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.

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.

A blue flame is hotter than a yellow one.

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?

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_____

_____

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.

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.

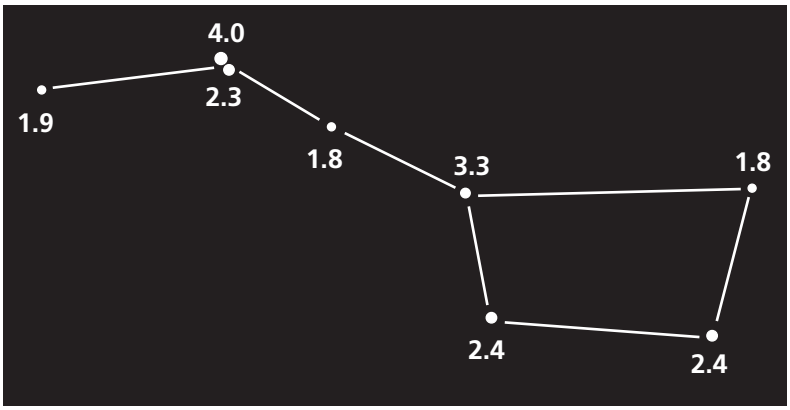
Today, scientists give each star a number to show its brightness, or *magnitude*. The dimmest stars have the largest numbers. The brightest stars have the smallest numbers. The magnitude of a very bright star can even be a negative number!

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

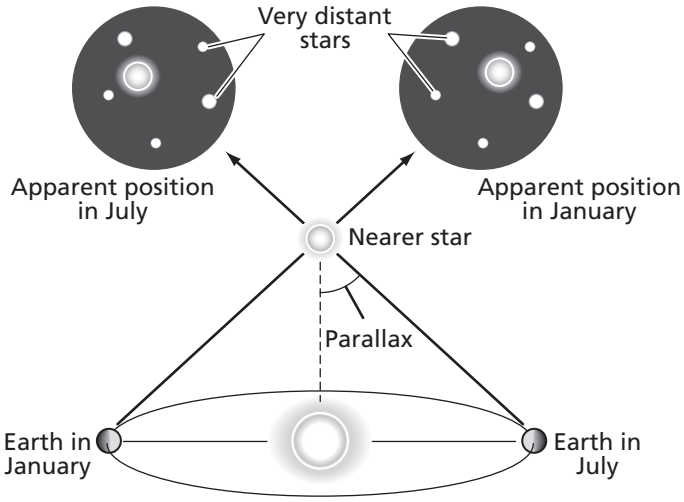
12. Calculate What is the distance in kilometers from Earth to a star that is 30 light years away?

_____

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.

Parallax



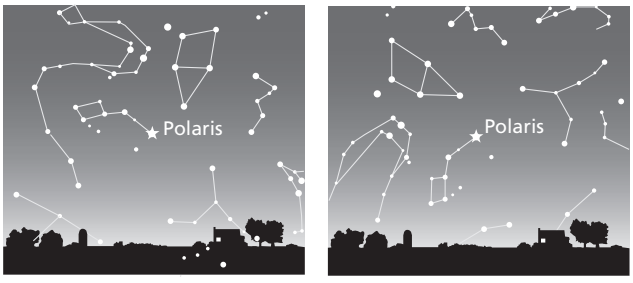
As the Earth revolves around the sun, a star's position seems to change.

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?

_____

_____

_____

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. ☑

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.

READING CHECK

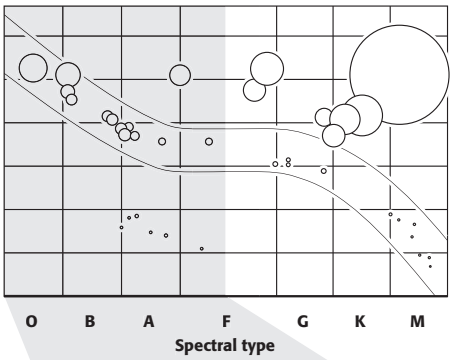
4. Identify Which two characteristics of a star must a scientist measure to make an H-R diagram?

_____

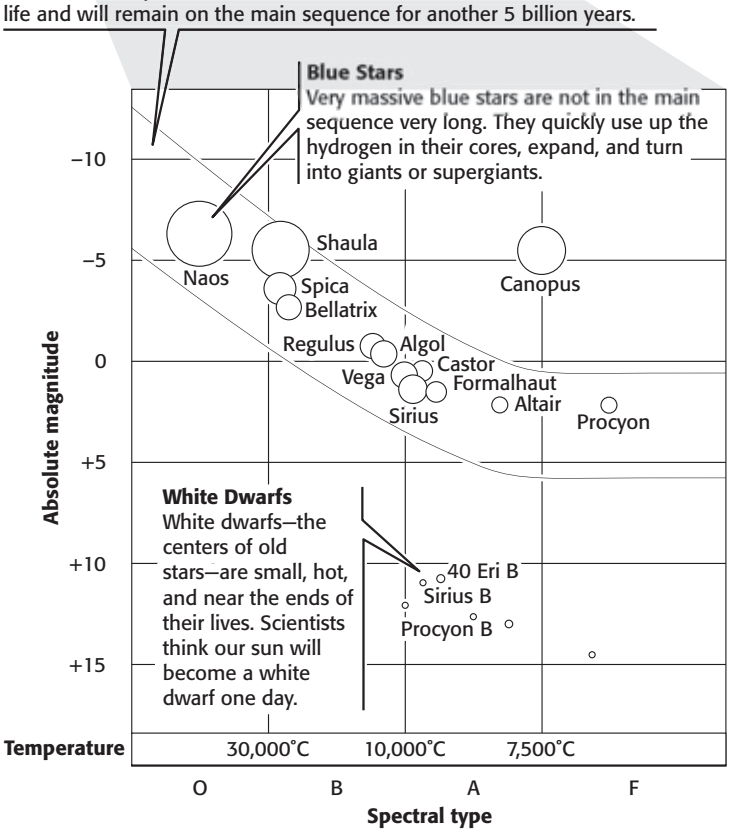
_____

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?

_____

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TAKE A LOOK

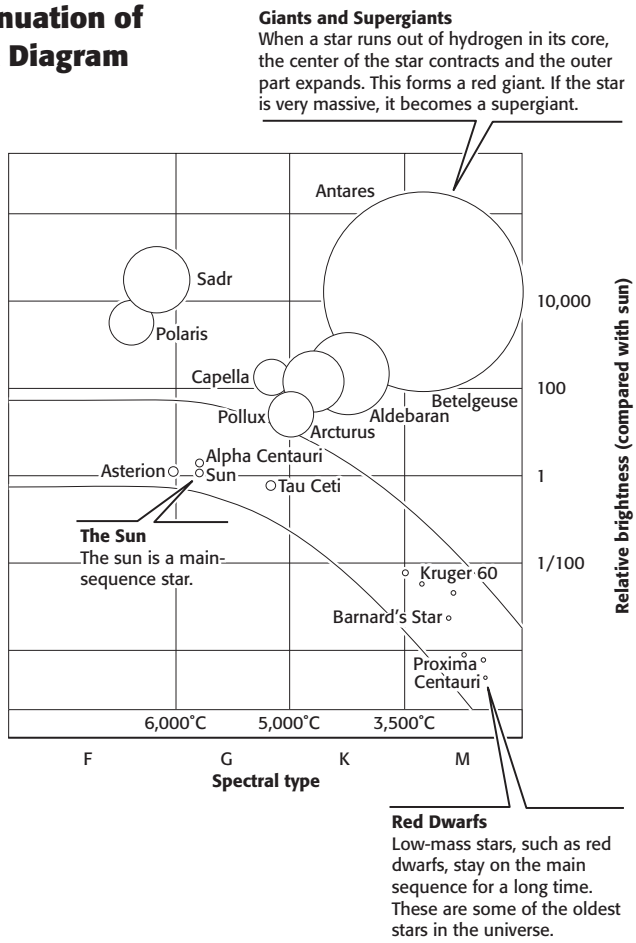
6. Identify Where in the H-R diagram are the brightest stars located?

_____

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?

_____

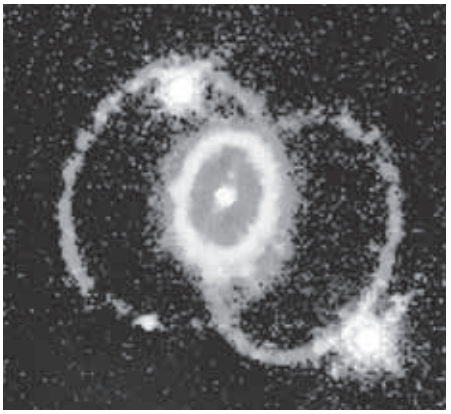
What Happens to Massive Stars as They Age?

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.

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_____

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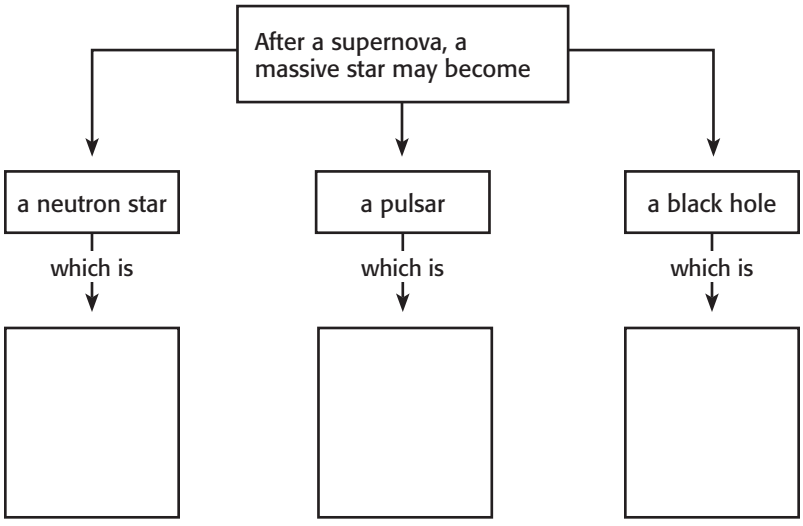
_____

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	**neutron star** a star that has collapsed under gravity to the point that the electrons and protons have smashed together to form neutrons
H-R diagram Hertzsprung-Russell diagram, a graph that shows the relationship between a star's surface temperature and absolute magnitude	**pulsar** a rapidly spinning neutron star that emits pulses of radio and optical energy
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)	**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?

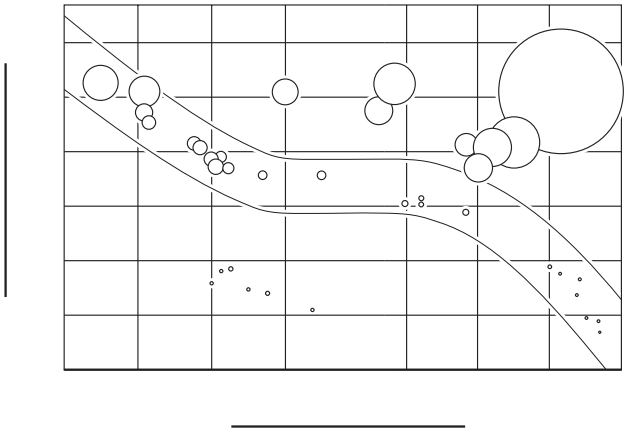
_____

_____

_____

_____

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?

_____

_____

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?

_____

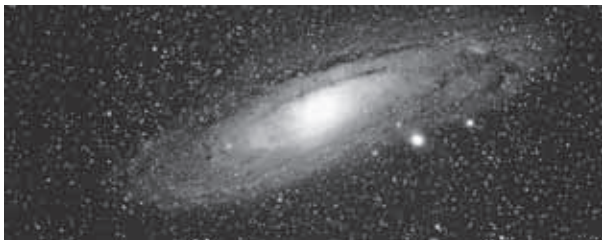
_____

_____

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?

_____

_____

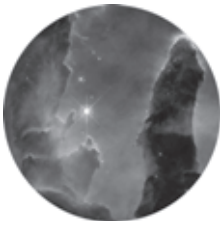
_____

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	**open cluster** a group of stars that are close together relative to surrounding stars
globular cluster a tight group of stars that looks like a ball and contains up to 1 million 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
nebula a large cloud of gas and dust in interstellar space; a region in space where stars are born	

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

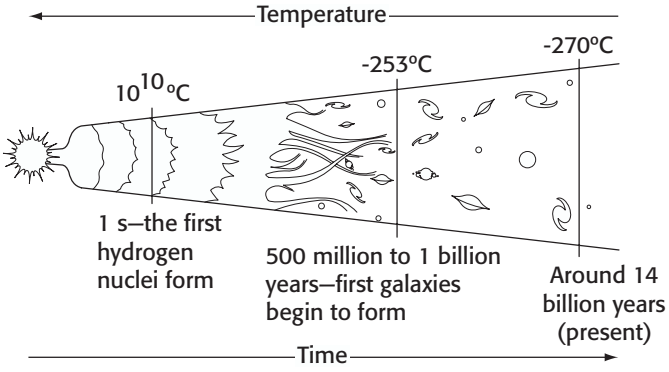
Predict Before you read this section, write down your prediction of how scientists think the universe formed and what will happen to it in the future. As you read, take notes on these topics.

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. ☑

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

READING CHECK

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

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_____

_____

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.

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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.

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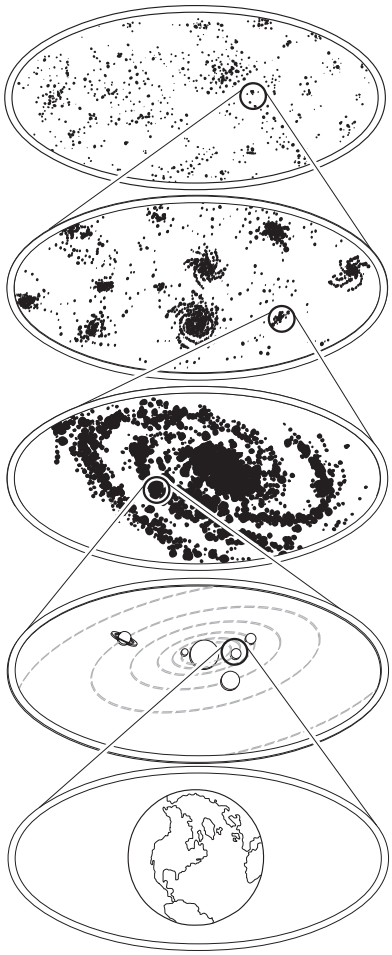

TAKE A LOOK

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?

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

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

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

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

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