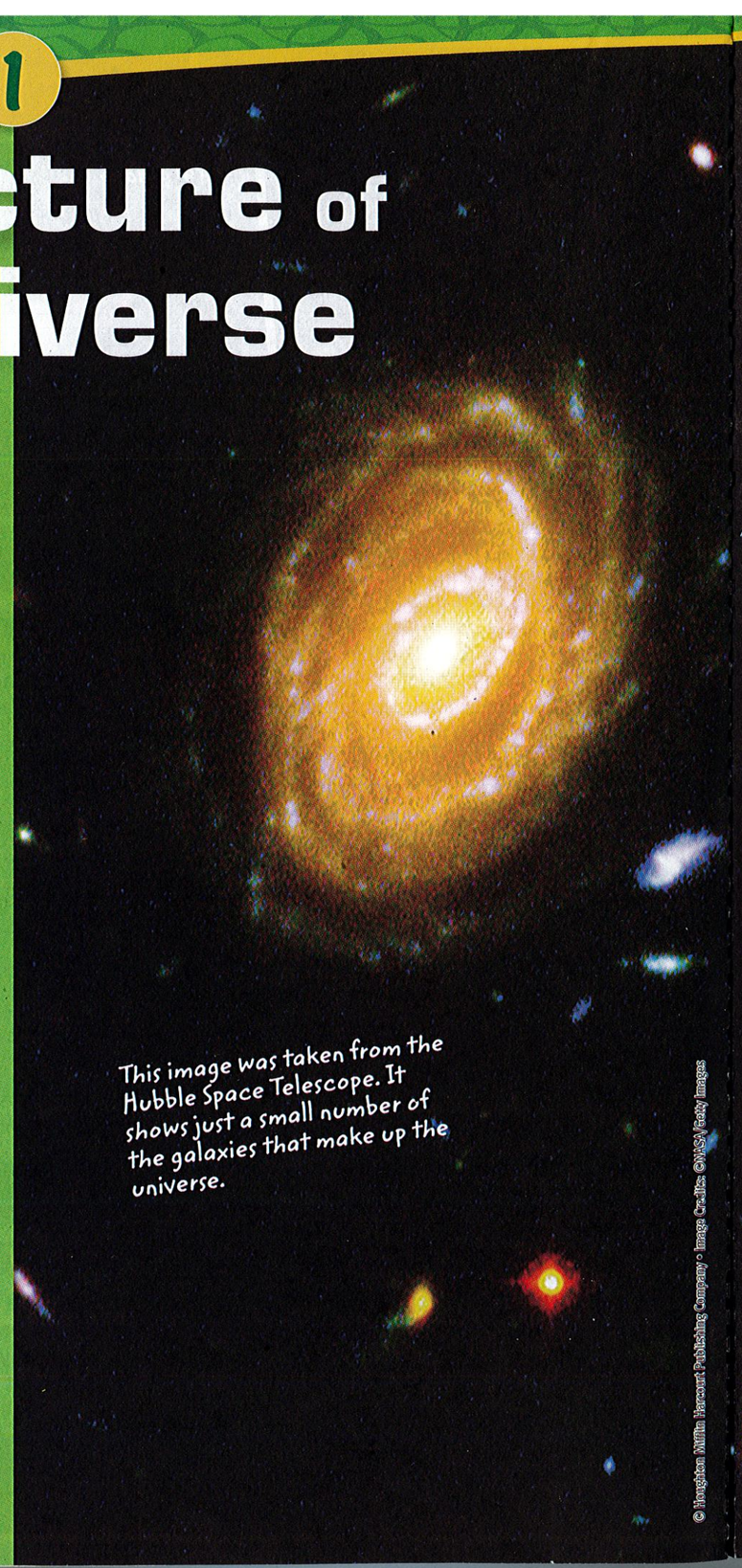
Lesson 1

Structure of the Universe

ESSENTIAL QUESTION

What makes up the universe?

By the end of this lesson, you should be able to describe the structure of the universe, including the scale of distances in the universe.



This image was taken from the Hubble Space Telescope. It shows just a small number of the galaxies that make up the universe.

Lesson Labs

Quick Labs
- Modeling the Expanding Universe
- Modeling Galaxies

Field Lab
- Schoolyard Solar System

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	You live on Earth.
☐	☐	Earth orbits a star called the *moon*.
☐	☐	Earth and the sun have the same composition.
☐	☐	The sun is just one of many stars in the Milky Way galaxy.
☐	☐	Distances in the universe are extremely large.

2 Draw When you look into the night sky, you are seeing only a very small part of the universe. Use the space below to draw what you see in the night sky.

Active Reading

3 Synthesize Many English words have their roots in other languages. Use the Latin words below to make an educated guess about the meaning of the word *universe*.

Latin word	Meaning
unus	one
vertere	to turn

Example sentence
Earth is part of the universe.

universe:

Vocabulary Terms

- solar system
- planet
- star
- galaxy
- light-year
- universe

4 Apply This list contains the key terms that you'll learn in this lesson. As you read, circle the definition of each term.

Our place in space

What makes up the universe?

You live on Earth, which is one of eight planets that orbit the sun. As you probably know, the sun is a star. A *star* is a large celestial body that is composed of gas and emits light. Stars are grouped together in structures known as galaxies. A *galaxy* is a large collection of stars, gas, and dust. Based on observations by the Hubble Space Telescope, there are an estimated 100 billion galaxies in the universe. *Universe* is the word that scientists use to describe space and all of the energy and matter in it.

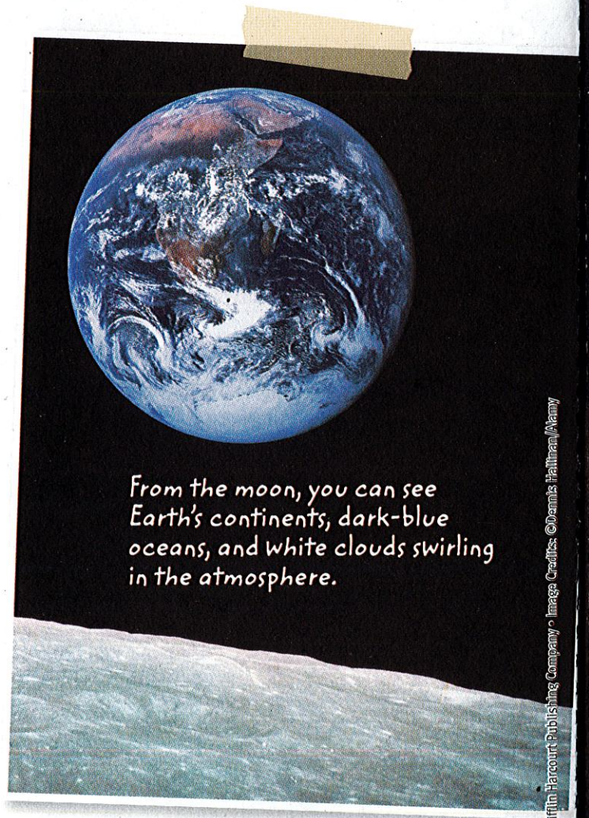
Active Reading

5 Identify As you read the text, underline those characteristics of Earth that make it a special place.

Earth—Our Home Planet

Earth is a special place. Imagine Earth without water. There would be no vast, deep, blue oceans or broad, muddy rivers. If there was no water, there would be no evaporation. Therefore, no clouds would form in Earth's atmosphere, so there would be no rain or snow. Without water, there would be no plants to add oxygen to the atmosphere. And without oxygen, there would be no animal life on Earth.

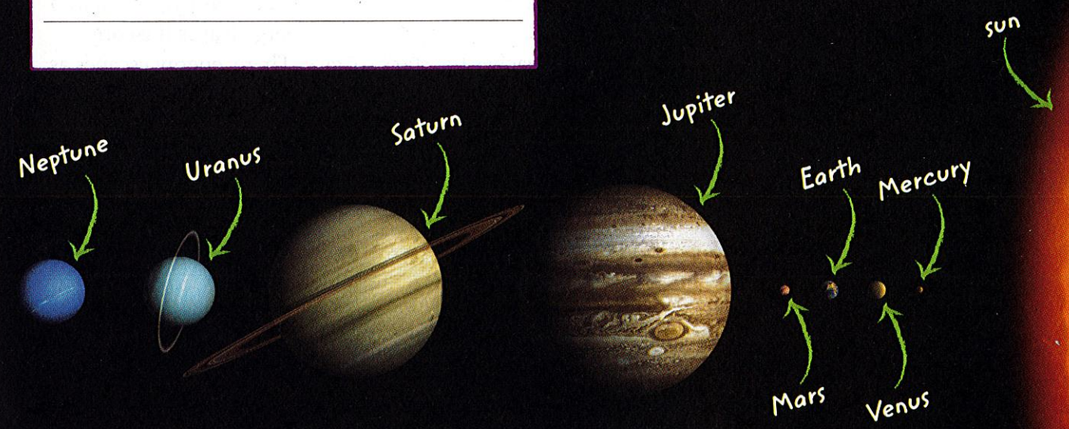
Earth's atmosphere contains the combination of gases that animals need to breathe. The atmosphere also contains a thin layer of ozone gas. Ozone molecules in this layer absorb radiation from the sun that can be harmful to life. In addition, there are certain gases in the atmosphere that keep temperatures on Earth warm enough for life to exist.



From the moon, you can see Earth's continents, dark-blue oceans, and white clouds swirling in the atmosphere.

Visualize It!

6 Analyze What is the relationship between the sizes of the planets and their distances from the sun?



Sizes are roughly to scale. Distances are not.

The Solar System

Active Reading **7 Identify** As you read the text, underline the different bodies that make up the solar system.

The **solar system** is the collection of large and small bodies that orbit our central star, the sun. The contents of the solar system are numerous and stretch across a large area of space. For example, the solar system is so big that the distance from the sun to Neptune is 4.5 billion kilometers.

If you crossed the solar system beginning at the sun, you would encounter eight large bodies called *planets*. A **planet** is a spherical body that orbits the sun. Planets are generally larger than the other bodies in the solar system. The four planets that orbit nearest to the sun are the terrestrial planets. They are Mercury, Venus, Earth, and Mars. The terrestrial planets are all rocky, dense, and relatively small. The four planets that orbit farthest from the sun are the gas giant planets. They are Jupiter, Saturn, Uranus, and Neptune. These large planets have thick, gaseous atmospheres; small, rocky cores; and ring systems of ice, rock, and dust.

Orbiting most of the planets are smaller bodies called *moons*. Earth has only one moon, but Jupiter has more than 60. The rest of the solar system is made up of other small bodies. These include dwarf planets, comets, asteroids, and meteoroids. Altogether, there are up to a trillion small bodies in the solar system.

Think Outside the Book

8 Apply Conduct research about one of the following aspects of stars:

- composition
- layers
- energy production
- size

Present your findings to the class in the form of an oral presentation or a poster presentation.

Stars

A **star** is a large celestial body that is composed of gas and emits light. Like the sun, most stars are composed almost entirely of hydrogen and helium. Small percentages of other elements are also found in stars. Energy production takes place in the center, or core, of a star. Energy is produced by the process of nuclear fusion. In this process, stars fuse lighter elements, such as hydrogen, into heavier elements, such as helium. This energy leaves the core and eventually reaches the star's surface. There, energy escapes as visible light, other forms of radiation, heat, and even wind.

Stars vary greatly in size. Small stars, such as white dwarfs, may be about the size of Earth. Giant and supergiant stars may be from 10 to as much as 1,000 times as large as the sun.

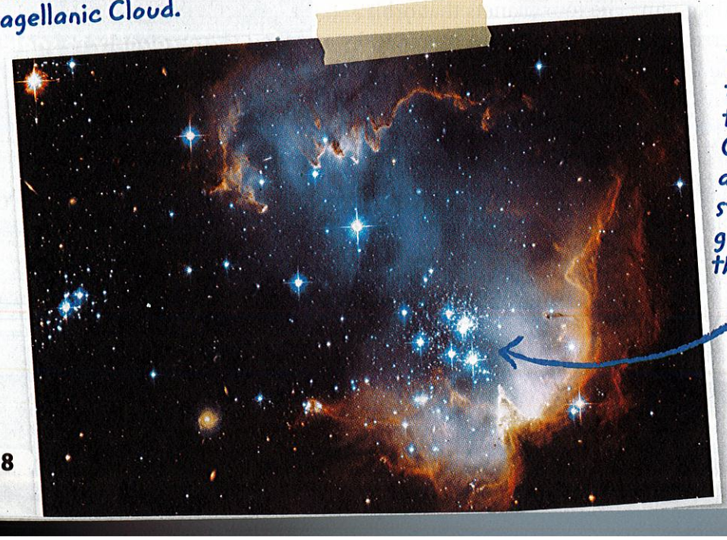
Active Reading **9 Compare** How does the composition of a star differ from the composition of a planet?

Galaxies

Our solar system is located in the Milky Way galaxy. A **galaxy** (GAL•eck•see) is a large collection of stars, gas, and dust that is held together by gravity. Small galaxies, called *dwarf galaxies,* may contain as few as 100 million stars. Giant galaxies, however, may contain hundreds of billions of stars.

The Milky Way is a spiral galaxy. Spiral galaxies are shaped like pinwheels. They have a central bulge from which two or more spiral arms extend. Stars form in or near the spiral arms. Elliptical galaxies and irregular galaxies are two other kinds of galaxies. Elliptical galaxies look like spheres or ovals, and they do not have spiral arms. Irregular galaxies appear as splotchy, irregularly shaped "blobs." Irregular galaxies are very active areas of star formation.

The Small Magellanic Cloud is an irregular dwarf galaxy that is located near the Milky Way. A few billion stars make up the Small Magellanic Cloud.

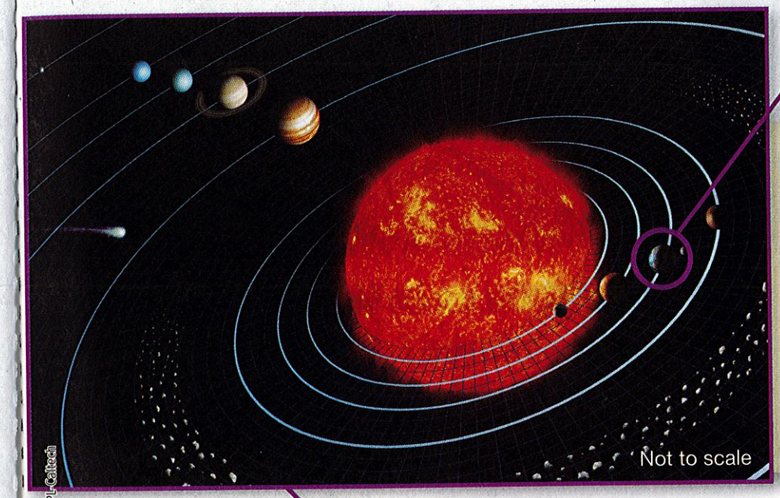


This image shows a star formation region within the Small Magellanic Cloud. The blue stars are very young and are still surrounded by the gas and dust from which they formed.

Visualize It!

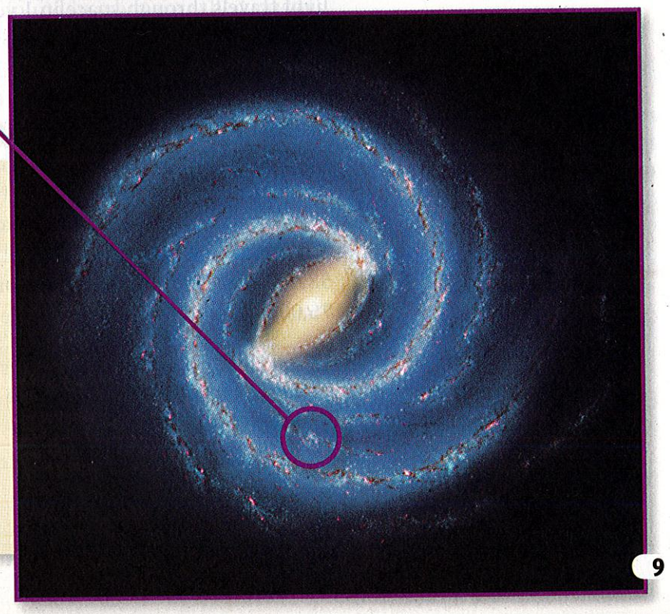
10 Describe In the boxes below, write in your answers to each of the questions.

You live on Earth. What is Earth's place in the universe?



Earth is part of the solar system. What bodies make up our solar system?

The solar system is located within a spiral arm of the Milky Way galaxy. What is a galaxy?



How big is big?

How are distances in the universe measured?

Distances between most objects in the universe are so large that astronomers do not use kilometers to measure distance. Instead, astronomers measure distance using the speed of light. This unit of measure is known as a light-year. A **light-year** is the distance that light travels through space in 1 year. Light travels through space at about 300,000 km/s, or about 9.5 trillion km in 1 year. The closest star to the sun and Earth is Proxima Centauri. It takes light about 4.3 years to travel from Proxima Centauri to us. Therefore, the distance from Proxima Centauri to Earth is around 4.3 light-years. Light from the sun travels to Earth in a little more than 8 minutes. Thus, the distance from the sun to Earth is around 8 light-minutes.

How do distances affect space travel? Our fastest interplanetary spacecraft travel through space at about 58,000 km/h. At this speed, it would take a spacecraft more than 75,000 years to reach Proxima Centauri.

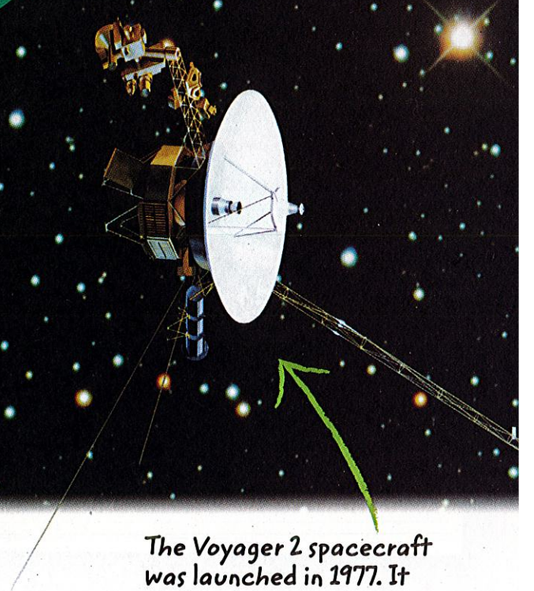
11 Explain The Andromeda galaxy is located approximately 2.5 million light-years from Earth. Why is the light that reaches Earth 2.5 million years old?

What is the structure of the universe?

The **universe** can be defined as space and all the matter and energy in it. However, this definition does not tell us about the structure of the universe. Astronomers now know that throughout the universe there are areas where galaxies are densely concentrated. These are areas where galaxies are found in what are called *clusters* and *superclusters*. Clusters contain as many as several thousand galaxies. Superclusters can be made up of ten or more clusters of galaxies. There are also areas throughout the universe where very little matter exists. These are huge, spherical areas called *voids*.

Astronomers have begun to think of the universe as having a structure similar to soap bubbles. Clusters and superclusters are located along the thin bubble walls. The interiors of the bubbles are voids. It takes light hundreds of millions of years to cross the largest voids.

Active Reading **13 Describe** What is the general structure of the universe?



The Voyager 2 spacecraft was launched in 1977. It explored Jupiter, Saturn, Uranus, and Neptune, and is now close to moving out of the solar system and into interstellar space.

Think Outside the Book **Inquiry**

12 Apply In the text, the universe is described as being composed of galaxies and voids. Design and build a model that shows the structure of the universe as you imagine it to be.

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

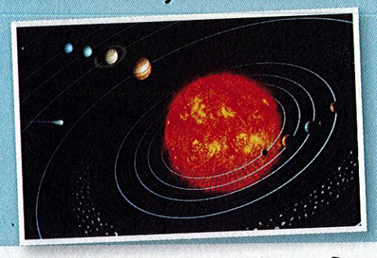
Structure of the Universe

Earth is a planet.

14 What is Earth's place in the universe?

_____

Bodies in our solar system orbit the sun.



15 What makes up our solar system?

_____

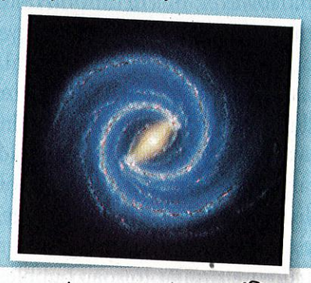
_____

The sun is a star.

16 What is a star?

_____

The Milky Way is a galaxy.



17 What are galaxies made up of?

_____

Answers: 14 a planet that orbits the sun; 15 the sun, planets, moons, dwarf planets, comets, asteroids, and meteoroids; 16 a large celestial body that is composed of gas and emits light; 17 stars, gas, and dust

18 Describe Beginning with Earth, summarize the structure of the universe.

Lesson Review

Vocabulary

Fill in the blank with the term that best completes the following sentences.

1 A _____ is a large collection of stars, gas, and dust that is held together by gravity.

2 Space and all matter and energy in it is called the _____.

3 A _____ consists of a star and all of the bodies in orbit around it.

Key Concepts

In the following table, write the name of the correct structure next to the definition.

Definition	Structure
4 Identify What is a large celestial body that is composed of gas and emits light?	
5 Identify What is a spherical body that orbits the sun?	

6 Explain Why can the structure of the universe be compared to soap bubbles?

7 Define Define light-year, and explain how and why light-years are used to measure distances in the universe.

Critical Thinking

Use the table to answer the following questions.

Object	Distance from Earth
sun (nearest star)	8.3 light-minutes
Proxima Centauri (nearest star to sun)	4.3 light-years
center of Milky Way galaxy	25,000 light-years
Andromeda galaxy (nearest large galaxy)	2.5 million light-years

8 Apply Given current spacecraft technology, which of the objects in the table do you think it would be possible for you to travel to in your lifetime?

9 Determine A planet in our solar system is located far from the sun. Describe the size and composition of this planet.

10 Deduce What do you think that astronomers mean when they use the term *observable universe*? (Hint: Think of the time it takes for light from very distant objects to reach Earth.)