightness of the star. If all stars were the same distance away, their absolute magnitudes would equal their apparent magnitudes. For example, the sun's absolute magnitude is +4.8, but because it is close to Earth, its apparent magnitude is −26.8.

How Do Scientists Measure Distance to a Star?

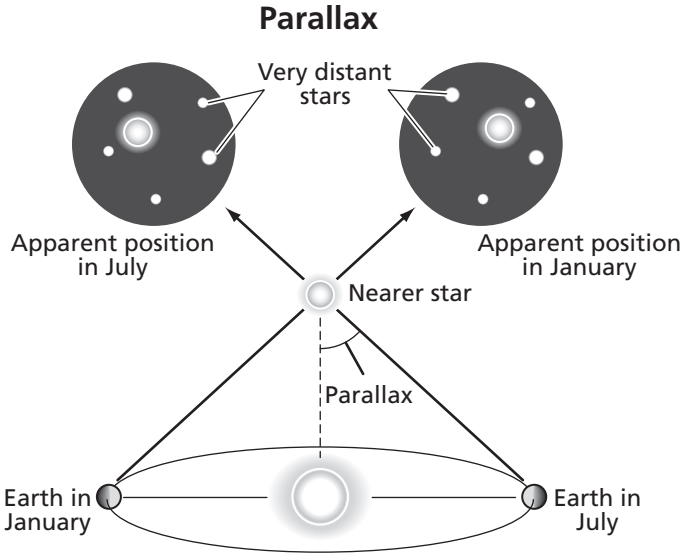
Math Focus

12. Calculate What is the distance in kilometers from Earth to a star that is 30 light years away?

_____

The distance between Earth and the stars is too large to be measured in miles or kilometers. Instead, scientists use a unit called a **light-year**, which is the distance that light can travel in one year. One light year equals 9.46 trillion kilometers. How can scientists measure such a large distance?

As Earth revolves around the sun, stars close to Earth seem to move, but far-off stars do not. This is called **parallax**. Scientists use parallax and math to find the distance between Earth and stars. To understand parallax, think about riding in a car past a large mountain. As you drive past the mountain, it seems to move. However, the mountain is not actually moving. It is your motion compared to the mountain that makes the mountain seem to move.



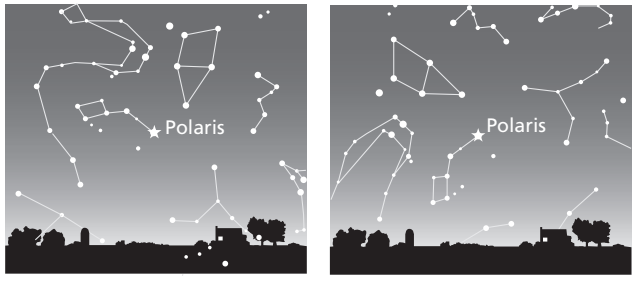
As the Earth revolves around the sun, a star's position seems to change.

Do Stars Move?

Stars move, but because they are so far away and move so slowly, we cannot see their movement easily. Every night stars seem to rise and set, but it is not the stars that are moving. It is the Earth.

The rotation of Earth causes daytime and nighttime. Because of Earth's rotation, the sun moves across the sky during the daytime. For this same reason, the stars seem to move across the sky at night. All of the stars that you see appear to rotate around Polaris, the North Star. The stars seem to make a full circle around Polaris every 24 hours.

Earth's tilt and revolution cause the seasons. During each season, any point on Earth faces a different part of the sky at night. That means that different stars appear in the night sky at different times of the year.



Because of the Earth's rotation, the stars seem to move across the sky.

In addition to their apparent motion, stars are moving through space. Because the stars are so far away, it is difficult for us to see their motions. Over thousands of years, however, the movements of the stars can cause the shapes of constellations to change.

TAKE A LOOK

13. Explain What causes parallax?

_____

_____

TAKE A LOOK

14. Compare Circle one star, other than Polaris, in the picture on the left. Then circle the same star in the picture on the right. Draw a curved arrow in the first picture that shows the direction that the star seemed to move.

Name _____ Class _____ Date _____

Section 1 Review

SECTION VOCABULARY

absolute magnitude the brightness that a star would have at a distance of 32.6 light-years from Earth **apparent magnitude** the brightness of a star as seen from Earth	**light-year** the distance that light travels in one year; about 9.46 trillion kilometers **parallax** an apparent shift in the position of an object when viewed from different locations **spectrum** the band of colors produced when white light passes through a prism

1. Identify What are the two main elements that make up most stars?

_____

_____

2. Apply Concepts Put the following star classes in order from hottest to coolest: A, B, G, K, O.

_____

3. Analyze Why do scientists use light-years to measure the distances between stars and Earth?

_____

_____

_____

4. Explain Why do stars seem to move in the sky?

_____

_____

5. Compare What is the difference between apparent magnitude and absolute magnitude?

_____

_____

_____

_____

6. Explain Why is the actual movement of stars hard to see?

_____

_____

_____

Name _____ Class _____ Date _____

CHAPTER 19 Stars, Galaxies, and the Universe

SECTION 2

The Life Cycle of Stars

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do stars change over time?
- What is an H-R diagram?
- What may a star become after a supernova?

How Do Stars Age?

Stars do not remain the same forever. Like living things, stars go through a life cycle from birth to death. The actual life cycle of a star depends on its size. An average star, such as the sun, goes through four stages during its life.

A star enters the first stage of its life cycle as a ball of gas and dust called a *protostar*. Gravity pulls the gas and dust together. As the ball becomes denser, it gets hotter. Eventually, the gas becomes so hot that it begins to react. These reactions produce energy, which keeps the new star from collapsing more.

The second, and longest, stage of a star's life cycle is the *main sequence star*. During this stage, hydrogen in the center of the star reacts to form helium. This produces a great deal of energy. As long as a main-sequence star has enough hydrogen to react, its size will not change very much.

When a main-sequence star uses up all of its hydrogen, it can start to expand and cool. This forms a huge star called a **red giant**.

In the final stage of its life cycle, an average star is classified as a white dwarf. A **white dwarf** is the small, hot, leftover center of a red giant.

STUDY TIP

Compare Make a chart comparing the steps in the life cycles of average stars and massive stars.

Critical Thinking

1. Infer A star can live for billions of years. Therefore, scientists can't watch a star through its entire life. How do you think scientists figure out the life cycle of a star?

_____

_____

_____

TAKE A LOOK

2. Identify This average star is in the last stage of its life cycle. What is that stage?

_____

Life Cycle of an Average Star

1. **Protostar** A *protostar* is a ball of gas and dust. Gravity pulls the gas and dust together, and its center gets hotter.

2. **Main-Sequence Star** The *main sequence* is the longest stage of a star's life cycle. The fusion of hydrogen atoms makes energy in the star.

3. **Red Giant** When a main sequence star uses up all its hydrogen, it can no longer give off energy. The star's center contracts and the outer layers expand and cool, forming a red giant.

4. **White Dwarf** A white dwarf is the leftover center of a red giant. It is a small, hot, and dim star that can shine for billions of years.

TAKE A LOOK

3. Identify What causes a main sequence star to become a red giant?

_____

_____

What Is an H-R Diagram?

An **H-R diagram** is a graph that shows the relationship between a star's temperature and its brightness. The H-R diagram also shows how stars change over time. The diagram is named after Ejnar Hertzsprung and Henry Norris Russell, the scientists who invented it. ☑

READING CHECK

4. Identify Which two characteristics of a star must a scientist measure to make an H-R diagram?

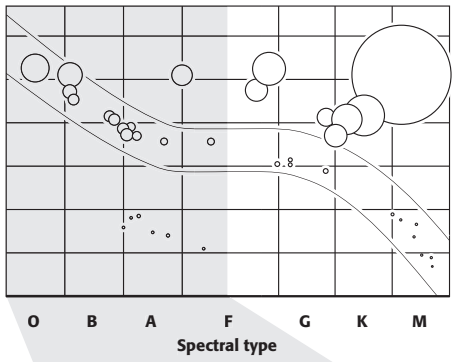
_____

_____

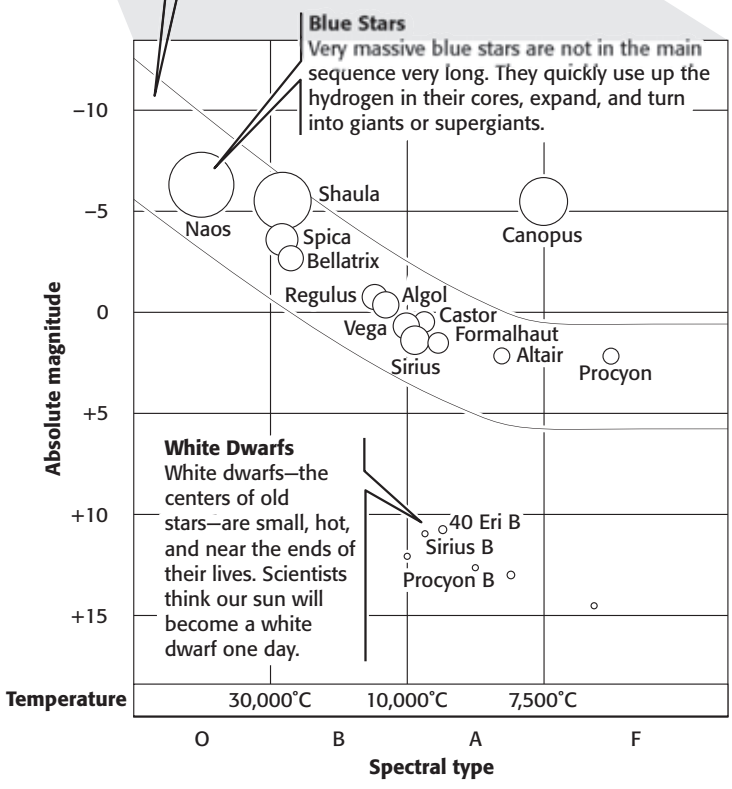
Temperature is given along the bottom of the diagram. Hotter (bluer) stars are on the left, and cooler (redder) stars are on the right. Brightness, or absolute magnitude, is given along the left side of the diagram. Bright stars are near the top, and dim stars are near the bottom. The bright diagonal line on the H-R diagram is called the **main sequence**. A star spends most of its life on the main sequence.

Why Does a Star's Position on the H-R Diagram Change?

As a main-sequence star ages, it becomes a red giant. When this happens, the star moves to a new place on the H-R diagram. The star's position on the diagram changes again when it becomes a white dwarf. These changes happen because the brightness and temperature of a star change throughout its life. ☑



Main-sequence Stars
Stars on the main sequence form a band that runs accross the H-R diagram. The sun is a main-sequence star. The sun has been shining for about 5 billion years. Scientists think that the sun is in the middle of its life and will remain on the main sequence for another 5 billion years.



An H-R diagram can show the life cycle of a star.

READING CHECK

5. Explain Why does a star's position on the H-R diagram change at different stages of its life cycle?

_____

_____

_____

_____

_____

TAKE A LOOK

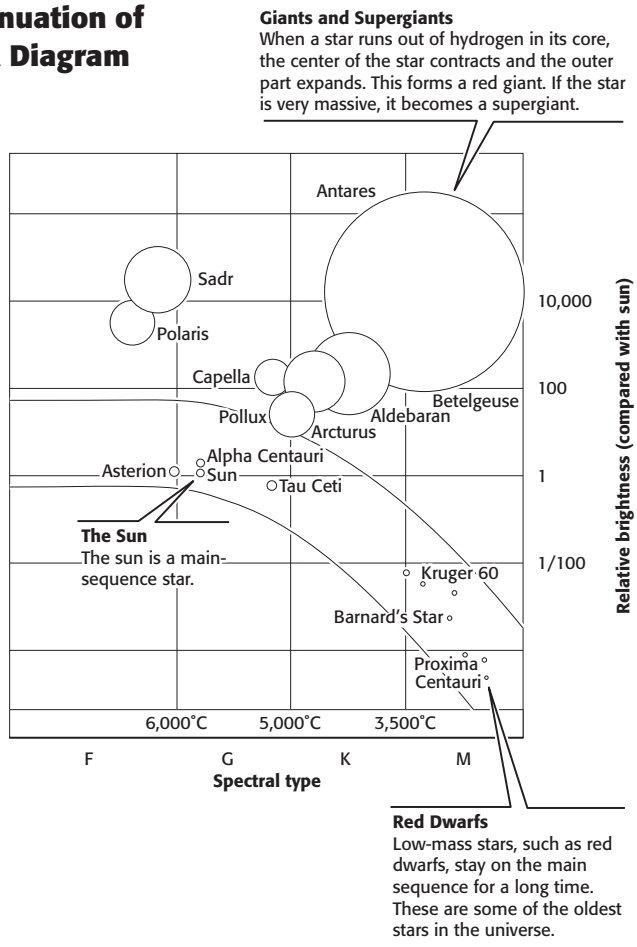
6. Identify Where in the H-R diagram are the brightest stars located?

_____

7. Identify Where in the diagram are the hottest stars located?

_____

A Continuation of the H-R Diagram



TAKE A LOOK

8. Compare Which star is hotter—Antares or Polaris?

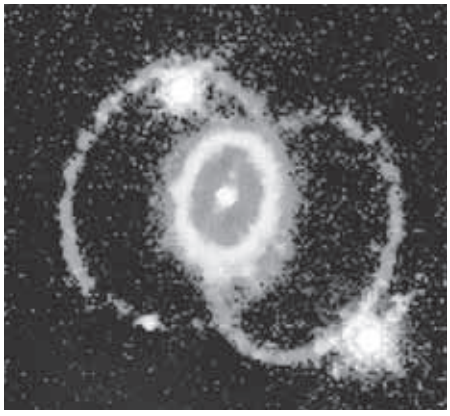
9. Read a Graph Is Betelgeuse on the main sequence?

What Happens to Massive Stars as They Age?

Massive stars use up their hydrogen much more quickly than smaller stars. As a result, massive stars give off much more energy and are very hot. However, they do not live as long as other stars. Toward the end of its main sequence, a massive star collapses in a gigantic explosion called a **supernova**. After such an explosion, a massive star may become a neutron star, a pulsar, or a black hole. ☑

READING CHECK

10. Identify What can cause a main-sequence star to turn into a neutron star, a pulsar, or a black hole?



These rings of dust and gas are the remains of a star that exploded in a supernova. Astronomers think that a neutron star or black hole was formed when this star exploded.

NEUTRON STARS

After a supernova, the center of a collapsed star may contract into a tiny ball of neutrons. This ball, called a **neutron star**, is extremely dense. On Earth, a single teaspoon of matter from a neutron star would weigh 100 million metric tons!

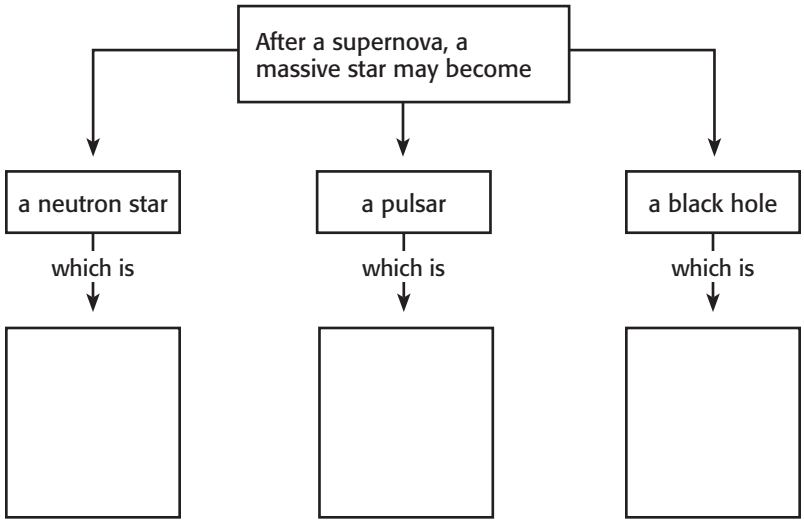
PULSARS

If a neutron star is spinning, it is called a **pulsar**. Pulsars send out beams of radiation that sweep through space. A radio telescope, an instrument that can pick up radiation with long wavelengths, can detect pulsars. Every time a pulsar's beam sweeps by Earth, scientists hear rapid clicks, or pulses, in the radio telescope.

BLACK HOLES

If the collapsed star is extremely massive, the force of its gravity may cause it to contract even more. This contraction crushes the dense center of the star, creating a **black hole**. Even though they are called holes, black holes aren't really empty spaces. A black hole is an object so dense that even light cannot escape its gravity.

Because black holes do not give off light, it can be hard for scientists to locate them. Gas and dust from a nearby star may fall into the black hole and give off X rays. When scientists find these X rays, they can infer that a black hole is close by.



Critical Thinking

11. Infer Could an average star, such as our sun, become a neutron star? Explain your answer.

Say It

Discuss In a small group, talk about other places you have heard about X rays. Where were they used? What were they used for?

TAKE A LOOK

12. Describe Fill in the blank spaces to describe neutron stars, pulsars, and black holes.

Name _____ Class _____ Date _____

Section 2 Review

SECTION VOCABULARY

black hole an object so massive and dense that even light cannot escape its gravity

H-R diagram Hertzsprung-Russell diagram, a graph that shows the relationship between a star's surface temperature and absolute magnitude

main sequence the location on the H-R diagram where most stars lie; it has a diagonal pattern from the lower right (low temperature and luminosity) to the upper left (high temperature and luminosity)

neutron star a star that has collapsed under gravity to the point that the electrons and protons have smashed together to form neutrons

pulsar a rapidly spinning neutron star that emits pulses of radio and optical energy

red giant a large, reddish star late in its life cycle

supernova a gigantic explosion in which a massive star collapses and throws its outer layers into space

white dwarf a small, hot, dim star that is the leftover center of an old star

1. List What are the four stages in the life cycle of an average star?

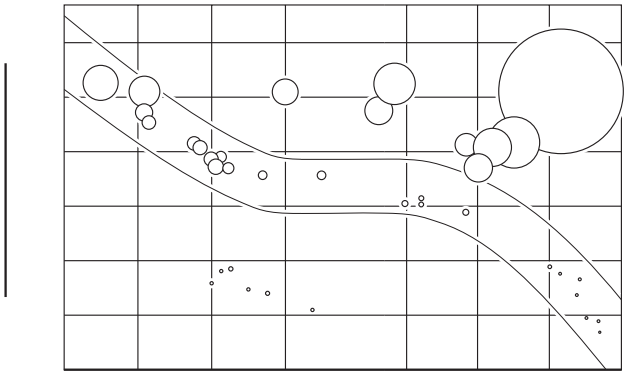
_____

_____

_____

_____

2. Identify Label the axes on this H-R diagram.



_____

3. Explain How does a star's temperature change as the star ages from a main sequence star to a red giant and from a red giant to a white dwarf?

_____

_____

4. Compare How is the life cycle of a massive star different from the life cycle of an average star?

_____

_____

Name _____ Class _____ Date _____

CHAPTER 19 Stars, Galaxies, and the Universe

SECTION 3

Galaxies

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are different shapes that a galaxy can have?
- What are galaxies made of?
- How do galaxies form?

What Is a Galaxy?

If you look out on a clear night far from city lights, you can see hundreds of stars. Many of these stars are part of our galaxy, which is called the *Milky Way*. Our galaxy actually contains many more stars than you can see.

A **galaxy** is a large group of gas, dust, and millions of stars. The biggest galaxies contain more than a trillion stars. Scientists can't actually count the stars, of course. They estimate how many stars are in a galaxy by measuring the size and brightness of the galaxy. The bigger and brighter the galaxy, the more stars it has. ☑

Galaxies come in different shapes and sizes. Scientists classify galaxies by shape. The three most common types of galaxies are spiral, elliptical, and irregular.

STUDY TIP

Compare As you read, make a table comparing the three different types of galaxies.

READING CHECK

1. Explain How do scientists estimate how many stars a galaxy has?

_____

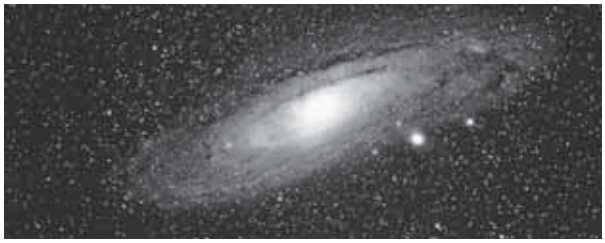
_____

_____

SPIRAL GALAXIES

A *spiral galaxy* has two parts: a central bulge and arms that form a spiral around the center. The bulge is a dense group of old stars. The arms are made of gas, dust, and much younger stars.

The Milky Way is a spiral galaxy. Our sun is one of the 200 billion stars in the Milky Way. From Earth, the edge of the Milky Way looks like a bright belt of stars that stretches across the night sky.



The Andromeda galaxy is a spiral galaxy. Our galaxy, the Milky Way, probably looks very much like Andromeda.

TAKE A LOOK

2. Identify Label the part of the galaxy that contains the oldest stars.

ELLIPTICAL GALAXIES

An *elliptical galaxy* is made of many stars and looks like a snowball. Elliptical galaxies are among the largest galaxies in the universe. Some may contain as many as 5 trillion stars! There is very little free gas in an elliptical galaxy. Therefore, few new stars form there.

TAKE A LOOK

3. Compare Name two ways that spiral galaxies differ from elliptical galaxies.

_____

_____

_____

_____

_____

_____

Galaxy M87, an elliptical galaxy, has no spiral arms.

IRREGULAR GALAXIES

An *irregular galaxy* has no clear shape. It may have as few as 10 million or as many as several billion stars. Some irregular galaxies form when two other galaxies collide.

The Large Magellanic Cloud, an irregular galaxy, is close to our own.

READING CHECK

4. Identify What are galaxies made of?

_____

_____

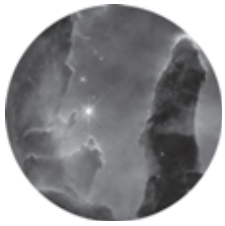
_____

What Objects May Be Found in Galaxies?

Remember that galaxies are made of gas, dust, and billions of stars. Some of these stars form different features, such as nebulas, open clusters, and globular clusters. When scientists study the stars in galaxies, they look for these features. ☑

NEBULAS

A **nebula** (plural, *nebulae* or *nebulas*) is a large cloud of gas and dust. Most stars are born in nebulas. Some nebulas glow or reflect starlight, but others absorb light and are too dark to see. Therefore, although nebulas can be found throughout a galaxy, they can be hard to see. ☑



This is part of a nebula. The tall, thin shape to the left of the bright star is wider than our solar system.

READING CHECK

5. Explain Why are some nebulas hard to see?

_____

STAR CLUSTERS

An **open cluster** is a group of 100 to 1,000 stars. The stars in an open cluster are closer together than stars in other parts of space. Open clusters are usually found in the arms of a spiral galaxy. All of the stars in an open cluster are the same age. They formed at the same time from the same nebula. Newly formed open clusters have many bright blue stars.

A **globular cluster** is a group of up to 1 million stars that are packed closely together. A globular cluster looks like a ball. Some globular clusters orbit spiral galaxies, such as the Milky Way. Others can be found near giant elliptical galaxies.

Critical Thinking

6. Compare How is a nebula different from a star cluster?

_____

_____

_____

_____

_____

What Are Quasars?

Remember that light from stars can take millions of years to reach Earth. Therefore, looking at distant stars is like looking back in time. Scientists study the early universe by studying objects that are very far away. Looking at distant galaxies shows what early galaxies looked like. By studying distant galaxies, scientists can learn how galaxies form and change.

Among the most distant objects are quasars. **Quasars** are starlike sources of light that are very far away. They are among the strongest energy sources in the universe. Some scientists think that quasars may be caused by black holes, but they are not sure how this happens.

Name _____ Class _____ Date _____

Section 3 Review

SECTION VOCABULARY

galaxy a collection of stars, dust, and gas bound together by gravity

globular cluster a tight group of stars that looks like a ball and contains up to 1 million stars

nebula a large cloud of gas and dust in interstellar space; a region in space where stars are born

open cluster a group of stars that are close together relative to surrounding stars

quasar quasi-stellar radio source; a very luminous object that produces energy at a high rate; quasars are thought to be the most distant objects in the universe

1. Compare How is a nebula different from a galaxy?

_____

_____

_____

2. List What three shapes can galaxies be?

_____

_____

_____

3. Compare Complete the chart below to describe different features of galaxies.

Galaxy feature	What they are made of	Where they are found	Other characteristics
		throughout a galaxy	where stars form
	100 to 1,000 stars, relatively close together		may contain bright blue stars
Globular cluster		around a spiral galaxy or near a large elliptical galaxy	

4. Explain What do some scientists think causes quasars?

_____

Name _____ Class _____ Date _____

CHAPTER 19 Stars, Galaxies, and the Universe

SECTION 4

Formation of the Universe

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is the big bang theory?
- How is the universe structured?
- How old is the universe?

How Do Scientists Think the Universe Formed?

Like all scientific theories, theories about the beginning and end of the universe must be tested by observations or experiments. The study of how the universe started, what it is made of, and how it changes is called **cosmology**.

To understand how the universe formed, scientists study the movements of galaxies. Careful measurements have shown that most galaxies are moving away from each other. This indicates that the universe is expanding. Based on this observation, scientists have made inferences about how the universe may have formed. ☑

Imagine that the formation and evolution of the universe was recorded on a video tape. If you rewound the video, the universe would seem to contract. At the beginning of the universe, all matter and energy would be squeezed into one small space. Now imagine running that same video forward. All the matter and energy in the universe would explode and begin to expand in all directions.

STUDY TIP

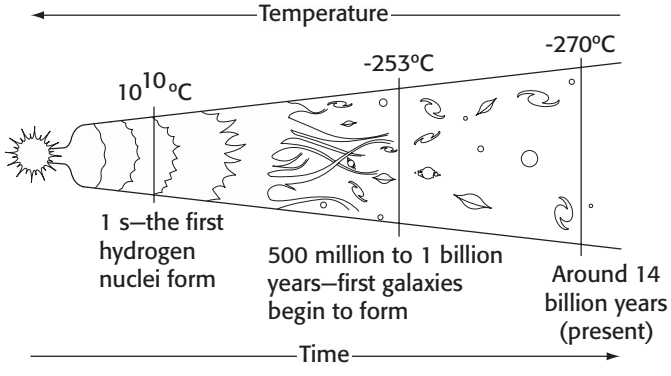
Predict Before you read this section, write down your prediction of how scientists think the universe formed and what will happen to it in the future. As you read, take notes on these topics.

READING CHECK

1. Complete Scientists took careful measurements of galaxies and found that the universe is

_____.

The Big Bang



Most astronomers think that the big bang caused the universe to expand in all directions.

TAKE A LOOK

2. Identify After the big bang, how did the temperature of the universe change?

_____

_____

What Is the Big Bang Theory?

The theory that the universe began with a huge explosion is called the **big bang theory**. It is the scientific model that explains why the universe is expanding. According to this theory, all the contents of the universe were originally squeezed into a very small volume. These contents were at extremely high pressure and temperature. About 14 billion years ago, this small volume rapidly expanded and cooled. ☑

READING CHECK

3. Identify Where were the contents of the universe before the big bang?

_____

_____

_____

Just minutes after the big bang, the following things had already formed:

- the light elements, such as helium
- the forces of nature, such as gravity
- the beginnings of galaxies

EVIDENCE FOR THE BIG BANG

All scientific theories must have evidence to support them. The first piece of evidence for the big bang theory is the expansion of the universe. The second piece of evidence is called *cosmic background radiation*.

Scientists use radio telescopes to pick up radiation with long wavelengths. Several decades ago, some scientists noticed a background "noise" coming from all directions in space. They think this cosmic background radiation is energy left over from the big bang. ☑

READING CHECK

4. List Give two pieces of evidence for the big bang theory.

_____

_____

What Is the Structure of the Universe?

The universe contains many different objects. However, these objects are not just scattered around the universe. They are grouped into systems. Every object in the universe is part of a larger system:

- A planet is part of a planetary system.
- A planetary system is part of a galaxy.
- A galaxy is part of a galaxy cluster.

Earth is part of the planetary system called the solar system. Our solar system is part of the Milky Way galaxy.

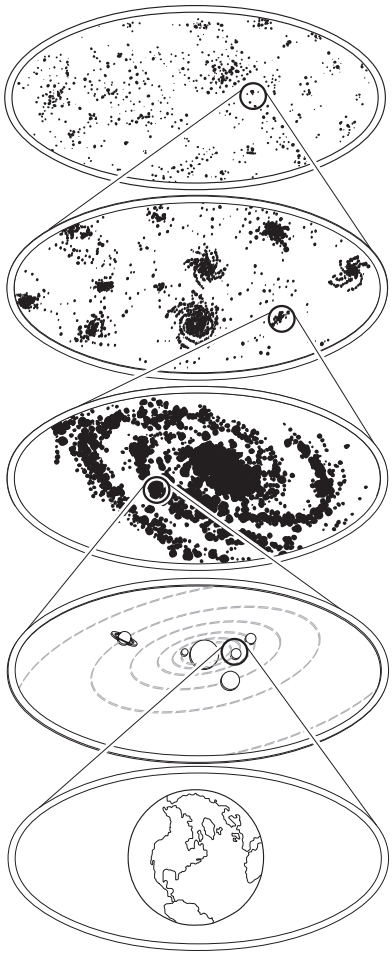
Critical Thinking

5. Apply Concepts Are there probably more planets or more galaxies in the universe? Explain your answer.

_____

_____

_____



TAKE A LOOK

6. Label On the figure, label the systems that make up the structure of the universe.

How Old Is the Universe?

Scientists can estimate the age of the universe by studying the oldest stars in the Milky Way galaxy. These stars are white dwarfs. The first stars that formed after the big bang became white dwarfs after about 1 billion years. The oldest white dwarfs are between 12 billion and 13 billion years old. Therefore, scientists think that the universe is about 14 billion years old. ☑

No one knows what will happen to the universe in the future. Some scientists think that the universe will continue to expand, faster and faster. Stars will age and die, and one day, the universe will become cold and dark. Even after the universe becomes cold and dark, it will continue to expand.

READING CHECK

7. Identify How old do scientists think the universe is?

_____

Name _____ Class _____ Date _____

Section 4 Review

SECTION VOCABULARY

big bang theory the theory that all matter and energy in the universe was compressed into an extremely small volume that 13 billion to 15 billion years ago exploded and began expanding in all directions	**cosmology** the study of the origin, properties, processes, and evolution of the universe

1. Explain How does the expansion of the universe support the big bang theory?

2. Explain How is cosmic background radiation related to the big bang theory?

3. Identify List three things that had formed by a few minutes after the big bang.

4. Describe Explain how every object in the universe is part of a larger system.

5. Explain Imagine you are a scientist studying the formation of the universe. How could you estimate the age of the universe?

Name _____ Class _____ Date _____

CHAPTER 20 Formation of the Solar System

SECTION 1

A Solar System Is Born

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a nebula?
- How did our solar system form?

National Science Education Standards
ES 3a, 3b, 3c

How Do Solar Systems Form?

You probably know that our solar system today includes the planets, moons, and other objects that orbit our sun. However, our solar system has existed for only about 5 billion years. It was not always the same as it is now. It began as a nebula

All solar systems start as clouds of gas and dust in space called **nebulas** (or *nebulae*). Our solar system probably formed from a nebula called the **solar nebula**. The gases in a nebula are mainly hydrogen and helium. The dust contains elements such as carbon and iron.

Solar systems form from nebulas. The gas and dust in nebulas become solar systems because of two forces: gravity and pressure. ☑

STUDY TIP

Organize As you read this section, make a flowchart showing the steps in the formation of a solar system like ours.

READING CHECK

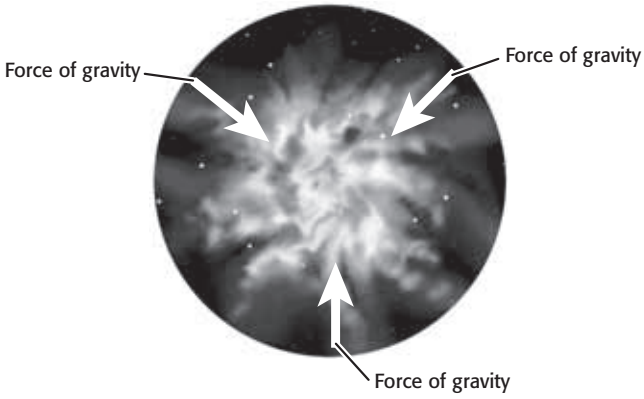
1. Identify Which two forces cause the gas and dust in nebulas to form solar systems?

_____

_____

GRAVITY: PULLING MATTER TOGETHER

Remember that gravity pulls objects together. The particles of matter in a nebula are very small. There is a lot of space between them. Therefore, the force of gravity holding the particles together is very weak. It is just strong enough to keep the nebula from drifting apart.



The force of gravity pulls the particles in a nebula together.

TAKE A LOOK

2. Identify What effect does gravity have on the particles in a nebula?

_____

_____

PRESSURE: PUSHING MATTER APART

Gravity pulls the particles in a nebula together. Why don't the particles collapse into a single point? The answer has to do with the pressure inside a nebula.

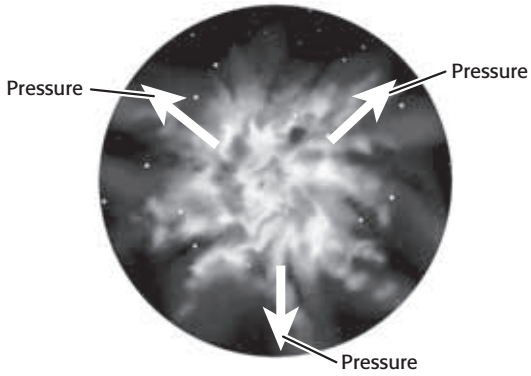
The particles in a nebula are always moving. As the particles move around, they sometimes bump into each other. When two particles bump into each other, they move apart. This produces *pressure* within the nebula. The closer the particles are, the more likely they are to bump into each other. Therefore, the pressure is high.

Critical Thinking

3. Apply Concepts How does high pressure probably affect the size of a nebula?

_____

_____



Pressure causes the particles in a nebula to move apart.

TAKE A LOOK

4. Identify What causes pressure inside a nebula?

_____

_____

THE BALANCE BETWEEN GRAVITY AND PRESSURE

High pressure causes the nebula to *expand*, or get larger. The particles spread farther apart, and pressure decreases. However, gravity increases pressure by pulling the particles together. When the nebula is just the right size, the pressure inside it exactly balances the force of gravity. This balance keeps the nebula the same size. It does not expand or shrink.

UPSETTING THE BALANCE

The balance between gravity and pressure in a nebula can be *upset*, or changed. For example, a supernova can produce a force on the nebula. The force can cause small regions of the nebula to be *compressed*, or pushed together. These small regions are called *globules*. ☑

READING CHECK

5. Define What are globules?

_____

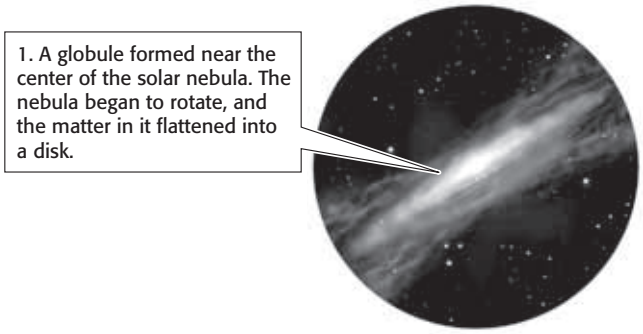
_____

_____

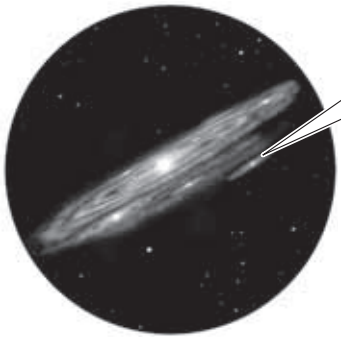
A globule can become very dense. Gravity can cause the globule to collapse. As it collapses, its temperature increases. The hot, dense globule can eventually become a star.

How Did the Solar System Form?

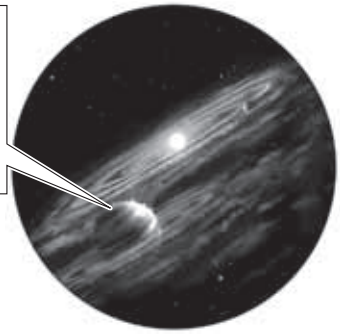
It took about ten million years for our solar system to form from the solar nebula. The figures below show some of the important events in the formation of our solar system.



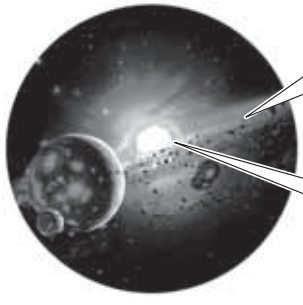
1. A globule formed near the center of the solar nebula. The nebula began to rotate, and the matter in it flattened into a disk.



2. In some parts of the rotating disk, bits of dust and rock collided and stuck together. The bodies the formed grew larger as more dust and rock collided with them. Some of these bodies got to be hundreds of kilometers wide. The were called *planetesimals*, or small planets.



3. The largest planetesimals formed far from the center of the disk. Their gravit attracted some of the gases in the nebula. These planetesimals became the gas giant planets: Jupiter, Saturn, Uranus, and Neptune.



4. Smaller planetesimals formed near the center of the disk. These planetesimals attracted more dust and less gas. The became the inner, rock planets: Mercur , Venus, Earth, and Mars.

5. Most of the gas in the solar nebula moved toward the center. The particles of gas became ver densel packed at the center. The began to react with each other. The reactions released huge amounts of energ . y ur sun was born.

TAKE A LOOK

6. Define What is a planetesimal?

_____

_____

STANDARDS CHECK

ES 3a The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

7. List What are the four gas giant planets?

_____

_____

_____

_____

Name _____ Class _____ Date _____

Section 1 Review

NSES ES 3a, 3b, 3c

SECTION VOCABULARY

nebula a large cloud of gas and dust in interstellar space; a region in space where stars are born	**solar nebula** a rotating cloud of gas and dust from which the sun and planets formed

1. Describe What happened to the solar nebula?

2. Identify What force pulls the matter in a nebula together?

3. Explain How did the gas giant planets form?

4. Explain How did the inner, rocky planets form?

5. Identify Where did most of the gas in the solar nebula end up?

6. List What are the four inner, rocky planets?

7. Apply Concepts What would happen to a nebula if the pressure inside it was greater than the force of gravity? Explain your answer.

Name _____ Class _____ Date _____

CHAPTER 20 Formation of the Solar System

SECTION 2

The Sun: Our Very Own Star

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

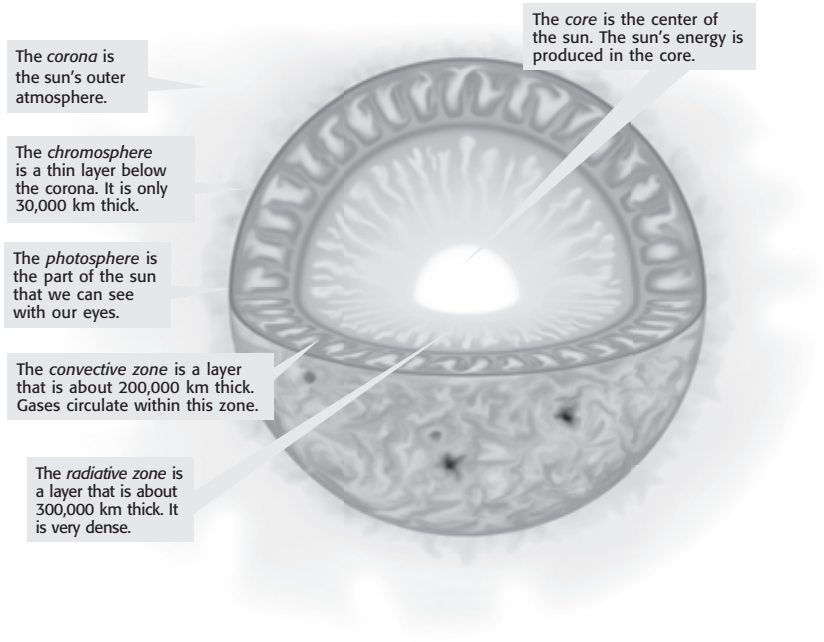
- Where does the sun's energy come from?
- How do sunspots and solar flares affect Earth?

National Science Education Standards

ES 3a

What Is the Structure of the Sun?

The sun is the largest part of our solar system. Ninety-nine percent of the matter in our solar system is found in the sun. Although the sun may look like a solid ball in the sky, it is actually made of gas. The gas is held together by gravity. The figure below shows the structure of the inside of the sun.



Energy is produced in the core of the sun. The energy produced in the core takes millions of years to move to the photosphere. First, the energy passes from the core into the radiative zone. Next, the energy reaches the convective zone. Within the convective zone, hot gases carry energy to the photosphere. Energy leaves the sun as light. It takes about 8.3 min for light to travel from the sun to Earth.

STUDY TIP

Ask Questions As you read, write down any questions you have. When you finish reading, discuss your questions with a partner or in a small group. Together, try to figure out the answers to your questions.

TAKE A LOOK

1. Identify What is the corona?

_____

_____

Where Does the Sun's Energy Come From?

Our sun has existed for about 4.6 billion years. Scientists have developed many theories about why the sun shines. For example, scientists used to think that the sun burns fuel, like a campfire. However, new observations about the age of the sun showed that this theory could not be correct. A sun that burns fuel could not last for more than about 10,000 years. ☑

READING CHECK

2. Identify About how long has the sun been shining?

_____

Scientists now know that nuclear fusion is the process that powers our sun and most other stars. To understand nuclear fusion, you must know a little bit about the structure of atoms.

Remember that all matter is made of atoms. Atoms, in turn, are made of even smaller particles called electrons, protons, and neutrons. Protons and neutrons make up the *nucleus* (plural, *nuclei*) of the atom. The electrons move around the nucleus. The figure below shows a model of an atom of the element helium. ☑

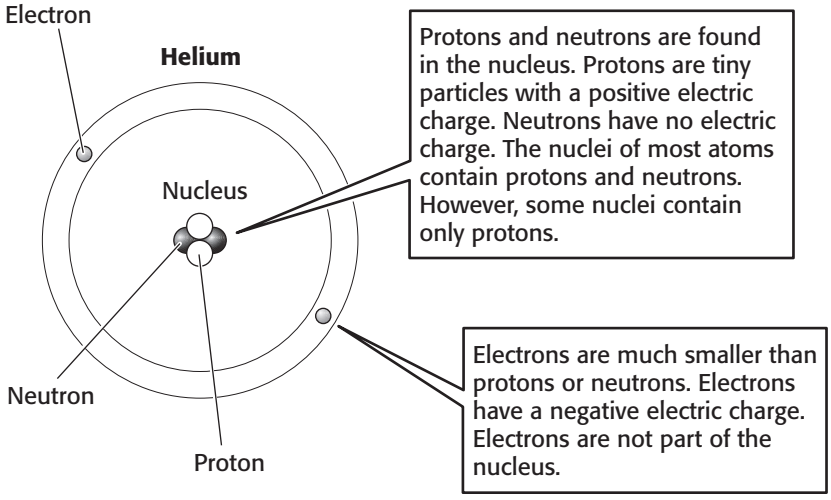
READING CHECK

3. List What are three particles that make up atoms?

_____

_____

_____



TAKE A LOOK

4. Identify Which kind of particle do all nuclei contain?

_____

The number of protons in an atom determines which element the atom is. For example, all atoms with only one proton are atoms of the element hydrogen. However, atoms of an element can contain different numbers of neutrons. For example, most hydrogen atoms contain no neutrons, but some contain one neutron. An atom with one proton and one neutron is still hydrogen. It is simply a different form of hydrogen.

Critical Thinking

5. Apply Concepts Atom A has three protons and three neutrons. Atom B has four protons and three neutrons. Are atom A and atom B atoms of the same element? Explain your answer.

_____

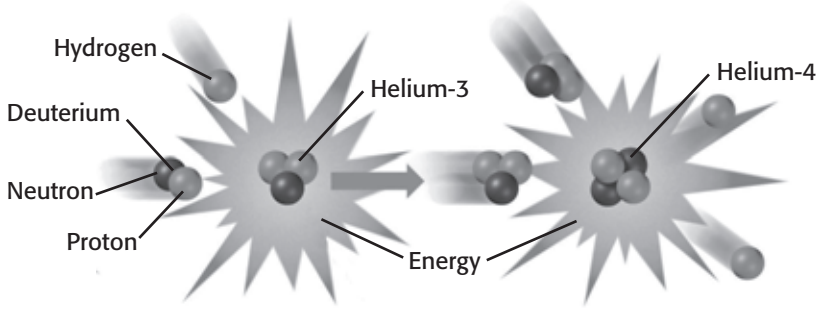
_____

_____

During **nuclear fusion**, two or more nuclei *fuse*, or join together, to form a new nucleus. This process releases a huge amount of energy. Within stars, nuclei of hydrogen fuse to form nuclei of helium. ☑

FUSION IN OUR SUN

Normally, hydrogen nuclei never get close enough to each other to fuse into helium. However, the pressure in the center of the sun is very high. This high pressure forces hydrogen nuclei together, so they can fuse. The figure below shows how hydrogen nuclei in the sun fuse to form helium. ☑



Deuterium is a form of hydrogen that contains one proton and one neutron in its nucleus. Within the sun, a nucleus of deuterium can collide with a nucleus of hydrogen, which contains only one proton. This releases a large amount of energy. It also forms a nucleus of a form of helium called *helium-3*. A nucleus of helium-3 contains two protons and one neutron.

Two helium-3 nuclei collide. This forms a nucleus of *helium-4*, which contains two protons and two neutrons. Two protons are released, along with a large amount of energy.

READING CHECK

6. Define What is nuclear fusion?

_____

_____

_____

TAKE A LOOK

7. Compare How is helium-3 different from helium-4?

_____

_____

_____

How Does Solar Activity Affect Earth?

The movement of energy in the photosphere causes the gases to churn. The circulation of gases and the sun's rotation produce magnetic fields. These magnetic fields reach far into space. They can cause changes in the photosphere. These changes can also affect the Earth.

SUNSPOTS

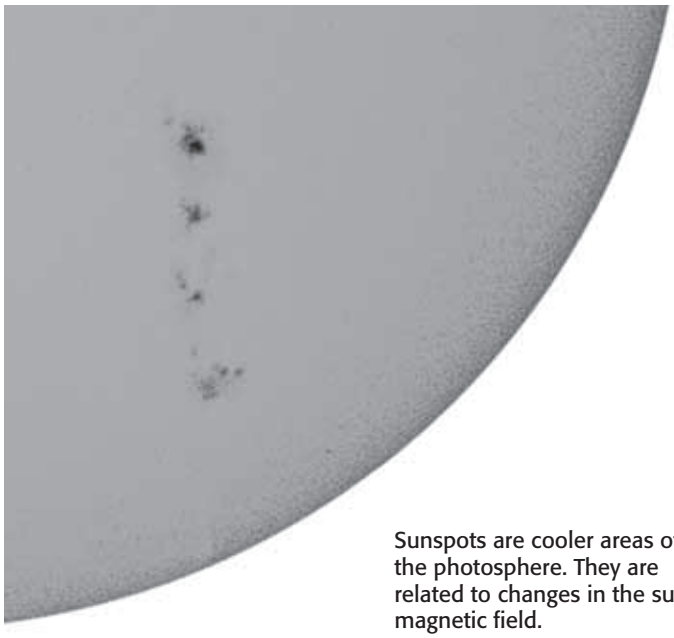
The sun's magnetic fields slow the movement of gases in the convective zone. This causes certain areas of the photosphere to become cooler than others. The cooler areas show up as sunspots. **Sunspots** are cooler, dark spots on the photosphere. They vary in size and shape. Some sunspots are as large as 80,000 km in diameter. ☑

READING CHECK

8. Define What are sunspots?

_____

_____



Sunspots are cooler areas of the photosphere. They are related to changes in the sun's magnetic field.

TAKE A LOOK

9. Identify What causes sunspots?

_____

_____

THE SUNSPOT CYCLE

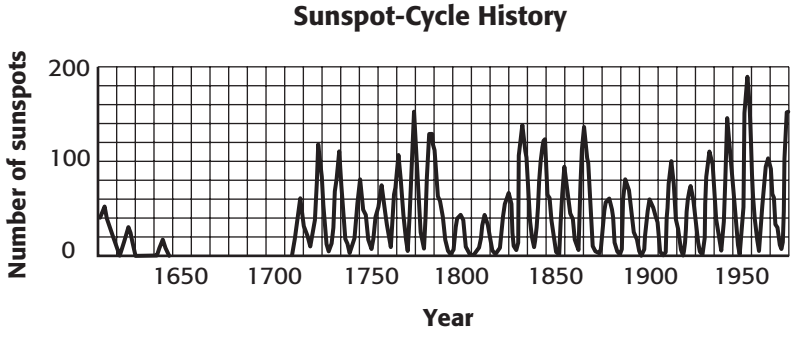
The Italian scientist Galileo was one of the first to study sunspots. Using a telescope, he observed the numbers, sizes, and locations of sunspots over time. He found that the numbers and locations of sunspots change in a predictable pattern. This pattern is called the *sunspot cycle*.

Today, scientists know that the sunspot cycle is about 11 years long. Every 11 years, the number of sunspots reaches a peak. Then it declines. The graph below shows how the number of sunspots has changed over time.

Math Focus

10. Read a Graph In about what decade was the maximum number of sunspots observed?

_____



This graph shows the number of sunspots observed in different years. Notice that the number of sunspots changes in a regular way.

EFFECTS OF SUNSPOTS ON CLIMATE

Scientists think that sunspot activity may affect Earth's weather. For example, there were few sunspots between the years of 1645 and 1715. During this time, Europe's climate was much colder than usual. In fact, the climate was so cold that this period is sometimes called the "Little Ice Age." However, scientists do not understand how a small number of sunspots may change the Earth's climate.

Most scientists agree that sunspots may affect the Earth's climate. However, the connection between sunspots and the climate on Earth is not clear. More research is needed in order for us to fully understand how sunspots can affect our climate.

Say It

Hypothesize What kinds of evidence could support the hypothesis that sunspots affect the Earth's climate? By yourself, think about some answers to this question. Then, talk about your answers with a partner or in a small group.

SOLAR FLARES

The magnetic fields that cause sunspots can also cause solar flares. *Solar flares* are extremely hot, bright regions on the sun's surface. They send huge streams of electrical particles throughout the solar system. Solar flares can extend up to several thousand kilometers within only a few minutes. ☑

Scientists do not know exactly what causes solar flares. However, they do know that most solar flares are associated with sunspots.

Solar flares can have significant effects on the Earth. The streams of charged particles solar flares emit can interact with the Earth's atmosphere. They can interfere with radio and television transmissions. Therefore, scientists are trying to find ways to predict solar flares.

READING CHECK

11. Define What is a solar flare?

_____

_____

_____

Type of solar activity	Description	How can it affect the Earth?
Sunspots		may cause climate change, but the connection is not clear
Solar flares		

TAKE A LOOK

12. Describe Fill in the blank spaces in the table.

Name _____ Class _____ Date _____

Section 2 Review

NSES **ES 3a**

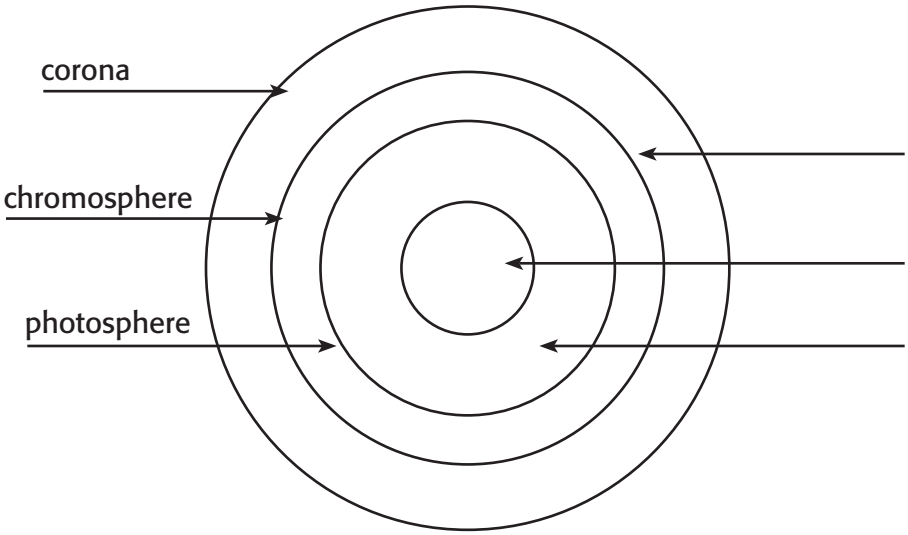
SECTION VOCABULARY

nuclear fusion the process by which nuclei of small atoms combine to form a new, more massive nucleus; the process releases energy	**sunspot** a dark area of the photosphere of the sun that is cooler than the surrounding areas and that has a strong magnetic field

1. Identify What process powers most stars, including our sun?

_____

2. Describe Label the layers of the sun that are missing from this diagram.



3. Explain Describe the process of nuclear fusion in our sun.

_____

_____

_____

_____

4. Identify What produces the sun's magnetic fields?

_____

_____

5. List What are two effects that are caused by changes in the sun's magnetic fields?

_____

_____

6. Describe How do solar flares affect the Earth?

_____

_____

Name _____ Class _____ Date _____

CHAPTER 20 Formation of the Solar System

SECTION 3

The Earth Takes Shape

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How did the Earth form?
- How did the Earth's atmosphere form?
- How did the Earth's oceans form?

National Science Education Standards
ES 2b

How Did the Earth Form?

The Earth is made mostly of rock. Water covers nearly three-fourths of its surface. A protective atmosphere of nitrogen and oxygen surrounds it. However, the Earth has changed a lot since it formed 4.6 billion years ago.

STUDY TIP

Summarize Before you read this section, make an outline using the headings from the section. As you read, fill in the main ideas of the section in your outline.

THE EFFECTS OF GRAVITY

Earth formed when rocky planetesimals collided and combined. When Earth was a young planet, it was smaller and had an uneven shape, like a potato. As it attracted more matter, gravity increased. When Earth reached a diameter of about 350 km, the rock at Earth's center was crushed by gravity. As a result, the planet started to become rounder. ☑

READING CHECK

1. Identify What caused the early Earth to change from an uneven shape to a round shape?

_____

THE EFFECTS OF HEAT

As Earth was changing shape because of gravity, it was also heating up. The energy from collisions with planetesimals, along with radiation from radioactive material, warmed the young planet. When the Earth got large enough, the temperature rose faster than the inside could cool. The rocky center began to melt.

Today, the Earth is still cooling from the energy produced when it formed. You can see evidence of Earth's internal heat in volcanoes, earthquakes, and hot springs.

Force	Effect
	• attracted matter to the early Earth • crushed rock at the early Earth's center
	• caused the inside of the early Earth to melt • is a cause of volcanoes, earthquakes, and hot springs today

TAKE A LOOK

2. Identify Fill in the blank spaces in the table.

How Did the Earth's Layers Form?

Today, geologists divide the Earth into three main layers. Each layer has a different composition. The three layers are the crust, the mantle, and the core.

The **crust** is the thin, outermost layer. It is between 5 km and 100 km thick. The rock in the crust is rich in elements such as oxygen, silicon, and aluminum.

The **mantle** is the layer beneath the crust. It extends 2,900 km below the Earth's surface. The solid rock in the mantle is rich in elements such as magnesium and iron. It is more dense than the rock in the crust.

The **core** is the central part of Earth. The core is made mostly of iron and nickel. It is the densest layer of the Earth. The core has a radius of about 3,400 km.

How did these three layers form from the rocky material that made up the early Earth? Remember that heat within the Earth caused the rocks to melt. As the rocks melted, more dense materials, such as nickel and iron, sank to the center. They formed the core. Less dense materials floated to the surface. They became the crust and mantle. ☑

Critical Thinking

3. Compare Give three differences between the crust and the mantle.

_____

_____

_____

READING CHECK

4. Explain How did the Earth's layers form?

_____

_____

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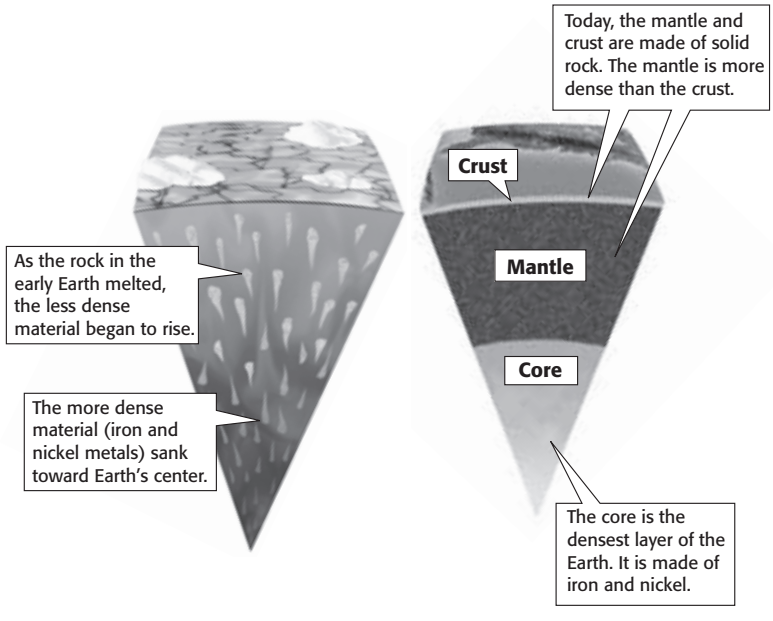


How Did the Earth's Atmosphere Form?

Today, the Earth's atmosphere contains 78% nitrogen, 21% oxygen and about 1% argon. It also contains tiny amounts of many other gases. However, like the inside of the Earth, the Earth's atmosphere has not always been the same. Early in Earth's history, the atmosphere was probably very different from the atmosphere today. ☑

EARTH'S EARLY ATMOSPHERE

Scientists think that Earth's early atmosphere was a mixture of gases that were given off as Earth cooled. Early in the Earth's history, its surface was very hot. In some places, it was *molten*, or melted. The molten rock gave off large amounts of carbon dioxide and water vapor. Therefore, the Earth's early atmosphere probably contained large amounts of these two gases. ☑

EARTH'S CHANGING ATMOSPHERE

As the Earth cooled and its layers formed, the atmosphere changed. Volcanoes released chlorine, nitrogen, and sulfur, as well as carbon dioxide and water vapor. These gases collected in the atmosphere.

Volcanoes on the early Earth released gases into the atmosphere.

Comets may also have helped to form the Earth's early atmosphere. *Comets* are planetesimals that are made mainly of ice. The material in comets contains many different elements. When the comets crashed into the Earth, these elements were released and became part of the atmosphere. Comets probably brought oxygen, nitrogen, and hydrogen gases to the Earth's atmosphere. They may also have brought some of the water that helped form the oceans.

READING CHECK

5. Identify Which two gases make up most of the Earth's atmosphere today?

_____

_____

READING CHECK

6. List Which two gases probably made up most of the Earth's earliest atmosphere?

_____

_____

TAKE A LOOK

7. Describe How did volcanoes affect the early Earth's atmosphere?

_____

_____

Where Did the Oxygen in Today's Atmosphere Come From?

Most living things on Earth today, including humans, need oxygen in order to survive. Comets brought only a small amount of oxygen to the atmosphere. Most of the oxygen in the atmosphere today is there because of life on Earth. ☑

READING CHECK

8. Identify Where does most of the oxygen in today's atmosphere come from?

_____

ULTRAVIOLET RADIATION

You may know that ultraviolet (UV) radiation in sunlight can cause sunburns. Scientists think that this radiation may also have helped to produce the conditions necessary for life to form on Earth.

Ultraviolet radiation contains a lot of energy. Therefore, it can break apart molecules in the air and on the Earth's surface. This is probably what happened on the early Earth. The smaller molecules collected in water. In the water, these chemicals might have combined to form the complex molecules that made life possible.

THE SOURCE OF OXYGEN

The first life forms did not need oxygen to live. By 3.4 billion years ago, organisms that could carry out photosynthesis had evolved. *Photosynthesis* is a process in which a living thing uses sunlight, carbon dioxide, and water to produce food and oxygen. ☑

READING CHECK

9. Define What is photosynthesis?

_____

_____

_____

_____

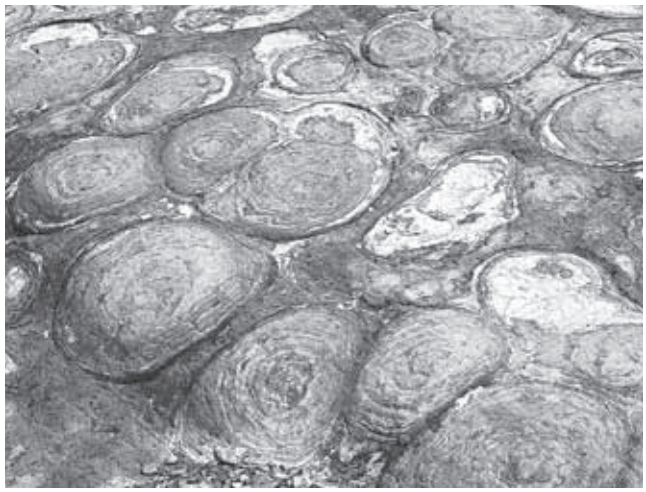
As these living things carried out photosynthesis, they added more and more oxygen to the atmosphere. At the same time, they removed carbon dioxide from the atmosphere.

Some of the oxygen reacted with sunlight to form ozone gas. This gas then formed the ozone layer. The ozone layer blocked much of the harmful UV radiation, making it possible for life to move onto land. The earliest forms of land life were simple plants, like algae today. They moved onto land about 2.2 billion years ago.

TAKE A LOOK

10. List Fill in the blank spaces in the table.

Source of atmospheric gases	Gases from this source
Molten rock on the early Earth's surface	
Volcanoes	
Comets	
Living things	



These *stromatolites* are mats of fossilized algae. Algae like these may have been some of the earliest forms of life on Earth.

TAKE A LOOK

11. Define What is a stromatolite?

_____

_____

How Did the Earth's Oceans and Continents Form?

At first, Earth was so hot that much of its water was in the form of water vapor in the atmosphere. Scientists think that the Earth's oceans formed once Earth had cooled enough for rain to fall. The rain collected on the Earth's surface. After millions of years of rainfall, water covered the planet. By about 4 billion years ago, the first global ocean covered the planet.

GROWTH OF CONTINENTS

There may not have been any dry land during the first few hundred million years of Earth's history. Scientists think that the rocks in the crust and mantle melted and cooled many times while the Earth formed. Each time the rocks melted, denser materials sank and less dense materials rose toward the surface.

After a while, some of the rocks were light enough to pile up on the surface. These rocks were the beginnings of the earliest continents. Over time, as the continents have moved over the surface, they have become even larger. The processes of plate tectonics, such as continental collisions, have produced new continental material. Most of the material in the continents today formed within the last 2.5 billion years. ☑

READING CHECK

12. Explain What has caused the continents to become larger?

_____

_____

Name _____ Class _____ Date _____

Section 3 Review

NSES **ES 2b**

SECTION VOCABULARY

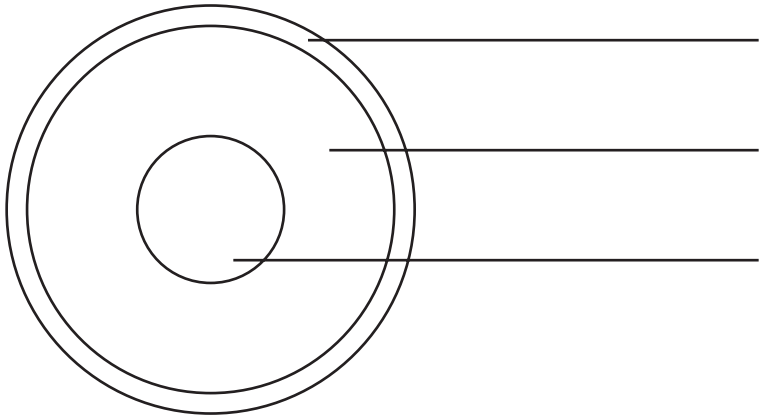
core the central part of the Earth below the mantle	**crust** the thin and solid outermost layer of the Earth above the mantle **mantle** the layer of rock between the Earth's crust and core

1. List Which two forces caused the early Earth's size and structure to change?

_____

_____

2. Identify Label the three layers of the Earth in the figure below.



3. Describe How did photosynthesis change the Earth's atmosphere? Give two ways.

_____

_____

4. Explain How did the ozone layer form?

_____

_____

5. Identify When did the ocean on Earth form?

_____

_____

6. Explain How did the continents form?

_____

_____

_____

_____

Name _____ Class _____ Date _____

CHAPTER 20 Formation of the Solar System

SECTION 4

Planetary Motion

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

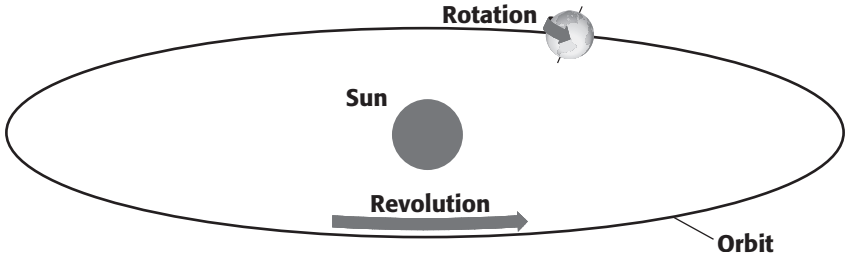
- What is the difference between rotation and revolution?
- What are Kepler's three laws of planetary motion?
- How does gravity affect the orbits of planets?

National Science Education Standards
ES 3b

How Do Scientists Describe the Motions of the Planets?

Remember that the Earth, like all planets, spins on its axis. Scientists use the term **rotation** to describe the motion of a body spinning on its axis. As the Earth rotates, different parts of its surface face the sun. It is daytime in the part that faces the sun. It is night in the part that faces away from the sun. At any time, only one-half of the Earth faces the sun.

In addition to rotating, all planets move around the sun. The path that a planet follows around the sun is called its **orbit**. One complete trip around the sun is called a **revolution**.



The amount of time it takes for a planet to complete one revolution is called its *period of revolution*. Each planet has a different period of revolution. For example, Earth's period of revolution is 365.24 days. Mercury's is only 88 days.

STUDY TIP

Summarize After you read this section, make a chart describing Kepler's laws of planetary motion.

Critical Thinking

1. Infer Venus rotates more slowly than the Earth. On which planet does daytime last longer?

_____

TAKE A LOOK

2. Describe What are two ways that planets move?

_____

_____

What Do We Know About How Planets Move?

Scientists have not always known how the planets move. Until the 1600s, scientists did not know the shapes of the planets' orbits or their periods of revolution accurately.

In the 1600s, a German scientist named Johannes Kepler made detailed observations of the motions of the planets. After analyzing his observations, he developed three laws of planetary motion. Kepler's observations and calculations were so accurate that scientists still use his laws today! ☑

READING CHECK

3. Describe How did Johannes Kepler come up with his three laws of planetary motion?

_____

_____

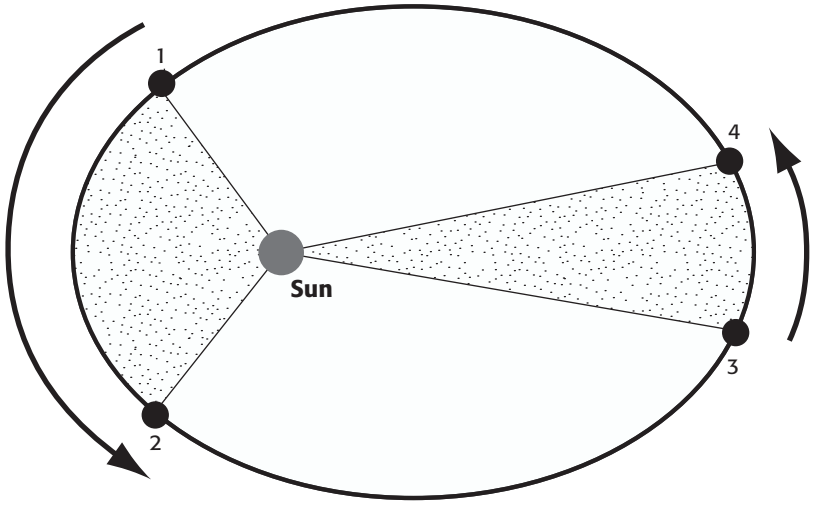
_____

KEPLER'S FIRST LAW

Kepler carefully observed the path that Mars takes through the sky. When he analyzed his observations, he found that Mars' orbit is not a perfect circle. Instead, it is shaped like an *ellipse*, or oval. Kepler's first law of planetary motion states that the orbits of all planets are ellipses.

KEPLER'S SECOND LAW

Kepler reasoned that the planets must move through their orbits faster in some places than in others. To understand why this is so, look at the figure below. The distance between point 1 and point 2 is longer than the distance between point 3 and point 4. The planet takes the same amount of time to travel both distances. Therefore, the planet must be moving faster between points 1 and 2 than between points 3 and 4. This is Kepler's second law.



TAKE A LOOK

4. Identify Label the place in the planet's orbit where it is moving the fastest.

KEPLER'S THIRD LAW

Kepler observed that planets that are far from the sun, such as Saturn, take longer to orbit the sun. This is Kepler's third law of planetary motion.

How Does Gravity Affect a Planet's Orbit?

Kepler never knew why planets orbit the sun. Another astronomer, Sir Isaac Newton, solved the puzzle. He combined the observations of earlier scientists with mathematical models to describe the force of gravity.

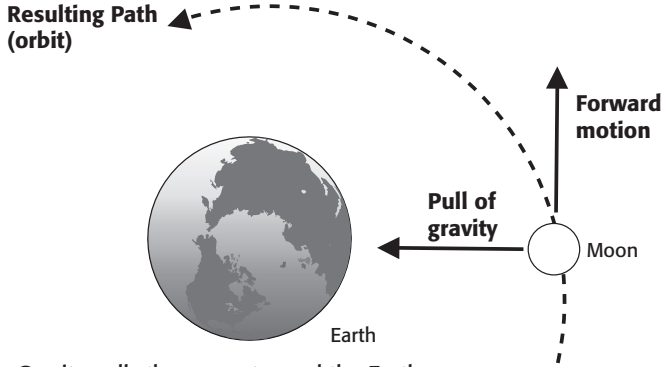
Newton observed that objects fall toward Earth. He reasoned that all objects are attracted to each other through the force of gravity. The strength of the force depends on two factors—the masses of the objects and the distance between them.

Newton's *law of universal gravitation* describes how the force of gravity is related to these two factors. When the masses are large, the force of gravity is strong. When the objects are far apart, the force of gravity is weak.

ORBITS AND GRAVITY

If gravity is pulling on the moon, why doesn't the moon fall to Earth? The answer has to do with the moon's inertia. *Inertia* is an object's resistance to changes in its speed or direction.

Gravity is like a string holding the moon in orbit around the Earth. Without gravity, the moon would move in a straight line away from the Earth. The moon's orbit is a balance between its inertia and the force of gravity. This balance is the reason that all bodies in orbit, including the Earth, travel along curved paths.



Gravity pulls the moon toward the Earth. Inertia keeps it moving in a straight line. The result is a curved orbit.

STANDARDS CHECK

ES 3b Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

Word Help: predictable able to be known ahead of time

Word Help: phenomenon (plural *phenomena*) any fact or event that can be sensed or described scientifically

5. Identify Relationships How is the distance of a planet from the sun related to its period of revolution?

_____

_____

_____

_____

TAKE A LOOK

6. Explain Why doesn't the moon move away from the Earth in a straight line?

_____

_____

Name _____ Class _____ Date _____

Section 4 Review

NSES **ES 3b**

SECTION VOCABULARY

orbit the path that a body follows as it travels around another body in space	**revolution** the motion of a body that travels around another body in space; one complete trip along an orbit **rotation** the spin of a body on its axis

1. Compare How is rotation different from revolution?

2. Define Explain Kepler's second law of planetary motion in your own words.

3. Describe Fill in the blank spaces in the table.

Factor	How it affects the force of gravity
Mass of the objects	
Distance between the objects	

4. Identify What two factors must be balanced in order for an object to remain in orbit?

5. Predict Consequences What would happen to an object in orbit around a planet if the planet's force of gravity were stronger than the object's inertia?

6. Apply Concepts Imagine a planet with two moons. Moon A is twice as far from the planet as moon B. Which moon will take longer to orbit the planet once? Explain your answer.

Name _____ Class _____ Date _____

CHAPTER 21 A Family of Planets

SECTION 1

The Nine Planets

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the parts of our solar system?
- When were the planets discovered?
- How do astronomers measure large distances?

National Science Education Standards

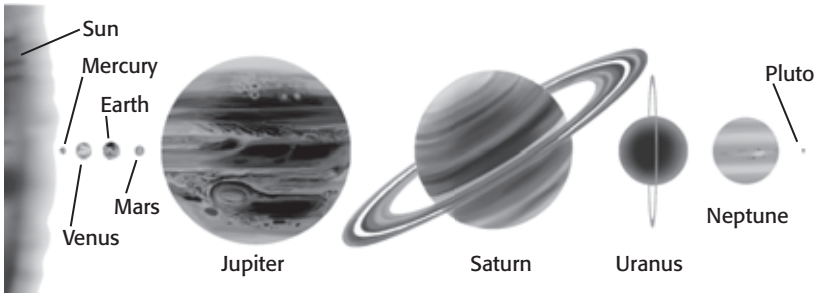
ES 1c, 3a, 3b, 3c

What Is Our Solar System?

Our *solar system* includes our sun, the planets, their moons, and many other objects. At the center of our solar system is a star that we call the sun. Nine planets and other smaller objects move around the sun. Most planets have one or more moons that move around them. In this way, our solar system is a combination of many smaller systems.

STUDY TIP

Describe As you read, make a chart showing the parts of our solar system that were discovered in the following time periods: before the 1600s; the 1700s; the 1800s; and the 1900s.



The planets and the sun are some of the objects in our solar system.

STANDARDS CHECK

ES 3a The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

1. Identify List three kinds of objects that make up our solar system.

_____

_____

_____

How Was Our Solar System Discovered?

Until the 1600s, people thought that there were only eight bodies in our solar system. These were the sun, Earth's moon, and the planets Earth, Mercury, Venus, Mars, Jupiter, and Saturn. These are the only objects in the solar system that we can see from Earth without a telescope.

Once the telescope was invented, however, scientists were able to see many more bodies in our solar system. In the 17th century, scientists discovered some of the moons of Jupiter and Saturn. Uranus and several other moons were discovered in the 1700s. Neptune was discovered in the 1800s. Pluto was not discovered until the 1900s.

How Do Scientists Measure Long Distances?

Remember that astronomers use light-years to measure long distances in space. To measure distances within our solar system, astronomers use two other units: the astronomical unit and the light-minute.

One **astronomical unit** (AU) is the average distance between the sun and Earth. This distance is about 150,000,000 km. Earth is 1 AU from the sun. Pluto is about 39.5 AU from the sun. Therefore, Pluto is about $39.5 \times 150{,}000{,}000 \text{ km} = 5{,}900{,}000{,}000 \text{ km}$ from the sun.

Another way to measure distances in space is by using the speed of light. Light travels at about 300,000 km/s in space. In one minute, light travels about 18,000,000 km. Therefore, one *light-minute* is equal to about 18,000,000 km. Light from the sun takes 8.3 minutes to reach Earth. Therefore, Earth is 8.3 light-minutes from the sun.

Math Focus

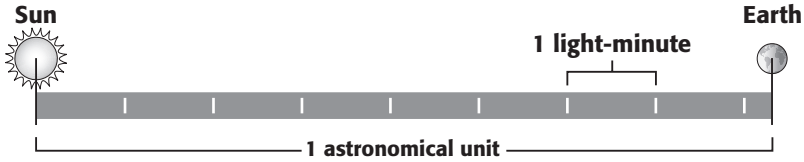
2. Convert Scientists discover an asteroid that is 3 AU from the sun. How far, in kilometers, is the asteroid from the sun?

_____

Math Focus

3. Convert About how many light-minutes from the sun is Pluto?

_____



One astronomical unit equals about 8.3 light-minutes.

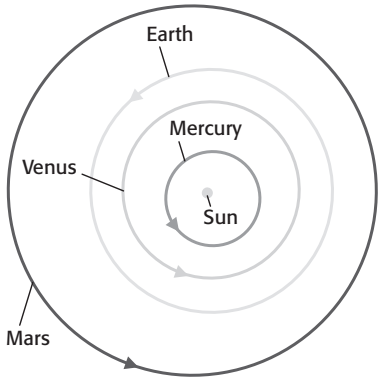
How Is Our Solar System Divided?

Astronomers divide our solar system into two main parts. These parts are called the *inner solar system* and the *outer solar system*.

THE INNER PLANETS

The inner solar system contains the four planets that are closest to the sun: Mercury, Venus, Earth, and Mars. The inner planets are also sometimes called the *terrestrial planets*. *Terrestrial* means "like Earth." Mercury, Venus, and Mars are like Earth because they have dense, rocky surfaces, as Earth does. The figure on the top of the next page shows the orbits of the inner planets.

The Inner Planets



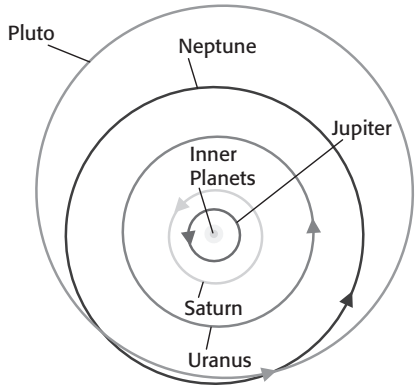
THE OUTER PLANETS

The outer solar system contains five planets: Jupiter, Saturn, Uranus, Neptune, and Pluto. The outer planets are very different from the inner planets.

Except for Pluto, the outer planets are very large and are made mostly of gases. Therefore, Jupiter, Saturn, Uranus, and Neptune are sometimes called the *gas giant* planets, or simply the "gas giants." Pluto is the only outer planet that is dense and rocky.

The distances between the outer planets are much larger than the distances between the inner planets. For example, the distance between Jupiter and Saturn is much larger than the distance between Mars and Earth. The figure below shows the orbits of the outer planets.

The Outer Planets



TAKE A LOOK

4. Identify Which of the inner planets is closest to the sun?

5. Identify Which of the inner planets is furthest from the sun?

Critical Thinking

6. Compare Give two differences between the inner solar system and the outer solar system.

TAKE A LOOK

7. Identify What planet is sometimes farther from the sun than Pluto?

Name _____ Class _____ Date _____

Section 1 Review

NSES ES 1c, 3a, 3b, 3c

SECTION VOCABULARY

astronomical unit the average distance between the Earth and the sun; approximately 150 million kilometers (symbol, AU)	

1. **Calculate** Mercury is about 0.39 AU from the sun. About how many kilometers from the sun is Mercury? Show your work.

2. **Identify** Name the four planets in the inner solar system.

3. **Compare** How is Pluto different from the other planets in the outer solar system?

4. **Identify** Name the four gas giant planets.

5. **Infer** Scientists sometimes use light-hours to measure distances in our solar system. What is a light-hour? About how many kilometers make up one light-hour?

6. **Explain** Why do scientists use light-minutes and light-hours instead of light-years to measure distances within our solar system?

Name _____ Class _____ Date _____

CHAPTER 21 A Family of Planets

SECTION 2

The Inner Planets

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Which planets are known as the inner planets?
- What properties do the inner planets share?

National Science Education Standards

ES 1c, 3a, 3b

Why Group the Inner Planets Together?

The inner solar system includes the only planet known to support life, Earth, and three other planets. These four inner planets are called **terrestrial planets** because they all have a chemical makeup similar to that of Earth. The terrestrial planets are much smaller, denser, and more rocky than most of the outer planets. ☑

STUDY TIP

Compare In your notebook, create a chart showing the similarities and differences among the inner planets.

READING CHECK

1. Explain Why are the inner planets called terrestrial planets?

_____

_____

Which Planet Is Closest to the Sun?

Mercury is the planet closest to the sun. After Earth, it is the second densest object in the solar system. This is because, like Earth, Mercury has a large iron core in its center. The surface of Mercury is covered with craters.

Mercury rotates on its axis much more slowly than Earth. Remember that the amount of time that a planet takes to rotate once is its *period of rotation*. It is the length of a day on the planet. Mercury's period of rotation is about 59 Earth days long. Therefore, a day on Mercury is about 59 Earth days long.

On Mercury, a year is not much longer than a day. Remember that the time it takes a planet to go around the sun once is the planet's *period of revolution*. It is the length of one year on the planet. A *Mercurian* year, or a year on Mercury, is equal to 88 Earth days. Therefore, each year on Mercury lasts only 1.5 Mercurian days.

Facts About Mercury

Distance from sun	0.38 AU
Period of rotation	58 Earth days, 19 hours
Period of revolution	88 Earth days
Diameter	4,879 km
Density	5.43 g/cm^3
Surface gravity	38% of Earth's

Critical Thinking

2. Infer Which of the facts on the table could scientists use to infer that Mercury has a core made of iron?

_____

Is Venus Earth's Twin?

The second planet from the sun is Venus. In some ways, Venus is more like Earth than any of the other planets. It is about the same size as Earth. However, Venus is slightly smaller, less dense, and less massive than Earth.

If you could observe the sun from the surface of Venus, you would see it rise in the west and set in the east. That is because Venus and Earth rotate on their axes in opposite directions.

If you looked down on Earth from above the North Pole, you would see Earth spinning counterclockwise. This is called **prograde rotation**. However, if you were to look down on Venus from above its north pole, you would see it spinning clockwise. This is called **retrograde rotation**. ☑

READING CHECK

3. Compare How do prograde rotation and retrograde rotation differ?

_____

_____

_____

THE ATMOSPHERE OF VENUS

Venus has the densest atmosphere of the terrestrial planets. The atmospheric pressure on Venus's surface is 90 times that on Earth. This pressure would instantly crush a human on Venus. Venus's atmosphere is mostly made of carbon dioxide and thick clouds of sulfuric acid. The thick atmosphere causes a strong greenhouse effect. As a result, surface temperatures on Venus average about 464°C. This is hot enough to melt lead and some other metals.

Facts About Venus

Distance from sun	0.72 AU
Period of rotation	243 Earth days, 16 hours
Period of revolution	224 Earth days, 17 hours
Diameter	12,104 km
Density	5.24 g/cm^3
Surface gravity	91% of Earth's

TAKE A LOOK

4. Compare Which is longer on Venus, one day or one year?

_____

Critical Thinking

5. Analyzing Methods Why did scientists use *Magellan's* radar instead of telescopes to map the surface of Venus?

_____

_____

_____

_____

MAPPING THE SURFACE OF VENUS

Because of its thick atmosphere, we cannot observe the surface of Venus from Earth with telescopes. Between 1990 and 1992, the *Magellan* spacecraft made maps of Venus using radar waves. These waves can travel through the atmosphere and bounce off the surface. Maps made from the radar data showed that Venus has craters, mountains, lava plains, and volcanoes.

What Makes Earth Unique?

Until the mid-1900s, no one knew what Earth looked like from space. Today, satellites and spacecraft can take pictures of a sparkling blue planet. Light reflecting off ocean water makes Earth look blue from space. ☑

READING CHECK

6. Identify What feature of Earth causes it to appear blue from space?

_____

WATER ON EARTH

Earth is the only planet in the solar system that can support life as we know it. This is because Earth has a certain combination of factors that make life possible. These factors include abundant water and just the right amount of energy from the sun.

Liquid water is vital to life as we know it. Earth is not the only planet in the solar system to have water on its surface. However, Earth is the only planet that has large amounts of liquid water on its surface. Earth is close enough to the sun that all the water does not freeze. It is far enough away that the water does not boil away. If Earth were much closer to or farther from the sun, liquid water—and life—could not exist here.

Facts About Earth

Distance from sun	1.0 AU
Period of rotation	23 hours, 56 minutes
Period of revolution	365 Earth days, 6 hours
Diameter	12,756 km
Density	5.52 g/cm^3
Surface gravity	100% of Earth's

Math Focus

7. Calculate Use the information on the table to explain why every fourth year on Earth is a leap year. Show your work.

(Hint: Compare Earth's period of revolution to the number of days in a calendar year.)

_____

_____

_____

_____

STUDYING EARTH FROM SPACE

NASA's Earth Science Enterprise is a program to study Earth from space. Studying Earth from space lets scientists study the Earth as a whole system. It helps them understand changes in Earth's atmosphere, oceans, ice, landforms, and living things. It may also be able to help them understand how humans affect the global environment. By studying Earth from space, scientists can learn how different parts of the Earth interact.

What Is the Red Planet?

Besides Earth, the most studied planet in the solar system is Mars. Mars looks red, so it is sometimes known as "the red planet." Some scientists think that there could be simple life on Mars.

Scientists have learned much about Mars by observing it from Earth. However, most of our knowledge of the planet has come from unmanned spacecraft. So far, these observations have found no evidence of life.

THE ATMOSPHERE OF MARS

Because it has a thinner atmosphere than Earth and is farther from the sun, Mars is colder than Earth. In the middle of the summer, the spacecraft *Mars Pathfinder* recorded a temperature range from −13°C to −77°C. The Martian atmosphere is made mainly of carbon dioxide. ☑

READING CHECK

8. Explain What are two reasons that the surface of Mars is colder than that of Earth?

_____

_____

_____

_____

The atmospheric pressure on Mars is very low. At the surface, it is about the same as the pressure 30 km above Earth's surface. Because of the low temperatures and air pressure, liquid water cannot exist on the surface of Mars. The only water on Mars's surface is in the form of ice.

Facts About Mars

Distance from sun	1.52 AU
Period of rotation	24 hours, 37 minutes
Period of revolution	687 Earth days
Diameter	6,794 km
Density	3.93 g/cm^3
Surface gravity	38% of Earth's

TAKE A LOOK

9. Compare How does the length of a day on Mars compare to the length of day on Earth?

_____

_____

WATER ON MARS

Even though water cannot exist on the surface of Mars today, it may have in the past. Evidence from spacecraft suggests that some of Mars's features were formed by liquid water. For example, some of Mars's features are similar to those caused by water erosion on Earth. Other features indicate that Mars's surface contains sediments that may have been deposited by the water from a large lake. ☑

READING CHECK

10. Identify What two features suggest that water once existed on the surface of Mars?

_____

_____

Scientists cannot prove that these features were caused by liquid water. However, they indicate that at some time in the past, Mars may have had liquid water. If this is true, it would show that Mars was once warmer and had a thicker atmosphere than it does today.

WHERE THE WATER IS NOW

Mars has two polar icecaps made of a combination of frozen water and frozen carbon dioxide. Most of the water on Mars is trapped in this ice. There is some evidence from the *Mars Global Surveyor* that water could exist just beneath the surface. If so, it may be in liquid form. If Mars does have liquid water beneath its surface, there is a possibility that some form of life may exist on Mars. ☑

READING CHECK

11. Identify Where does water exist on Mars today?

_____

_____

VOLCANOES ON MARS

The remains of giant volcanoes exist on the surface of Mars. They show that Mars has had active volcanoes in the past. Unlike on Earth, however, the volcanoes are not spread across the whole planet. There are two large volcanic systems on Mars. The largest one is about 8,000 km long.

The largest mountain in the solar system, Olympus Mons, is a Martian volcano. It is a shield volcano, similar to Mauna Kea on the island of Hawaii. However, Olympus Mons is much larger than Mauna Kea. The base of Olympus Mons is 600 kilometers —about 370 miles—across. It is nearly 24 kilometers tall. That is three times as tall as Mount Everest! It may have grown so tall because the volcano erupted for long periods of time. ☑

READING CHECK

12. Explain What may have allowed Olympus Mons to grow so large?

_____

_____

_____

MISSIONS TO MARS

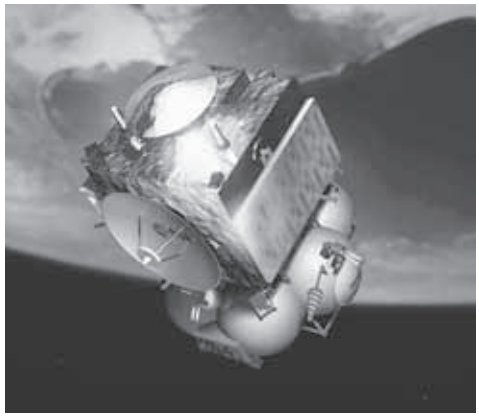
Scientists sent several vehicles to Mars in the early 21st century. The figure below shows *Mars Express Orbiter*, which reached Mars in December 2003. In January 2004, the exploration rovers *Spirit* and *Opportunity* landed on Mars. These solar-powered wheeled robots have found evidence that water once existed on the Martian surface. ☑

READING CHECK

13. Describe What have the rovers *Spirit* and *Opportunity* found?

_____

_____



The *Mars Express Orbiter* helps scientists map Mars and study Mars's atmosphere.

Name _____ Class _____ Date _____

Section 2 Review

NSES ES 1c, 3a, 3b

SECTION VOCABULARY

prograde rotation the counterclockwise spin of a planet or moon as seen from above the planet's North Pole; rotation in the same direction as the sun's rotation

retrograde rotation the clockwise spin of a planet or moon as seen from above the planet's North Pole

terrestrial planet one of the highly dense planets nearest to the sun; Mercury, Venus, Mars, and Earth

1. **Identify** Does Earth show prograde or retrograde rotation?

2. **Compare** Fill in the blanks to complete the table.

Planet	Distance from sun	Period of revolution
	0.38 AU	58 Earth days, 19 hours
	0.72 AU	243 Earth days, 16 hours
	1.00 AU	365 Earth days, 6 hours
	1.52 AU	687 Earth days

3. **Analyze Ideas** Why do scientists think that Mars was once warmer and had a thicker atmosphere than it does today?

4. **Identify Relationships** How is the period of revolution of a planet related to its distance from the sun? (Hint: examine the statistics tables.)

5. **Explain** Why is the surface temperature of Venus higher than the surface temperatures of the other inner planets?

6. **Explain** Why could life probably not have developed on Earth if Earth were closer to the sun?

Name _____ Class _____ Date _____

CHAPTER 21 A Family of Planets

SECTION 3

The Outer Planets

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How are Jupiter, Saturn, Uranus, and Neptune similar?
- How does Pluto differ from the other planets?

National Science Education Standards

ES 1c, 3a, 3b

How Are the Outer Planets Different from the Inner Planets?

Except for Pluto, the outer planets are very large and are made mostly of gases. These planets are called **gas giants**. Unlike the inner planets, they have very thick atmospheres and not very much hard, rocky material on their surfaces.

STUDY TIP

Compare In your notebook, create a chart showing the similarities and differences among the outer planets.

Which Planet Is the Biggest?

Jupiter is the largest planet in our solar system. Its mass is twice as large as the other eight planets combined. Even though it is large, Jupiter's rotation takes less than 10 hours.

Like the sun, Jupiter is made mostly of hydrogen and helium. Jupiter's atmosphere also contains small amounts of ammonia, methane, and water. These gases form clouds in the outer part of Jupiter's atmosphere. The outer atmosphere also contains storms, such as the Great Red Spot. This huge storm is about 3 times the diameter of Earth. It has lasted for over 400 years! ☑

READING CHECK

1. List Give four gases that are found in Jupiter's atmosphere.

_____

_____

_____

_____

Deeper into Jupiter's atmosphere, the pressure is so high that hydrogen turns to liquid. Deeper still, the pressure is even higher. Because of the high pressures, the inside of Jupiter is very hot. It is so hot that Jupiter produces more heat than it gets from the sun.

The information that scientists have about Jupiter has come from five space missions: *Pioneer 1*, *Pioneer 2*, *Voyager 1*, *Voyager 2*, and *Galileo*. The Voyager probes showed that Jupiter has a thin, faint ring.

Facts About Jupiter

Distance from sun	5.20 AU
Period of rotation	9 hours, 55.5 minutes
Period of revolution	11 Earth years, 313 days
Diameter	142,984 km
Density	1.33 g/cm^3
Surface gravity	236% of Earth's

TAKE A LOOK

2. Identify Which of the facts in the table could you use to infer that Jupiter has a shorter day than Earth does?

_____

What Are Saturn's Rings Made Of?

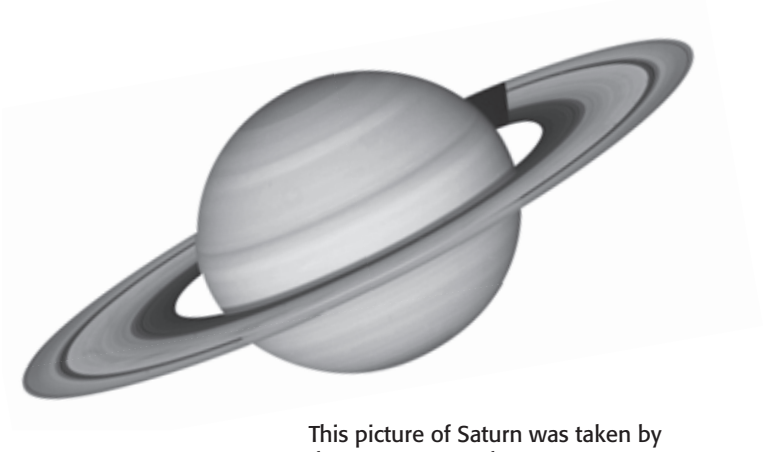
Saturn is the second-largest planet in the solar system. Like Jupiter, Saturn is made up mostly of hydrogen with some helium and traces of other gases and water. Saturn has about 764 times more volume than Earth and about 95 times more mass. Therefore, it is much less dense than Earth.

Facts About Saturn

Distance from sun	9.54 AU
Period of rotation	10 hours, 42 minutes
Period of revolution	29 Earth years, 155 days
Diameter	120,536 km
Density	0.69 g/cm^3
Surface gravity	92% of Earth's

The inside of Saturn is probably similar to the inside of Jupiter. Also, like Jupiter, Saturn gives off more heat than it gets from the sun. Scientists think that Saturn's extra energy comes from helium condensing from the atmosphere and sinking toward the core. In other words, Saturn is still forming.

Saturn is probably best known for the rings that orbit the planet above its equator. They are about 250,000 km across, but less than 1 km thick. The rings are made of trillions of particles of ice and dust. These particles range from a centimeter to several kilometers across. ☑



This picture of Saturn was taken by the *Voyager 2* probe.

Critical Thinking

3. Compare About how many times does Earth revolve around the sun in the time it takes Saturn to revolve once?

_____

READING CHECK

4. Identify What two materials make up the rings of Saturn?

_____

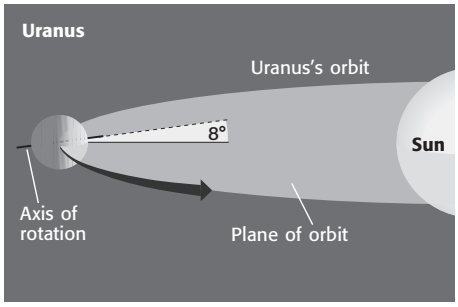
_____

How Is Uranus Unique?

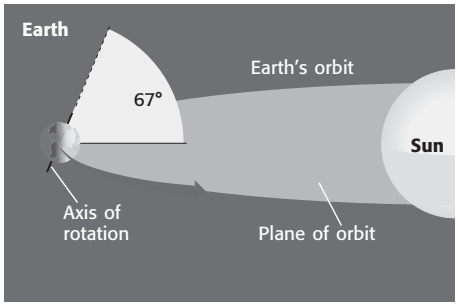
Uranus is the third-largest planet in the solar system. It is so far from the sun that it does not reflect much sunlight. You cannot see it from Earth without using a telescope. ☑

Uranus is different from the other planets because it is "tipped" on its side. As shown in the figure below, the north and south poles of Uranus point almost directly at the sun. The north and south poles of most other planets, like Earth, are nearly at right angles to the sun.

For about half the Uranian year, one pole is constantly in sunlight, and for the other half of the year it is in darkness. Some scientists think that Uranus may have been tipped over by a collision with a massive object.



Uranus is tilted so that its poles point almost directly at the sun.



In contrast, Earth's poles, like those of most other planets, are nearly at right angles to the sun.

Like Jupiter and Saturn, Uranus is made mostly of hydrogen, helium, and small amounts of other gases. One of these gases, methane, filters sunlight and makes the planet look bluish-green. ☑

Facts About Uranus

Distance from sun	19.22 AU
Period of rotation	17 hours, 12 minutes
Period of revolution	83 Earth years, 273 days
Diameter	51,118 km
Density	1.27 g/cm^3
Surface gravity	89% of Earth's

READING CHECK

5. Identify Why can't Uranus be seen from Earth without a telescope?

_____

_____

TAKE A LOOK

6. Explain Why do scientists say that Uranus is "tipped over"?

_____

_____

TAKE A LOOK

7. Compare How does the length of a year on Uranus compare to the length of a year on Earth?

_____

_____

What Is Neptune Like?

Some astronomers predicted that there was a planet beyond Uranus before the planet was observed. Uranus did not move in its orbit exactly as they expected. The force of gravity due to another large object was affecting it. Using predictions of its effect on Uranus, astronomers discovered Neptune in 1846. ☑

READING CHECK

8. Explain What evidence did astronomers have that Neptune existed before they actually observed it?

_____

_____

Neptune is the fourth-largest planet in the solar system. Like the other gas giants, Neptune is made up mostly of hydrogen, helium, and small amounts of other gases. It has a deep blue color, which is caused by methane in its atmosphere.

Clouds and weather changes are seen in the atmosphere of Neptune. The spacecraft *Voyager 2* flew past Neptune in 1989 and observed a Great Dark Spot in the southern hemisphere. This spot was a storm as large as Earth. It moved across the planet's surface at about 300 m/s. By 1994, the Great Dark Spot had disappeared. Another dark spot was then found in the northern hemisphere. *Voyager 2* images also showed that Neptune has very narrow rings.

TAKE A LOOK

9. Compare How does Neptune's average distance from the sun compare to Earth's?

_____

_____

_____

Facts About Neptune

Distance from sun	30.06 AU
Period of rotation	16 hours, 6 minutes
Period of revolution	163 Earth years, 263 days
Diameter	49,528 km
Density	1.64 g/cm^3
Surface gravity	112% of Earth's

Why Is Pluto Called the Mystery Planet?

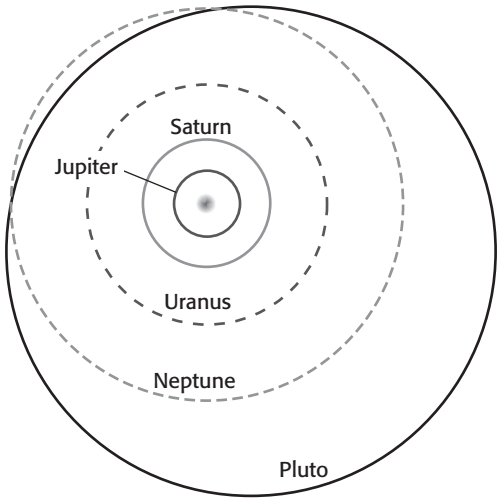
Scientists thought the path of Neptune's orbit indicated another gas giant even farther from the sun. So, they looked for another planet. It turned out another gas giant does not exist. However, scientists did discover another planet, Pluto, in 1930.

A SMALL WORLD

Unlike the other outer planets, Pluto is not a gas giant. In fact, it is the smallest planet in the solar system. Pluto is made of rock and ice and has a thin atmosphere made of methane and nitrogen. Scientists do not know if Pluto formed along with the other planets.

AN UNUSUAL ORBIT

The shape of Pluto's orbit is different from the shapes of other planets's orbits. As you can see in the figure below, sometimes Pluto is closer to the sun than Neptune. At other times, Neptune is closer to the sun.



The shape of Pluto's orbit is very different from the orbits of other planets.

TAKE A LOOK

10. Compare How is Pluto's orbit different from the orbits of the other outer planets?

_____

_____

_____

_____

A LARGE MOON

Pluto's moon, Charon, is more than half the size of Pluto. From Earth, it is hard to separate the images of Pluto and Charon because they are so far away. Charon may be covered by frozen water.

Because Pluto is so small and unusual, some scientists think that it should not be considered a planet. Instead, they think that Pluto should be classified as a large asteroid or comet. However, because Pluto has been considered a planet for so long, it will probably remain so.

Critical Thinking

11. Infer How do you think scientists learned that Pluto has a moon if it is difficult to separate their images?

_____

_____

_____

_____

Facts About Pluto

Distance from sun	39.5 AU
Period of rotation	6 days, 10 hours
Period of revolution	248 Earth years, 4 days
Diameter	2,390 km
Density	1.75 g/cm^3
Surface gravity	6% of Earth's

Name _____ Class _____ Date _____

Section 3 Review

NSES ES 1c, 3a, 3b

SECTION VOCABULARY

gas giant a planet that has a deep, massive atmosphere, such as Jupiter, Saturn, Uranus, or Neptune	

1. Identify What is the main element found in the atmosphere of a gas giant planet?

_____

2. Compare Fill in the blanks to complete the table.

Planet	Distance from sun	Period of revolution
	5.20 AU	11 Earth years, 313 days
	9.54 AU	29 Earth years, 155 days
	19.22 AU	83 Earth years, 273 days
	30.06 AU	163 Earth years, 263 days
	39.5 AU	248 Earth years, 4 days

3. Evaluate Data How are the surface temperature and length of year on a planet related to the planet's distance from the sun?

_____

_____

_____

4. Make Comparisons How do the gas giants differ from the inner planets of the solar system? In your answer, discuss composition, size, distance from the sun, length of a year, and solar energy received.

_____

_____

_____

_____

5. Identify What gives Neptune and Uranus their blue to blue-green colors?

_____

6. Describe What did the Voyager probes discover about Jupiter?

_____

Name _____ Class _____ Date _____

CHAPTER 21 A Family of Planets

SECTION 4

Moons

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How did Earth's moon probably form?
- How does the moon's appearance change with time?
- What moons revolve around other planets?

National Science Education Standards

ES 1a, 3a, 3b, 3c

What Are Moons?

Satellites are natural or artificial bodies that revolve around larger bodies in space, such as planets. Except for Mercury and Venus, all of the planets have natural satellites called *moons*. Moons come in a wide variety of sizes, shapes, and compositions.

STUDY TIP

Describe In your notebook, create a Concept Map about Earth's moon, including information about its origin, why it shines, phases, and eclipses.

What Do We Know About Earth's Moon?

Scientists have learned a lot about Earth's moon, which is also called *Luna*. Much of what we know comes from observations from Earth, but other discoveries have come from visiting the moon. Some lunar rocks brought back by Apollo astronauts were found to be almost 4.6 billion years old. These rocks have not changed much since they were formed. This tells scientists that the solar system itself is at least 4.6 billion years old. ☑

READING CHECK

1. Explain How do scientists know what moon's crust is made of?

_____

_____

_____

_____

THE MOON'S SURFACE

The moon is almost as old as Earth. It is covered with craters, many of which can be seen from Earth on a clear night. Because the moon has no atmosphere and no erosion, its surface shows where objects have collided with it. Scientists think that many of these collisions happened about 3.8 billion years ago. They were caused by matter left over from the formation of the solar system.

Facts About Luna

Period of rotation	27 Earth days, 9 hours
Period of revolution	27 Earth days, 7 hours
Diameter	3,475 km
Density	3.34 g/cm3
Surface gravity	16% of Earth's

Math Focus

2. Identify What fraction of Earth's gravity is the moon's gravity?

_____

THE ORIGIN OF THE MOON

When scientists studied the rock samples brought back from the moon by astronauts, they found some surprises. The composition of the moon is similar to that of Earth's mantle. This evidence led to a theory about the moon's formation. ☑

Scientists now think that the moon formed when a large object collided with the early Earth. The object was probably about the size of Mars. The collision was so violent that a large mass of material was thrown into orbit around Earth. Gravity pulled this material into a sphere. The sphere continued to revolve around the planet. Eventually, it became the moon.

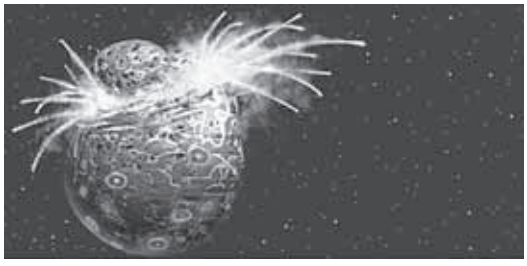
READING CHECK

3. Identify What discovery caused scientists to revise their theory about the origin of the moon?

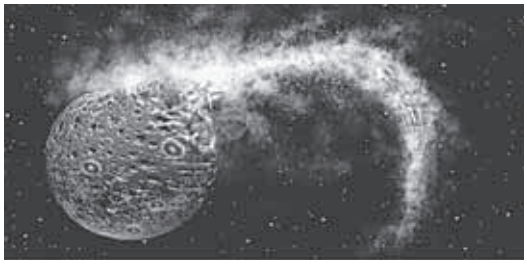
_____

_____

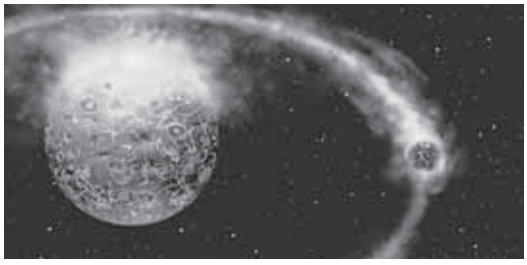
Formation of the Moon



❶ About 4.6 billion years ago, a large body collided with Earth. At this time, Earth was still mostly molten. The collision blasted part of Earth's mantle into space.



❷ Within a few hours of the collision, the debris began to orbit the Earth. The debris was made of mantle material from Earth and some iron core material from the colliding body.



❸ In time, the material began to clump together. Eventually, the moon formed. As it cooled, collisions with smaller objects produced cracks in the moon's crust. Lava flowed onto the moon's surface. This formed the dark patches, or *maria*, that we can see on the moon today.

TAKE A LOOK

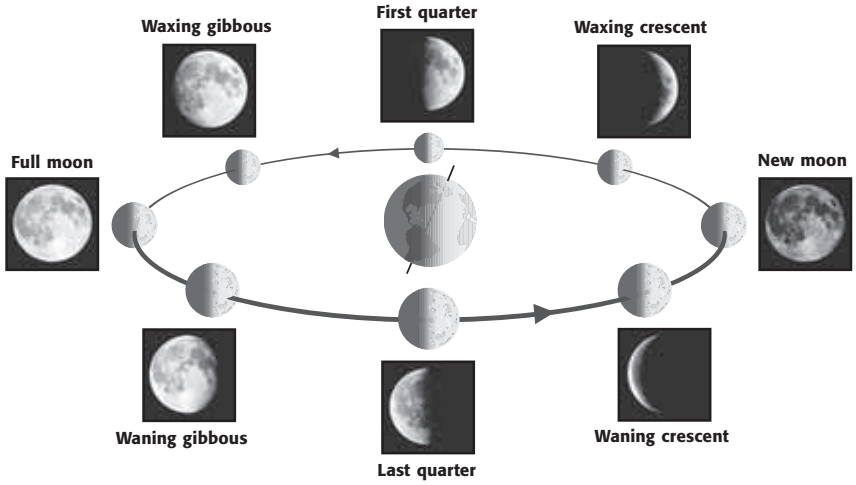
4. Identify According to this theory, material was thrown from Earth in clumps. What caused the material to come together as a sphere?

_____

PHASES OF THE MOON

The moon revolves around the Earth once each month. It rotates on its axis in almost the same period. Therefore, we always see the same side of the moon. However, the moon does not always look the same. This is because we cannot always see all of the part that is reflecting light.

As the moon's position changes compared to the sun and Earth, it looks different to people on Earth. During a month, the face of the moon that we can see changes from a fully lit circle to a thin crescent and then back to a circle. The figure below shows how the moon's appearance changes as it moves around Earth.



The different appearances of the moon are called **phases**. When the moon is *waxing*, the part of the sunlit side that we can see increases every day. The moon appears to get bigger. When the moon is *waning*, the part of the sunlit side that we can see decreases every day. The moon appears to get smaller.

What Is an Eclipse?

An **eclipse** happens when the shadow of one body in space falls on another. A *solar eclipse* happens when the moon comes between the sun and Earth. Then, the shadow of the moon falls on part of Earth's surface. A *lunar eclipse* happens when Earth comes between the sun and the moon. Then, the shadow of Earth falls on the moon. ☑

Critical Thinking

5. Explain The moon does not produce its own light. How can the moon be seen from Earth?

TAKE A LOOK

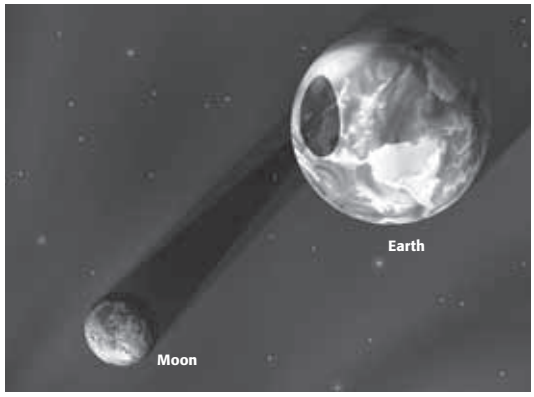
6. Explain Why does the moon look different on different nights?

READING CHECK

7. Explain What happens during a solar eclipse?

SOLAR ECLIPSES

Because the moon's orbit is elliptical (oval-shaped) instead of circular, the distance between Earth and the moon changes. When the moon is close to Earth, the moon appears to be the same size as the sun. If the moon passes between the sun and Earth during that time, there is a *total solar eclipse*. If the moon is farther from earth, the eclipse is an annular eclipse. During an *annular eclipse*, a thin ring of the sun can be seen around the moon.



During a solar eclipse, the moon passes between the Earth and the sun.

TAKE A LOOK

8. Explain Why can't a solar eclipse be seen from every point on Earth?

_____

_____

_____

LUNAR ECLIPSES

A lunar eclipse happens during a full moon when the moon passes through the shadow of Earth. Unlike a solar eclipse, a lunar eclipse can be seen from much of the night side of the planet. The figure below shows the position of Earth and the moon during a lunar eclipse.

During a lunar eclipse, the Earth passes between the sun and the moon.

TAKE A LOOK

9. Describe What happens during a lunar eclipse?

_____

_____

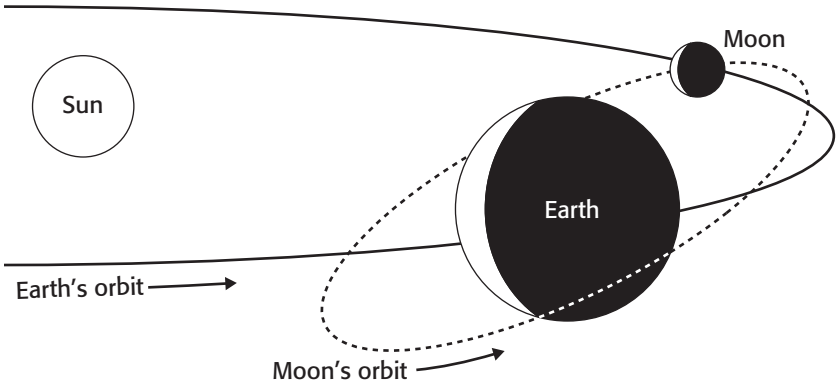
_____

Lunar eclipses are interesting to watch. At the beginning and end of a lunar eclipse, the moon is in the outer part of the shadow. In this part of the shadow, Earth's atmosphere filters out some of the blue light. As a result, the light that is reflected from the moon is red.

THE MOON'S TILTED ORBIT

The moon rotates around Earth each month, so you might expect that there would be an eclipse each month. However, eclipses happen only about once a year.

Eclipses don't happen every month because the moon's orbit is slightly tilted compared to Earth's orbit. This tilt is enough to place the moon out of Earth's shadow during most full moons. It also causes the Earth to be out of the moon's shadow during most new moons. ☑



The moon's orbit is tilted compared to the Earth's. Therefore, eclipses do not happen every month.

READING CHECK

10. Explain Why don't solar eclipses occur each month?

_____

_____

_____

_____

Say It

Discuss In a group, discuss why you can't look at the sun during a solar eclipse but you can look at the moon during a lunar eclipse.

Are Other Moons Like Earth's Moon?

All of the planets, except Mercury and Venus, have moons. Pluto has three known moons, and Mars has two. All of the gas giants have many moons. Many of these moons were discovered fairly recently using spacecraft cameras or the Hubble Space Telescope. Some moons may not have been discovered yet. ☑

The solar system's moons vary widely. They range in size from very small bits of rock to objects as large as a terrestrial planet. Their orbits range from nearly circular to very elliptical. Most moons orbit in the same direction as the planets orbit the sun. However, some orbit in the opposite direction.

READING CHECK

11. Compare Which types of planets have the most moons—terrestrial planets or gas giants?

_____

THE MOONS OF MARS

Mars has two moons, Phobos and Deimos. They are small, oddly shaped satellites. Both moons have dark surfaces and resemble *asteroids*, or rocky bodies in space. Phobos is about 22 km across at its largest dimension. Deimos is about 15 km across. Both moons may be asteroids that were captured by Mars's gravity. ☑

READING CHECK

12. Identify What are the names of Mars's moons?

_____

_____

THE MOONS OF JUPITER

Jupiter has more than 60 moons. The four largest were discovered in 1610 by Galileo. When he observed Jupiter through a telescope, Galileo saw what looked like four dim stars that moved with Jupiter. He observed that they changed position compared to Jupiter and each other from night to night.

These moons—Ganymede, Callisto, Io, and Europa—are known as the *Galilean satellites*. They appear small compared to the giant planet. However, Ganymede is larger than Mercury. ☑

Io, the Galilean satellite closest to Jupiter, is covered with active volcanoes. There are at least 100 active volcanoes on its surface. In fact, Io is the most volcanically active body in the solar system.

Recent pictures of the moon Europa suggest that liquid water may exist below its icy surface. If Europa does contain liquid water, it is one of the few bodies in the solar system to have an ocean. ☑

READING CHECK

13. Identify What are the names of the Galilean satellites?

_____

_____

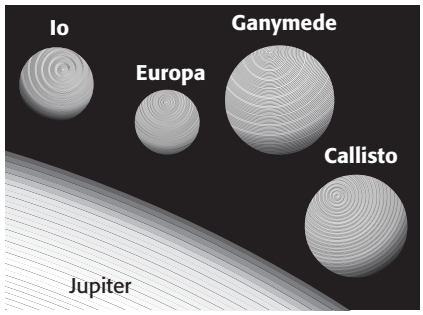
_____

_____

READING CHECK

14. Identify What may lie below the icy surface of Europa?

_____



This figure shows the sizes of the four Galilean satellites compared to Jupiter.

THE MOONS OF SATURN

Saturn has more than 50 moons. Saturn's largest moon, Titan, is slightly smaller than Ganymede. Unlike most moons, Titan has an atmosphere. Its atmosphere is composed mostly of nitrogen, with small amounts of other gases, such as methane. Scientists think that Titan's atmosphere is similar to Earth's early atmosphere.

None of Saturn's other moons are as large as the Galilean moons of Jupiter. Most of them are from several kilometers to several hundred kilometers across. They are made mostly of frozen water and rocks.

Critical Thinking

15. Make Inferences Would humans be able to live unprotected on the surface of Titan? Explain your answer.

_____

_____

_____

_____

THE MOONS OF URANUS

Uranus has at least 27 moons. Most of them are small. They were discovered by space probes or orbiting observatories, such as the Hubble Space Telescope. Like the moons of Saturn, Uranus's largest moons are made of ice and rock. ☑

READING CHECK

16. Describe What are Uranus's largest moons made of?

_____

THE MOONS OF NEPTUNE

Neptune has 13 known moons. The largest, Triton, revolves in a *retrograde*, or "backward," orbit. Triton's unusual orbit suggests that it was captured by Neptune's gravity after forming somewhere else in the solar system. Triton has a thin nitrogen atmosphere. Its surface is mostly frozen nitrogen and methane. It has active "ice volcanoes" that send gas high into its atmosphere. Neptune's other moons are small and are made of ice and rock.

THE MOONS OF PLUTO

Pluto has three moons. The diameter of Charon, the largest moon, is about half that of Pluto. Two additional moons of Pluto, discovered by the Hubble telescope in 2005, are much smaller than Charon. Charon revolves around Pluto in 6.4 days, the same period as Pluto's rotation. That means that Charon is always located at the same place in Pluto's sky.

Charon's orbit around Pluto is tilted compared to Pluto's orbit around the sun. As a result, Charon sometimes blocks the view of Pluto from Earth. However, this happens only once every 120 years.

Some of the Moons of the Solar System

Planet	Moon	Diameter	Period of revolution
Earth	Luna	3475 km	27.3 Earth days
Mars	Phobos	26 km	0.3 Earth days
Mars	Deimos	15 km	1.3 Earth days
Jupiter	Io	3636 km	1.8 Earth days
Jupiter	Europa	3120 km	3.6 Earth days
Jupiter	Ganymede	5270 km	7.1 Earth days
Jupiter	Callisto	4820 km	16.7 Earth days
Saturn	Titan	5150 km	15.9 Earth days
Uranus	Titania	1580 km	8.7 Earth days
Neptune	Triton	2700 km	5.9 Earth days
Pluto	Charon	1180 km	6.4 Earth days

Critical Thinking

17. Identify Relationships Some of the moons of the gas giants are larger than Mercury. Why are they not considered to be planets?

_____

_____

_____

Name _____ Class _____ Date _____

Section 4 Review

NSES ES 1a, 3a, 3b, 3c

SECTION VOCABULARY

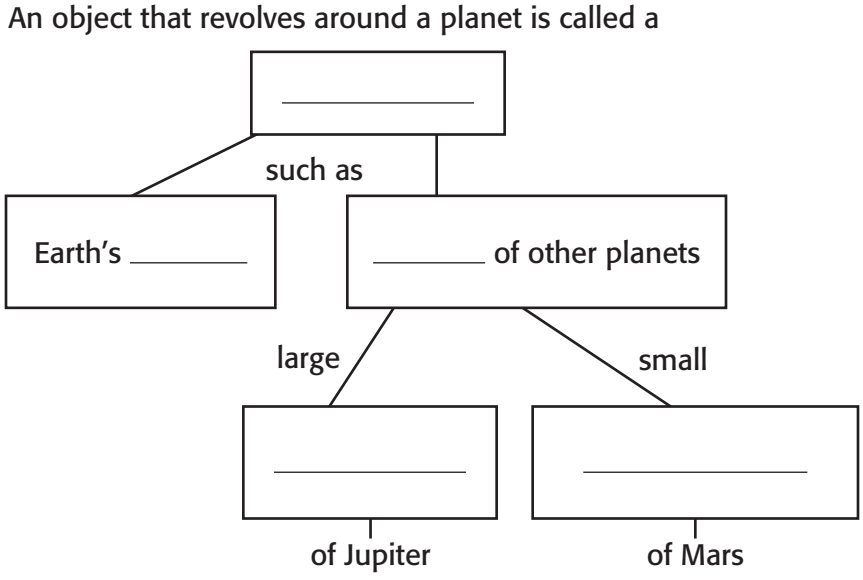
eclipse an event in which the shadow of one celestial body falls on another **phase** the change in the sunlit area of one celestial body as seen from another celestial body	**satellite** a natural or artificial body that revolves around a planet

1. Compare How is a solar eclipse different from a lunar eclipse?

_____

_____

2. Identify Fill in the blanks to complete the chart.



3. Analyze Methods How can astronomers use rocks from the moon to estimate the age of the solar system?

_____

_____

_____

4. Explain Why don't eclipses happen every month?

_____

_____

Name _____ Class _____ Date _____

CHAPTER 21 A Family of Planets

SECTION 5

Small Bodies in the Solar System

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are comets?
- What are asteroids?
- What are meteoroids?

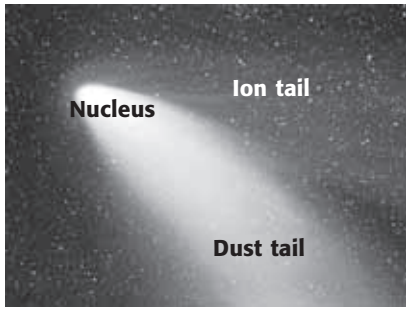
What Are Comets?

The sun, the planets, and their moons are not the only objects in our solar system. There are also a large number of smaller bodies, including comets, asteroids, and meteoroids. Scientists study these objects to learn about the formation and composition of the solar system.

A **comet** is a small, loosely packed body of ice, rock, and dust. The *nucleus*, or core, of a comet is made of rock, metal, and ice. A comet's nucleus can range from 1 km to 100 km in diameter. A spherical cloud of gas and dust, called a *coma*, surrounds the nucleus. The coma may extend as far as 1 million kilometers from the nucleus. ☑

COMET TAILS

A comet's tail is its most spectacular feature. Sunlight changes some of the comet's ice to gas, which streams away from the nucleus. Part of the tail is made of *ions*, or charged particles. The *ion tail*, pushed by the solar wind, always points away from the sun, no matter which way the comet is moving. A second tail, the *dust tail*, follows the comet in its orbit. Some comet tails are more than 80 million kilometers long, glowing brightly with reflected sunlight.



This image shows the physical features of a comet when the comet comes close to the sun. The nucleus of the comet is hidden by the brightly lit gases and dust of the coma.

Say It

Compare In your notebook, create a table that compares comets, asteroids, and meteoroids.

READING CHECK

1. Describe What are comets made of?

_____

_____

TAKE A LOOK

2. Identify Draw an arrow from the nucleus label showing the direction the comet is moving.

COMET ORBITS AND ORIGINS

Remember that the planets move in *elliptical*, or oval-shaped, orbits. Comets also move in elliptical orbits. However, the orbits of comets are much more stretched out than the orbits of planets.

Scientists think that many comets come from the Oort cloud. The *Oort cloud* is a spherical cloud of dust and ice. It surrounds the solar system, far beyond the orbit of Pluto. Pieces of the Oort cloud may fall into orbits around our sun and become comets. Some comets may also come from the *Kuiper belt*, a flat ring of objects just beyond Neptune's orbit. ☑

READING CHECK

3. Identify Where is the Oort cloud located?

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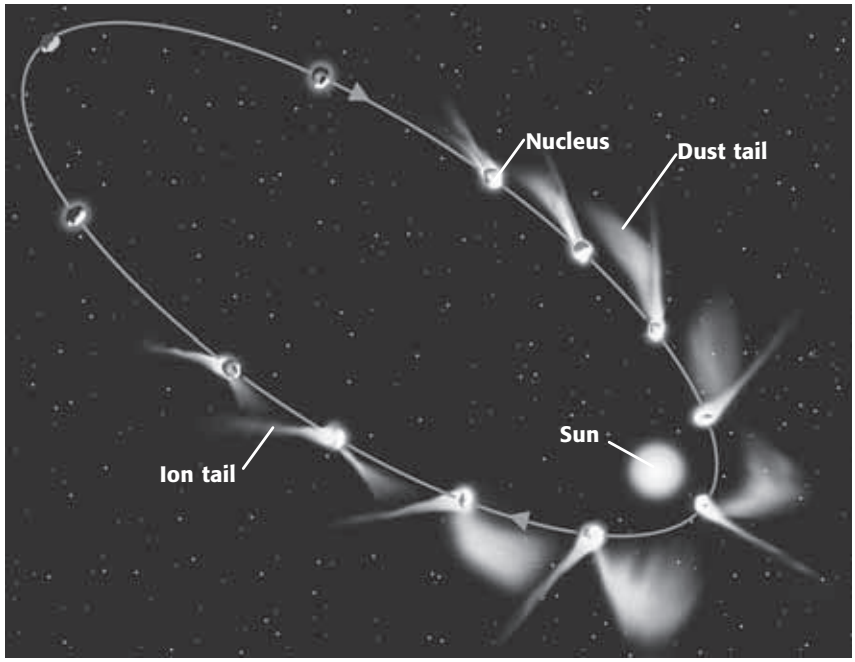
_____



Comets have very long orbits that take them close to the sun and well beyond Pluto.

TAKE A LOOK

4. Explain Why does the ion tail extend in different directions during most of the comet's orbit?

_____

_____

_____

What Are Asteroids?

Asteroids are small, rocky bodies that revolve around the sun. They range from a few meters to almost 1,000 km in diameter. More than 50,000 asteroids have been discovered. None of them can be seen from Earth without a telescope. In fact, scientists didn't know that asteroids exist until 1801.

Most asteroids orbit the sun in the **asteroid belt**. This is a region that is 300 million km wide and is located between the orbits of Mars and Jupiter. Astronomers think that asteroids are made of material from the early solar system. The pull of Jupiter's gravity prevented this material from coming together to form a planet. ☑

READING CHECK

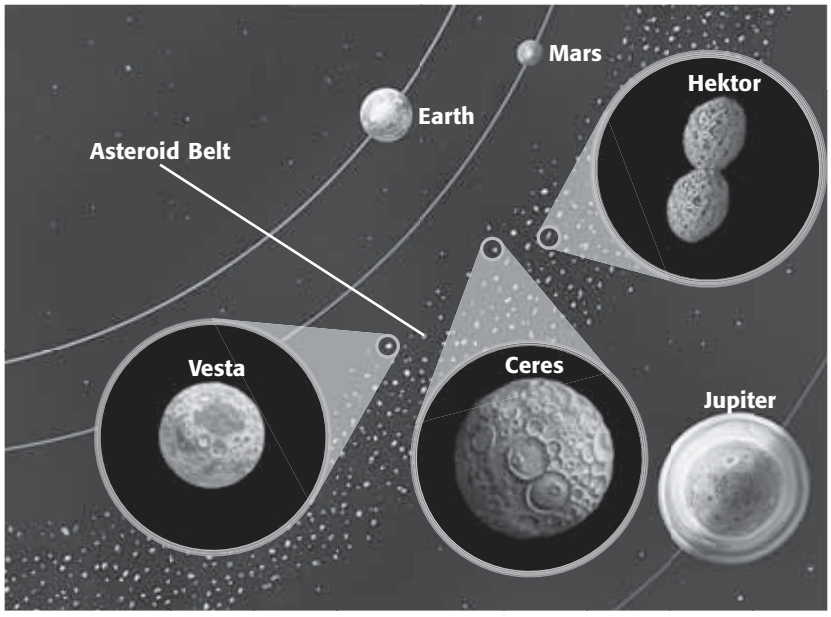
5. Identify Where is the asteroid belt?

_____

COMPOSITION OF ASTEROIDS

It is hard to determine what asteroids are made of. This is because they are small and usually far away from Earth. Mostly, they are composed of either rock or metal. Some asteroids may contain carbon and carbon compounds.

In general, asteroids do not have a spherical shape because of their small size. Gravity must be very strong to pull matter together into a spherical shape. Only the largest asteroids are spherical.



What Are Meteoroids?

Pieces of dust and debris from asteroids and comets, called **meteoroids**, are scattered throughout the solar system. Most meteoroids are about the size of a grain of sand. When a meteoroid enters Earth's atmosphere, it can reach a speed of up to 250,000 km/h.

Friction with the atmosphere heats meteoroids and the air around them, causing them to glow brightly. The glowing trails that form when meteoroids burn up in the atmosphere are called **meteors**. A meteor can be a few hundred meters in diameter and tens of kilometers long before it fades.

Sometimes, a larger meteoroid enters the atmosphere. Some of these meteoroids pass through the atmosphere without burning up completely. When they reach Earth's surface, they are called **meteorites**. ☑

Critical Thinking

6. Make Inferences How do you think scientists know what asteroids are made of?

_____

_____

_____

TAKE A LOOK

7. Compare How do asteroid sizes compare to planet sizes?

_____

_____

READING CHECK

8. Compare What is the difference between a meteoroid and a meteorite?

_____

_____

_____

_____

_____

TYPES OF METEORITES

Scientists classify meteorites based on composition. There are three main types of meteorites: stony, metallic, and stony-iron. *Stony meteorites* are similar to rocks on Earth. Some of them contain carbon compounds similar to those found in living organisms. Stony meteorites probably come from carbon-rich asteroids. ☑

Metallic meteorites have a distinctive metallic appearance and do not look like terrestrial rocks. They are made mainly of iron and nickel. *Stony-iron meteorites* are made of a combination of rocky material, iron, and nickel.

READING CHECK

9. List What are the three types of meteorites?

_____

_____

_____

Three Major Types of Meteorites

Stony Meteorite: rocky material

Metallic Meteorite: iron and nickel

Stony-iron Meteorite: rocky material, iron, and nickel

Scientists study meteorites to learn about the early solar system.

TAKE A LOOK

10. Identify What two metals are found in metallic meteorites?

_____

Remember that asteroids and comets are probably made of debris from the formation of our solar system. Meteorites are easier for scientists to study than asteroids and comets. Because meteorites are pieces of asteroids and comets, scientists study meteorites to learn about the early solar system.

Critical Thinking

11. Infer Why are meteorites easier to study than asteroids or comets?

_____

_____

METEOR SHOWERS

Meteors can be seen on most clear nights. When many small meteoroids enter the atmosphere in a short period, it is called a *meteor shower*. During some meteor showers, several meteors are visible every minute. Meteor showers happen at the same time each year. These showers happen when Earth passes through orbits of comets that have left a dust trail.

IMPACTS IN OUR SOLAR SYSTEM

Impacts are common in our solar system. An *impact* happens when an object in space collides with another object. In many cases, impacts produce impact craters. Many of the planets and moons in our solar system, including Earth, have visible impact craters.

Planets and moons with atmospheres have fewer impact craters than those without atmospheres. For example, there are only a few visible impact craters on Earth. However, the surface of our moon is covered with impact craters. Earth has fewer craters because the atmosphere acts as a shield. Most objects that enter Earth's atmosphere burn up before they reach the surface. ☑

READING CHECK

12. Identify Why do fewer meteorites hit Earth's surface than the surface of the moon?

Another reason that there are few visible impact craters on Earth is that Earth has a very active surface. Plate tectonics, weathering, erosion, and deposition act to smooth out and change Earth's surface. These processes are less common on other planets and moons.

Most objects that enter Earth's atmosphere are small and burn up completely before reaching the surface. However, scientists think that impacts powerful enough to cause a natural disaster happen every few thousand years. An impact large enough to cause a global catastrophe may happen once every 50 to 100 million years.

THE TORINO SCALE

Scientists can track objects that are close to Earth to learn whether they might hit Earth. Scientists use the *Torino scale* to rate the chance than an object will hit the Earth. The Torino scale ranges from 0 to 10. Zero indicates that an object has a very small chance of hitting the Earth. Ten indicates that the object will definitely hit the Earth. The Torino scale is also color coded, as shown in the table below.

Color	Number	Hazard level
White	0	very low; almost certainly will not hit the Earth
Green	1	low
Yellow	2, 3, or 4	moderate
Orange	5, 6, or 7	high
Red	8, 9, or 10	very high; almost certainly will hit the Earth

TAKE A LOOK

13. Identify Which color on the Torino scale is used to describe an object that will probably hit the Earth?

Name _____ Class _____ Date _____

Section 5 Review

SECTION VOCABULARY

asteroid a small, rocky object that orbits the sun; most asteroids are located in a band between the orbits of Mars and Jupiter

asteroid belt the region of the solar system that is between the orbits of Mars and Jupiter and in which most asteroids orbit

comet a small body of ice, rock, and cosmic dust that follows an elliptical orbit around the sun and that gives off gas and dust in the form of a tail as it passes close to the sun

meteor a bright streak of light that results when a meteoroid burns up in Earth's atmosphere

meteorite a meteoroid that reaches the Earth's surface without burning up completely

meteoroid a relatively small, rocky body that travels through space

1. Describe How can a comet become the source of meteoroids and meteors?

_____

_____

2. Classify Fill in the blanks to complete the table.

Object	Composition	Main Location
	Large chunk of rock or metal—much smaller than planets	
		Oort cloud and Kuiper belt
	small chunk of rock or metal	throughout the solar system

3. Identify Connections Why is information about comets, asteroids, and meteoroids important for understanding the development of the solar system?

_____

_____

_____

4. Apply Concepts Why would scientists want to know if an asteroid is on a course to collide with Earth in 20 years?

_____

_____

Name _____ Class _____ Date _____

CHAPTER 22 Exploring Space

SECTION 1

Rocket Science

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How were rockets developed?
- How do rockets work?

How Did Rocket Science Begin?

Years ago, people could only dream of traveling into space. The problem was that no machine could generate enough force to overcome Earth's gravity.

In the early 1900s, a Russian teacher named Konstantin Tsiolkovsky proposed that rockets could take people into space. A **rocket** is a machine that moves because of the force produced by escaping gas.

Tsiolkovsky proved that rockets could produce enough force to reach outer space. However, he never built any rockets himself. The first rockets were built by Robert Goddard, an American physicist and inventor. Over time, Goddard tested more than 150 rocket engines. He is sometimes called the "father of modern rocketry." ☑

During World War II, the United States military became interested in Goddard's work on rocket engines. They were interested in rockets because of a new German weapon.

Germany had developed the V-2 rocket. It could carry explosives over long distances. The German scientists who developed this rocket surrendered to the Americans near the end of the war. The United States gained 127 of the best German rocket scientists. They helped improve rocket science in the United States during the 1950s.

The German V-2 rocket is the ancestor of all modern rockets.

STUDY TIP

Compare After you read this section, make a chart comparing orbital velocity and escape velocity. In your chart, define each velocity and give the speed an object has to travel in order to reach each velocity.

READING CHECK

1. Identify Who was Robert Goddard?

_____

_____

_____

_____

TAKE A LOOK

2. Describe What was the V-2 rocket?

_____

_____

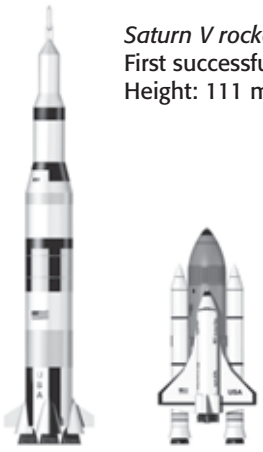
_____

Say It

Investigate The U.S. government formed NASA as part of a "space race" with the U.S.S.R. during the Cold War. Find out more about the Cold War. Share what you learn with a small group.

THE FORMATION OF NASA

In 1958, the U.S. government combined all of the rocket-development teams in the country into one new group. This group was called the National Aeronautics and Space Administration, or **NASA**. The scientists at NASA have developed many rockets to explore space. Two of these rockets are shown in the figure below.



Saturn V rocket
First successful launch: 1967
Height: 111 m

Space shuttle and boosters
First successful launch: 1981
Height: 56 m

Math Focus

3. Calculate The space shuttle is about what fraction of the height of the *Saturn V* rocket?

_____

How Do Rockets Work?

Many people think that rockets move because gases from the rocket push down on the launch pad. However, this is not the case. If it were, rockets could not move in space, where there is nothing for the gases to push against. Instead, rockets move because the forces on them are not balanced. ☑

READING CHECK

4. Explain Why do rockets move?

_____

_____

To understand how this works, imagine blowing up a balloon and holding its end closed. The air in the balloon pushes on all parts of the balloon with the same force. The forces on the balloon are balanced, so it does not move. Now, imagine letting go of the end of the balloon. The end of the balloon is open, so the air cannot push on it. The air still pushes on the front of the balloon. The forces on the balloon are not balanced, so it moves forward.

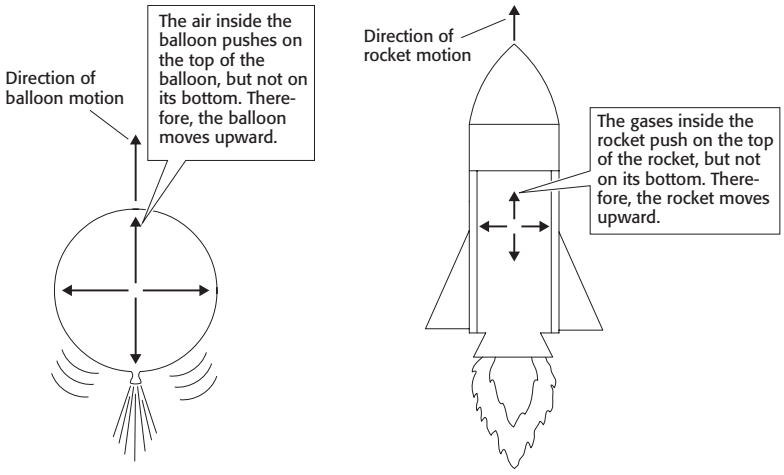
This is similar to how a rocket works. The fuel inside the rocket produces gases as it burns. These gases push on the inside of the rocket. The rocket is like the balloon with the open end. The gases can't push on the bottom of the rocket, but they can push on the top. Therefore, the rocket moves upward. The force that makes the rocket move is called **thrust**. The figure on the top of the next page shows how unbalanced forces cause rockets to move. ☑

READING CHECK

5. Define What is thrust?

_____

_____



TAKE A LOOK

6. Explain Why do the balloon and the rocket move upward?

CARRYING OXYGEN

Rockets burn fuel to produce the gas that causes them to move. Fuel requires oxygen to burn, but there is almost no oxygen in space. Therefore, rockets that go into outer space must carry oxygen with them.

ORBITAL VELOCITY AND ESCAPE VELOCITY

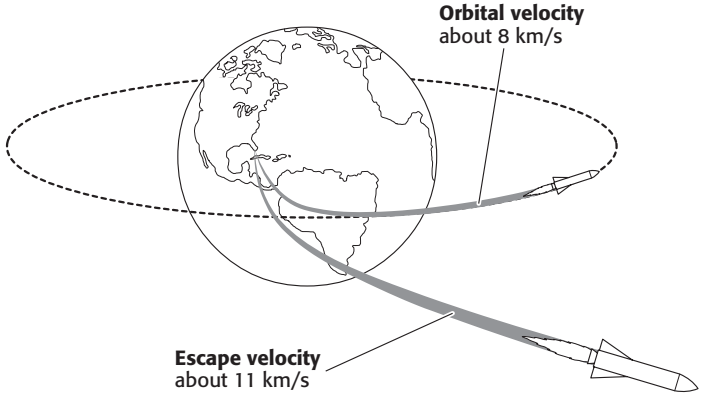
Remember that gravity attracts objects toward the Earth. A rocket must reach a certain *velocity*, or speed and direction, to orbit the Earth or escape its gravity.

Orbital velocity is the velocity a rocket must travel in order to orbit a planet or moon. The orbital velocity for the Earth is about 8 km/s. If a rocket goes any slower, it will fall back to Earth.

Escape velocity is the velocity a rocket must travel to break away from a planet's gravitational pull. The escape velocity for the Earth is about 11 km/s.

Critical Thinking

7. Compare How is orbital velocity different from escape velocity?



Name _____ Class _____ Date _____

Section 1 Review

SECTION VOCABULARY

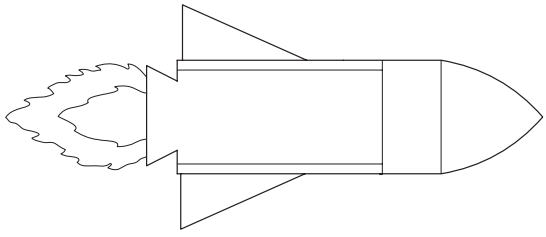
NASA the National Aeronautics and Space Administration	**rocket** a machine that uses escaping gas from burning fuel to move **thrust** the pushing or pulling force exerted by the engine of an aircraft or rocket

1. **Describe** How did Konstantin Tsiolkovsky contribute to rocket science?

2. **Explain** Why did the United States government become interested in Robert Goddard's work on rocket engines?

3. **Identify** How did NASA form?

4. **Apply Concepts** Draw an arrow on the figure below to show which direction the rocket will move.



5. **Explain** Why do rockets carry oxygen in addition to fuel?

6. **Identify** What must a rocket overcome in order to reach escape velocity?

7. **Infer** Is escape velocity the same for every planet and moon? Explain your answer.

Name _____ Class _____ Date _____

CHAPTER 22 Exploring Space

SECTION 2

Artificial Satellites

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is an artificial satellite?
- What are LEO and GEO?
- How do satellites benefit people?

How Do Satellites Affect Our Lives?

Imagine that you are watching TV. An emergency weather bulletin interrupts your favorite show. There is a hurricane warning. You grab your cell phone to call your friend. She lives in the hurricane's path.

The TV show, the weather bulletin, and probably even the phone call were made possible by artificial satellites. An **artificial satellite** is a human-made object that orbits a body in space. ☑

There are many kinds of artificial satellites. *Weather satellites* track the movements of gases in the atmosphere. This allows us to predict weather on Earth's surface. *Communications satellites* relay TV programs, phone calls, and computer data. *Remote-sensing satellites* monitor changes in the environment.

STUDY TIP

Compare As you read this section, make a table comparing the advantages and disadvantages of low Earth orbits and geostationary orbits.

READING CHECK

1. Define What is an artificial satellite?

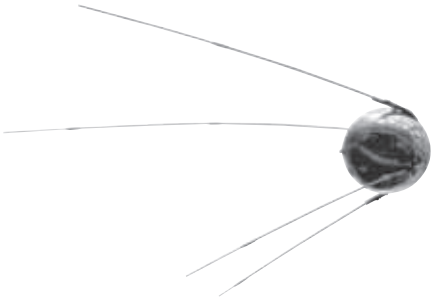
_____

_____

_____

THE FIRST ARTIFICIAL SATELLITES

The Soviet Union launched the first artificial satellite, *Sputnik 1*, in 1957. It orbited for 57 days before it fell back to Earth. Two months later, *Sputnik 2* carried the first living thing, a dog, into space. The United States launched its first satellite, *Explorer 1*, in 1958. By 1964, communications satellite networks were sending messages around the world.



Sputnik 1 was the first artificial satellite to orbit the Earth.

TAKE A LOOK

2. Identify What was *Sputnik 1*?

_____

_____

How Do Artificial Satellites Orbit?

Artificial satellites orbit the Earth in two main ways: low Earth orbit and geostationary orbit. Early satellites were placed in **low Earth orbit** (LEO). Low Earth orbit is a few hundred kilometers above the Earth's surface. A satellite in LEO moves around the Earth very quickly. Because it is close to the Earth's surface, it can provide clear images of Earth. ☑

READING CHECK

3. Describe About how far above the Earth's surface are satellites in LEO?

_____

_____

Satellites transmit their information back to the Earth's surface. In order for a place on Earth to receive information from a satellite, the satellite must be nearby. Satellites in LEO can be above different places on Earth at different times. They cannot always transmit their information back to receivers on Earth, because they are not always above their recievers. Therefore, they are out of contact with the surface for much of the time.

Most communications satellites and weather satellites move in geostationary orbits. In **geostationary orbit** (GEO), a satellite travels in an orbit that matches Earth's rotation. Therefore, the satellite is always above the same spot on Earth. Satellites in GEO are farther from the Earth than satellites in LEO. Therefore, satellites in GEO cannot produce such detailed images of the Earth's surface.

A satellite in GEO is always above its receivers on Earth. Therefore, these satellites are not out of contact with the surface. This allows the satellite transmissions, such as TV programs and phone calls, to be uninterrupted.

Critical Thinking

4. Infer Why is it important for communications satellites to be in GEO?

_____

_____

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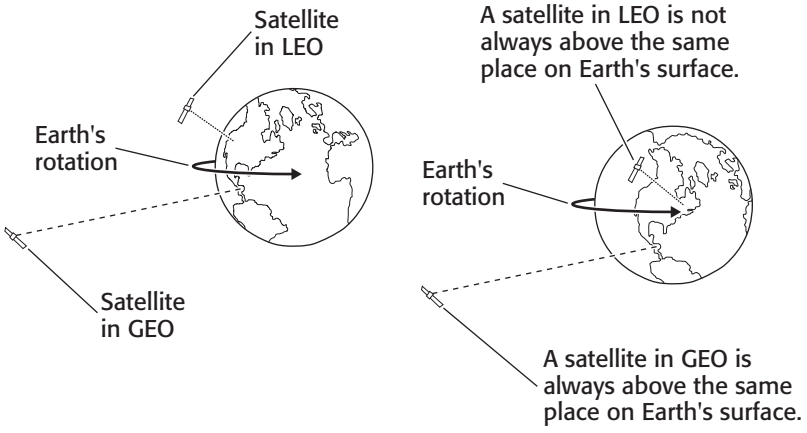
_____

_____

TAKE A LOOK

5. Identify Which kind of orbit allows a satellite to stay over the same place on Earth all the time?

_____



MILITARY SATELLITES

Cameras on satellites in LEO can take very detailed photos. The United States and the former Soviet Union used photographs from satellites to spy on each other. The United States and many other countries continue to use spy satellites for defense purposes. Scientists can also use photographs from military satellites to study changes on the Earth's surface. These changes include flooding, erosion, forest fires, and animal movements. ☑

READING CHECK

6. Explain How do scientists use the information from military satellites?

This photograph of San Francisco was taken by a Soviet spy satellite in LEO in 1989. The satellite was about 220 km above San Francisco when it took this picture.

Math Focus

7. Convert About how many miles above San Francisco was the satellite that took this picture?
1 km = 0.62 mi

THE GLOBAL POSITIONING SYSTEM

The *Global Positioning System* (GPS) is an example of military technology that has become part of everyday life. The GPS is made of 27 satellites that constantly send radio signals to the Earth. Receivers on Earth pick up these signals. The receivers can determine how far they are from each satellite. By combining information from four satellites, a GPS receiver can calculate its exact location on the Earth's surface. ☑

READING CHECK

8. Identify What is the GPS?

People use GPS receivers for many different reasons. Some are placed in cars to help prevent people from getting lost. Hikers and boaters use them as guides when they travel.

How Do Weather Satellites Work?

Weather satellites provide important information about conditions in Earth's atmosphere. Some weather satellites are in GEO. These satellites provide a "big-picture" view of the Earth's atmosphere. They monitor the atmosphere and look for places where severe weather may happen.

Some weather satellites are in LEO. These satellites are usually placed in polar orbits. *Polar orbits* are orbits that are nearly at right angles to Earth's direction of rotation. The figure below shows a satellite in polar LEO. ☑

READING CHECK

9. Define What is a polar orbit?

_____

_____

_____

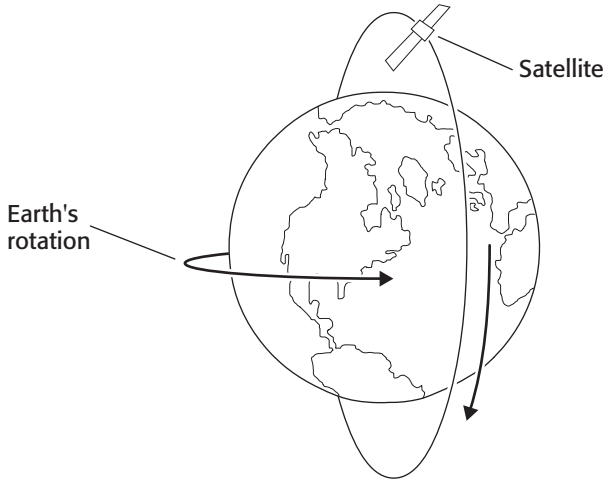
TAKE A LOOK

10. Infer How is the information from a weather satellite in LEO different from that of a satellite in GEO?

_____

_____

_____



Weather satellites in polar LEO can provide detailed information about the weather in an area.

How Do Communications Satellites Work?

Many types of communications use radio waves or microwaves to carry messages. These waves are useful for communications because they can travel over long distances. However, the waves travel in straight lines, and they cannot travel through the Earth. This means that it is impossible to send a message directly to someone on the other side of the Earth. ☑

READING CHECK

11. Explain Why is it impossible to send a microwave or radio wave message directly to someone on the other side of the Earth?

_____

_____

_____

Communications satellites in GEO have helped to solve this problem. They *relay*, or send, information from one point on Earth's surface to another. For example, people in the United States can watch television programs from China. The television signals travel from China to a communications satellite in GEO. The satellite transmits the signal to other communications satellites. These satellites transmit the signal to receivers in the United States.

What Are Remote-Sensing Satellites?

Scientists can use satellites to study the Earth in ways that were not possible before. Satellites gather information by remote sensing. *Remote sensing* is the gathering of images and data from a distance. Remote-sensing satellites measure light and other forms of energy that are reflected from the Earth's surface. They use the measurements to make detailed maps of the Earth's surface. ☑

READING CHECK

12. Explain How do remote-sensing satellites make maps of the Earth's surface?

_____

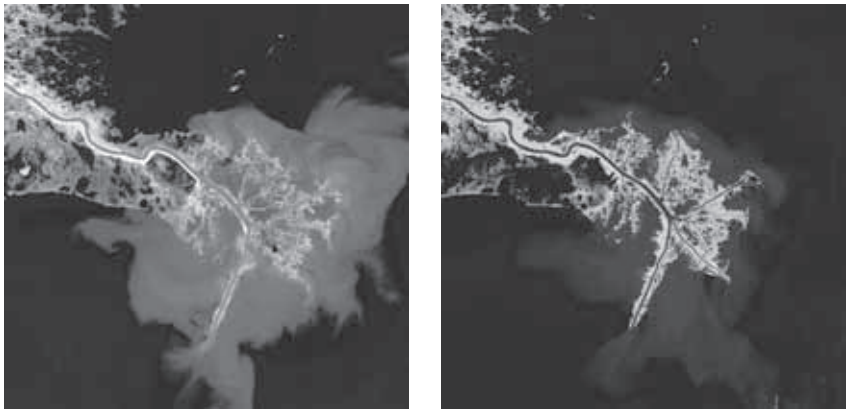
_____

_____

THE LANDSAT PROGRAM

The Landsat program is one of the most successful remote-sensing projects. It began in 1972 and continues today.

Landsat images have helped scientists to identify and track environmental changes. For example, the figures below show Landsat images of part of the Mississippi Delta. One image was taken in 1973. The other was produced in 2003. The images show that the delta is shrinking because less silt is reaching it. They also show that wetlands in the area are disappearing. The information from these satellite images can help scientists reduce these problems.



These Landsat images show how the Mississippi Delta changed over 30 years. Because of human activities, the delta is shrinking and wetlands are disappearing.

TAKE A LOOK

13. Describe What do the Landsat images of the Mississippi Delta show?

_____

_____

NEWER REMOTE-SENSING SATELLITES

One of the newest remote-sensing satellites is *Terra 1*. This satellite is part of NASA's Earth Observing System (EOS). Satellites in the EOS program are designed to work together to combine many kinds of data. For example, these satellites can track changes in the land, the atmosphere, the oceans, and the icecaps.

Name _____ Class _____ Date _____

Section 2 Review

SECTION VOCABULARY

artificial satellite any human-made object placed in orbit around a body in space **geostationary orbit** an orbit that is about 36,000 km above Earth's surface and in which a satellite is above a fixed spot on the equator	**low Earth orbit** an orbit that is less than 1,500 km above Earth's surface

1. **Identify** What was the first artificial satellite that the United States placed in orbit around the Earth?

2. **Compare** Give two differences between a satellite in GEO and one in LEO.

3. **Describe** How does the Global Positioning System work?

4. **Identify** What do weather satellites do?

5. **Explain** How do communications satellites allow people in the United States to watch television programs from China?

6. **Define** What is remote sensing?

Name _____ Class _____ Date _____

CHAPTER 22 Exploring Space

SECTION 3

Space Probes

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Why do we use space probes to visit other planets?
- What kinds of information can space probes gather?

What Are Space Probes?

What does the surface of Mars look like? Does life exist anywhere else in the solar system? To answer questions like these, scientists send space probes through the solar system. A **space probe** is a vehicle that carries scientific instruments into outer space, but has no people on board. Space probes visit planets or other bodies in space. They can complete missions that would be too dangerous or expensive for humans to carry out.

STUDY TIP

Summarize Make a timeline showing when the space probes in this section were launched. On the timeline, describe the destination of each probe.

LUNA AND *CLEMENTINE*

Luna 1, the first space probe, was launched by the Soviet Union in 1959. It flew past the moon. In 1966, *Luna 9* made the first soft landing on the moon's surface. In all, space probes from the United States and the Soviet Union have completed more than 30 lunar missions.

In 1994, the United States probe *Clementine* discovered that craters on the moon may contain water. The water may have been left from comet impacts. In 1998, the *Lunar Prospector* confirmed that frozen water exists on the moon. This ice would be valuable to a human colony on the moon.

***Luna 9* (U.S.S.R)**
Launched: January 1966
Purpose: to land the first spacecraft on the moon

***Clementine* (U.S.)**
Launched: January 1994
Purpose: to map the composition of the moon's surface

Critical Thinking

1. Infer Why would frozen water on the moon be useful for a human colony there?

_____

_____

_____

_____

TAKE A LOOK

2. Identify What was the first spacecraft to land softly on the moon?

_____

VENERA 9: THE FIRST PROBE TO LAND ON VENUS

The Soviet probe *Venera 9* was the first probe to land on Venus. It parachuted into Venus's atmosphere and transmitted images of the surface to Earth. *Venera 9* found that the surface temperature and atmospheric pressure on Venus are much higher than on Earth. ☑

Venera 9 and earlier missions to Venus showed that Venus has a severe greenhouse effect. Today, scientists study Venus's atmosphere to learn about the effects of increased greenhouse gases in Earth's atmosphere.

READING CHECK

3. Identify What was the first space probe to land on Venus?

_____

THE MAGELLAN MISSION: MAPPING VENUS

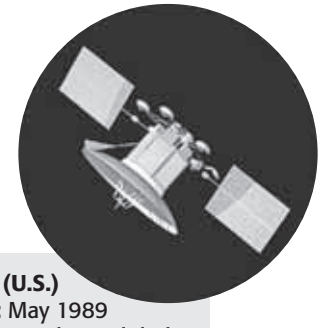
The United States launched the *Magellan* probe in 1989. This probe mapped 98% of the surface of Venus. The data were transmitted back to Earth. Computers used the data to produce three-dimensional images of the surface of Venus. The Magellan mission showed that Venus has surface features that are similar to Earth's. Some of these features suggest that plate tectonics occurs there. Venus also has volcanoes.

Math Focus

4. Reduce Fractions What fraction of Venus' surface did *Magellan* map? Give your answer as a reduced fraction.

_____

***Venera 9* (U.S.S.R.)**
Launched: June 1975
Purpose: to record the surface conditions of Venus



***Magellan* (U.S.)**
Launched: May 1989
Purpose: to make a global map of the surface of Venus

TAKE A LOOK

5. Identify What was the purpose of the *Venera 9* probe?

_____

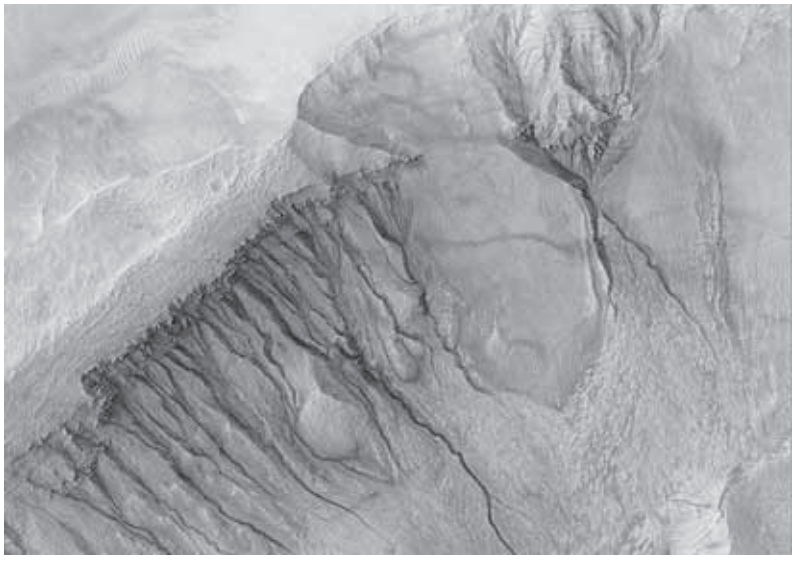
_____

THE VIKING MISSIONS: EXPLORING MARS

The United States sent a pair of probes called *Viking 1* and *Viking 2* to Mars in 1975. The surface of Mars is similar to the Earth's surface. Therefore, one of the main goals of the Viking mission was to look for signs of life on Mars. The probes gathered soil and tested it for evidence of life. They did not find signs of life. However, they did discover that Mars was once much warmer and wetter than it is now.

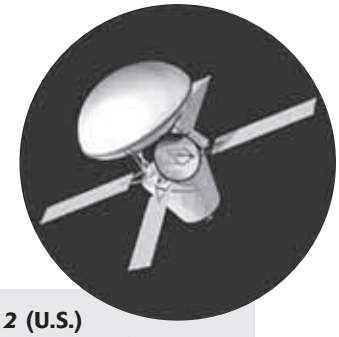
THE MARS PATHFINDER MISSION: REVISITING MARS

A NASA space probe, the *Mars Pathfinder*, visited the surface of Mars again in 1997. The goal of the Mars Pathfinder mission was to explore Mars more cheaply than the Viking missions. The probe sent back images of channels on the planet's surface. The channels look like dry river valleys on Earth. These images suggest that running water may once have flowed on Mars.

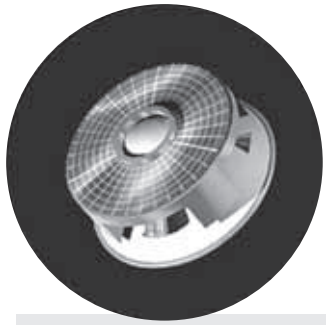


The *Mars Pathfinder* probe took many photographs of the surface of Mars. These photographs showed many features on the surface of Mars. Some of the features, like those shown here, indicate that liquid water may once have flowed over Mars' surface.

The *Mars Pathfinder* probe landed on Mars and sent out the *Sojourner* rover. The *Sojourner* traveled across the surface of Mars for almost three months, collecting data and recording images. The European Space Agency and NASA have more Mars missions planned in the near future. ☑



***Viking 2* (U.S.)**
Launched: September 1975
Purpose: to search for life on the surface of Mars



***Mars Pathfinder* (U.S.)**
Launched: December 1996
Purpose: to use inexpensive technology to study the surface of Mars

TAKE A LOOK

6. Explain How do scientists know that liquid water may once have flowed on the surface of Mars?

_____

_____

_____

_____

READING CHECK

7. Identify What did the Sojourner rover do?

_____

_____

_____

How Can Space Probes Help Us Learn About the Outer Solar System?

Jupiter, Saturn, Uranus, Neptune, and Pluto make up the outer solar system. These planets are very far away. Probes to these planets may take 10 years or more to complete their missions. ☑

READING CHECK

8. Explain Why do probes to the outer solar system take so long to complete their missions?

_____

_____

PIONEER AND VOYAGER: TO JUPITER AND BEYOND

The *Pioneer 10* and *Pioneer 11* space probes were the first to visit the outer planets. These probes sampled the *solar wind*—the flow of particles coming from the sun. The Pioneer probes also gathered a lot of data about the composition of Jupiter's atmosphere. In 1983, *Pioneer 10* became the first probe to travel past the orbit of Pluto.

The Voyager space probes were the first to detect Jupiter's faint rings. *Voyager 2* was the first probe to fly by the gas giants—Jupiter, Saturn, Uranus, and Neptune. Today, the Pioneer and Voyager probes are near the edge of the solar system. Some of them are still sending back data! ☑

READING CHECK

9. Identify What was the first probe to fly by all four of the gas giants?

_____

THE GALILEO MISSION

The *Galileo* probe arrived at Jupiter in 1995. It sent a smaller probe to measure the composition, density, temperature, and cloud structure in Jupiter's atmosphere. *Galileo* gathered data about Jupiter's magnetic properties and the geology of some of Jupiter's moons. *Galileo* discovered that some of the moons have magnetic fields. It also found that one of the moons, Europa, may have an ocean of liquid water under its icy surface.

Pioneer 10 (U.S.)
Launched: March 1972
Purpose: to study Jupiter and the outer solar system

Galileo (U.S.)
Launched: October 1989
Purpose: to study Jupiter and its moons

TAKE A LOOK

10. Infer How long did it take Pioneer 10 to travel from Earth to Pluto?

_____

THE CASSINI MISSION: EXPLORING SATURN'S MOONS

The *Cassini* space probe was launched in 1997 on a seven-year journey to Saturn. In 2005, it launched a small probe to examine the atmosphere of Titan, one of Saturn's moons. Scientists think that Titan's atmosphere is similar to the Earth's early atmosphere. Therefore, studying Titan's atmosphere may help scientists learn how Earth's atmosphere formed and changed.

Critical Thinking

11. Explain Why are scientists interested in the atmosphere of Titan?

What Are Some More Recent Space Probes?

The early space probe missions were large and expensive. Probes such as *Voyager 2* and *Galileo* took many years to develop. Today, NASA is trying to develop missions that are "faster, cheaper, and better."

STARDUST: COMET DETECTIVE

The *Stardust* space probe was the first probe to focus only on a comet. The probe was launched in 1999 and arrived at the comet in 2004. It gathered samples of the comet's dust tail and returned the samples to Earth in 2006.

Critical Thinking

12. Infer What was the purpose of the *Stardust* probe?

DEEP SPACE 1: TESTING ION PROPULSION

Another new space probe project is the New Millennium program. The purpose of this program is to test new technologies that can be used in the future. *Deep Space 1*, launched in 1998, is the first mission of this program. ☑

The purpose of the *Deep Space 1* mission is to test a new type of propulsion system. *Deep Space 1* uses an ion-propulsion system. Ion-propulsion systems may help future space probes travel more quickly with less fuel.

READING CHECK

13. Describe What is the purpose of the New Millennium program?

Deep Space 1 uses an ion rocket to move.

Name _____ Class _____ Date _____

Section 3 Review

SECTION VOCABULARY

space probe an uncrewed vehicle that carries scientific instruments into space to collect scientific data	

1. Identify What was the first space probe to fly past the moon?

_____

2. Describe Complete the table below.

Probe	Year of launch	Purpose
Venera 9		
Viking 2		
Clementine		
Pioneer 10		
Galileo		
Cassini		
Deep Space 1		

3. Describe What did the Magellan probe discover?

_____

_____

4. Explain What was unique about the mission of the *Stardust* probe?

_____

_____

5. Identify Relationships How can missions to Venus and Titan help scientists learn about the Earth?

_____

_____

_____

_____

_____

Name _____ Class _____ Date _____

CHAPTER 22 Exploring Space

SECTION 4

People in Space

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Who was the first person in space?
- How are space shuttles different from other space vehicles?
- Why are space stations important?

Who Were the First People in Space?

On April 12, 1961, a rocket stood on a launch pad in the Soviet Union. A cosmonaut named Yuri Gagarin waited inside. He was about to do what no human had done before. He was about to travel to outer space. No one knew if his brain would function in space or if he would be instantly killed by radiation.

Later that day, Yuri Gagarin became the first human to orbit Earth. His flight lasted 108 minutes. News of his success was quickly broadcast around the world. ☑

In February 1962, John Glenn became the first American to orbit the Earth. Seven years later, the world watched on television as the *Apollo 11* landing module landed on the moon. During the *Apollo 11* mission, Neil Armstrong became the first person to stand on a world other than Earth. *Apollo 11* carried moon rocks back to Earth for scientists to study. Its crew also put devices on the moon to study moonquakes and the solar wind.

Person	Accomplishment
Yuri Gagarin	
John Glenn	
	first person to stand on a world other than Earth

STUDY TIP

Outline Before you read this section, make an outline of it using the headings from the section. As you read, fill in the outline with the main ideas of the section.

READING CHECK

1. Identify Who was the first person to orbit the Earth?

_____

TAKE A LOOK

2. Describe Fill in the blank spaces in the table.

REUSABLE SPACE VEHICLES

The Saturn V rockets, which carried the Apollo astronauts to the moon, were large and expensive. To save money and natural resources, NASA began to develop the space shuttle program in 1972. A **space shuttle** is a reusable space vehicle that takes off like a rocket and lands like an airplane. Since 1981, NASA has completed more than 100 space shuttle missions.

Critical Thinking

3. Apply Concepts Why doesn't the orbiter need booster rockets to keep it in orbit?

(Hint: Why doesn't the moon need booster rockets to stay in orbit?)

TAKE A LOOK

4. Identify What part of the space shuttle carries the crew?

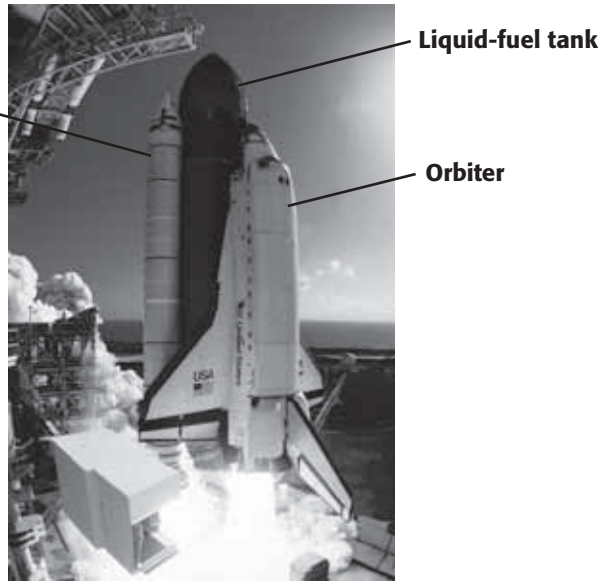
Math Focus

5. Convert About how high, in miles, did *SpaceShipOne* carry its crew?

1 km = 0.62 mi

PARTS OF A SPACE SHUTTLE

A space shuttle has three main parts. The *orbiter* is the part that looks like an airplane. The orbiter carries the astronauts and equipment into space. The *liquid-fuel tank* carries some of the fuel for the rockets. Two white *solid-fuel booster* rockets help the shuttle reach orbit. Then, they fall back to Earth, along with the liquid-fuel tank. The booster rockets are reused, but the fuel tank is not.



SHUTTLE TRAGEDIES

On January 28, 1986, a booster rocket on the space shuttle *Challenger* exploded just after takeoff. In 2003, the space shuttle *Columbia* exploded as it reentered the atmosphere. In both instances, all the astronauts on board each shuttle were killed. Tragedies such as these show some of the dangers of space travel. However, scientists have learned from these accidents. They try to make sure that future space flights are safer.

SPACESHIPONE: PRIVATE SPACECRAFT

In 2004, *SpaceShipOne* won the $10 million X Prize. *SpaceShipOne* was the first privately owned, reusable vehicle to carry a crew to an altitude of 100 km. The X Prize was offered to encourage private companies to develop space technology. Some day, ships like *SpaceShipOne* may offer flights to space, much like airplanes carry people to places on Earth today. ☑

What Is a Space Station?

A **space station** is a large artificial satellite where people can live and work. In 1971, the Soviet Union became the first to successfully place a space station in orbit. By 1982, the Soviets had put up seven space stations, including the space station *Mir*. Cosmonauts on these space stations studied the effects of weightlessness on humans and carried out many other experiments. ☑

Skylab was the United States' first space station. It was a science and engineering laboratory. Scientists on *Skylab* carried out experiments in biology, astronomy, and manufacturing.

READING CHECK

6. Identify What country was the first to successfully place a space station in orbit?

_____

THE *INTERNATIONAL SPACE STATION*

The *International Space Station* (*ISS*) is being constructed in LEO by Russia, the United States, and 14 other countries. Construction began in 1998. The first crew boarded in 2000. The *ISS* will provide a unique laboratory for research and experiments. It is scheduled to be completed by 2010.

Critical Thinking

7. Apply Ideas Is the International Space Station always above the same point on Earth's surface? Explain your answer.

_____

_____

_____

_____

What Are the Benefits of the Space Program?

Space offers resources beyond those on Earth. For example, a rare form of helium is found on the moon. Some day, this helium might be a fuel in nuclear fusion reactors. These reactors could produce a lot of energy with little harmful waste.

A base on the moon could be used to manufacture materials in low gravity or in a vacuum. A colony on the moon or Mars could help bring space resources to Earth. It could also be a base to explore the rest of the solar system.

Space exploration can be expensive. Why do we continue to explore space? Space exploration serves our quest for new knowledge. It challenges our courage. It also has expanded our technology. Many technologies that were developed for the space program are now used in everyday life. A few of these technologies are listed below.

• smoke detectors	• cordless power tools
• pacemakers	• artificial heart pumps
• land mine removal devices	• medical lasers
• fire fighting equipment	• invisible dental braces
• video game joysticks	• ear thermometers

Name _____ Class _____ Date _____

Section 4 Review

SECTION VOCABULARY

space shuttle a reusable space vehicle that takes off like a rocket and lands like an airplane	**space station** a long-term orbiting platform from which other vehicles can be launched or scientific research can be carried out

1. Compare What is the main difference between space shuttles and Saturn V rockets?

2. Identify Who was the first person on the moon?

3. List What are the three main parts of the space shuttle?

4. Identify Which two parts of the space shuttle are reused?

5. List Give five technologies that were developed for the space program that are now used in everyday life.

6. Identify What is *SpaceShipOne*?

7. Describe Give two ways that space exploration may benefit people on Earth.