The Milky Way galaxy, which is composed of billions of stars, is one of billions of galaxies in the universe.

**Lesson 1**

**Stars**

(Main Idea) Although the Sun is considered to be a fairly typical star, analysis of starlight indicates that stars vary greatly in size, temperature, and color and are composed primarily of hydrogen and helium.

**Lesson 2**

**How Stars Shine**

(Main Idea) Stars generate light from energy released in nuclear fusion.

**Lesson 3**

**Galaxies**

(Main Idea) Gravitational attraction causes stars to group together into galaxies.

---

**Spinning Through Space?**

These circles in the night sky are not a new type of fireworks. Instead, this image was formed by pointing a camera at the night sky and keeping the shutter open for several hours. As Earth rotates, the stars seem to move across the sky, forming circular streaks on the camera film.

**Science Journal**

Write a short paragraph describing where you think stars are located relative to the solar system.
Humans have asked these questions since time began. Try to model what you know about the stars, galaxies, and the universe.

**Think About This**
Make a concept map with answers to questions such as these and anything else you know about the universe.
- How old and how big is the universe?
- How did the universe form?
- How do stars shine?
- How far apart are the galaxies?
- How many galaxies are there?

**Procedure**
After you have thought about the questions, draw the universe as you think it looks.

**Foldables Study Organizer**

**Stars and Galaxies**
Make the following Foldable to help you organize information about stars and galaxies.

**STEP 1** Fold the bottom of a horizontal sheet of paper up about 2 cm.

**STEP 2** Fold in half.

**STEP 3** Unfold once and dot with glue to make two pockets.

**Determining the Main Idea**
As you read this chapter, write the main ideas about stars and galaxies on note cards and sort them into their correct pockets.
Learn It! When you make inferences, you draw conclusions that are not directly stated in the text. This means you “read between the lines.” You interpret clues and draw upon prior knowledge. Authors rely on a reader’s ability to infer because all the details are not always given.

Practice It! Read the excerpt below and pay attention to highlighted words as you make inferences. Use this Think-Through chart to help you make inferences.

If the molecules in a nebula block light from stars contained within it, the nebula is called an absorption nebula. If the nebula’s molecules become excited by energy from the stars within it, they emit their own light. These are called emission nebulae.

—from page 520

<table>
<thead>
<tr>
<th>Text</th>
<th>Question</th>
<th>Inferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecules in a nebula</td>
<td>What are they?</td>
<td>Dust? Gas?</td>
</tr>
<tr>
<td>Become excited</td>
<td>What is this?</td>
<td>Higher energy state?</td>
</tr>
<tr>
<td>Emit their own light</td>
<td>How do they do this?</td>
<td>Return to original state releasing energy?</td>
</tr>
</tbody>
</table>

Apply It! As you read this chapter, practice your skill at making inferences by making connections and asking questions.
# Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1. **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
   - Write an A if you **agree** with the statement.
   - Write a D if you **disagree** with the statement.

2. **After you read** the chapter, look back to this page to see if you’ve changed your mind about any of the statements.
   - If any of your answers changed, explain why.
   - Change any false statements into true statements.
   - Use your revised statements as a study guide.

<table>
<thead>
<tr>
<th>Before You Read A or D</th>
<th>Statement</th>
<th>After You Read A or D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>1</strong> The Sun has an atmosphere.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>2</strong> Gravity helped form our solar system.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>3</strong> Planets produce their own light.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>4</strong> Everything you see in the night sky is inside the Milky Way galaxy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>5</strong> A star’s color is related to its temperature.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>6</strong> The space between stars is totally empty.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>7</strong> Gravity causes stars to cluster together.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>8</strong> Astronomers use kilometers to measure distances between stars.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>9</strong> The Sun is a supergiant star.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>10</strong> The light from some galaxies can take over a billion years to reach Earth.</td>
<td></td>
</tr>
</tbody>
</table>

Sometimes you make inferences by using other reading skills, such as questioning and predicting.

Print a worksheet of this page at ca8.msscience.com.
Stars

(Main Idea) Although the Sun is considered to be a fairly typical star, analysis of starlight indicates that stars vary greatly in size, temperature, and color and are composed primarily of hydrogen and helium.

Real-World Reading Connection Have you ever wondered how stars generate the light that allows us to see them in the night sky? You may have noticed that some stars appear blue or red. What are stars and why do stars have different colors?

What are stars?

A star is a large ball of gas that emits energy produced by nuclear reactions in the star’s interior. Much of this energy is emitted as electromagnetic radiation, including visible light. Light emitted by stars enables other objects in the universe to be seen by reflection. For example, planets, comets, and asteroids shine by reflecting light from the Sun.

The Structure of Stars

The layered structure of a star is shown in Figure 1. Energy is produced at the core, which is denser than the outer layers. The temperature in the core can range from 5,000,000 K to more than 100,000,000 K, causing atoms to separate into their nuclei and electrons, forming plasma. Energy produced in a star’s core travels outward to the photosphere, where most light is emitted. The photosphere is the surface of the Sun—the part that we see.

Figure 1 A star’s interior includes two distinct zones that surround the core. Most light is emitted by the photosphere at the surface.
### Table 1: Properties of Different Types of Stars

<table>
<thead>
<tr>
<th>Star Type</th>
<th>Diameter (1 = Sun’s diameter)</th>
<th>Mass (1 = Sun’s Mass)</th>
<th>Surface Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supergiant</td>
<td>100–1,000</td>
<td>8–17</td>
<td>variable</td>
</tr>
<tr>
<td>Red giant</td>
<td>10–100</td>
<td>1–4</td>
<td>3,000–4,000</td>
</tr>
<tr>
<td>Main sequence</td>
<td>0.1–15</td>
<td>0.1–60</td>
<td>2,400–50,000</td>
</tr>
<tr>
<td>White dwarf</td>
<td>0.01</td>
<td>0.5–1.44</td>
<td>100,000–6,000</td>
</tr>
<tr>
<td>Neutron star</td>
<td>0.00</td>
<td>1–4</td>
<td>variable</td>
</tr>
</tbody>
</table>

### Types of Stars

Stars come in many different sizes and have various masses and surface temperatures. Table 1 shows some different types of stars. The Sun is medium sized with a surface temperature of about 5,800 K. Supergiants, the largest stars, are as big as the orbits of our outer planets. Red giant stars began with a mass and a diameter similar to those of our Sun, but later expanded to be 10–100 times larger. Eventually, our Sun will expand into a red giant, too. Neutron stars are only a few kilometers in diameter, but have a mass greater than that of the Sun.

### The Distances Between Stars

Recall from the previous chapter that one AU is the average distance between Earth and the Sun or about 150 million km. Distances between stars are so much greater than the distances in the solar system that a larger unit of measure is needed. This unit is a light-year (ly), which equals the distance light travels in one year. Because light travels at a speed of 300,000 km/s, a light-year is approximately 9,500,000,000,000 km, or about 63,000 AU. Figure 2 shows some of the stars nearest to our solar system.

**Visual Check** How many years pass before light from Alpha Centauri reaches Earth?

---

Figure 2: The nearest star to our solar system, Alpha Centauri, is 4.3 ly or more than 40 trillion km away.
What are stars made of?

Because stars other than the Sun are so far away, they can only be studied by analyzing the light they emit. By analyzing the light emitted by a star, you can learn about the star's motion, its temperature, and the chemical elements it contains.

Spectroscopes

A spectroscope is an instrument that can be used to study the light that comes from stars. Figure 3 shows the different parts of a spectroscope. Spectroscopes often contain elements, such as slits, prisms, diffraction gratings, and lenses to distribute and focus light. Using spectroscopes, astronomers can determine what elements are present in stars.

Continuous Spectra

When light from a bright lightbulb passes through a prism, it is spread out in a rainbow of colors. This “rainbow” is called a continuous spectrum. A continuous spectrum is emitted by hot, dense materials, such as the filament of a lightbulb or the hot, dense gas of the Sun’s photosphere.

Absorption Spectra

Sometimes when a continuous spectrum is examined in a spectroscope, some dark lines might be seen. This is called an absorption spectrum. Absorption spectra are produced when the light emitted from a hot, dense material passes through a cooler, less dense gas. Atoms in the cooler gas absorb certain wavelengths of light, producing dark lines superimposed on the continuous spectrum. These lines correspond to energy states of atoms in the gas. Each element absorbs only certain wavelengths, as shown in Figure 4. Thus, analyzing the pattern of these dark lines tells you what elements are present in the cooler gas.

Figure 3 A simple spectroscope uses a slit and a prism to break light into its component wavelengths or colors.

Figure 4 Dark lines in the continuous spectrum reveal the elements present in the cooler gas. Each element has its own distinctive pattern or fingerprint.
Identifying Elements in a Star

When light from a star is passed through a spectroscope, astronomers see dark absorption lines that are produced as light passes through the star’s cooler, less dense atmosphere. Each element contributes its own set of absorption lines to this absorption spectrum, such as those shown in Figure 5. When many elements are present, an absorption spectrum has many lines. However, astronomers know the pattern of lines each element produces. As a result, from an absorption spectrum they can determine which elements are present in a star’s outer layers. The pattern of these absorption lines is like a fingerprint that identifies the elements in the star’s outer layers.

Why do stars produce absorption spectra?

Astronomers have found that most stars are composed mainly of hydrogen and a smaller amount of helium. In fact, helium was first discovered in stars before it was found on Earth. Stars contain much smaller amounts of other chemical elements, such as carbon, nitrogen, and oxygen.

Temperature and Color of Stars

Have you ever watched a piece of metal being heated in a hot fire? As the metal gets hotter, its color changes. First it glows red, then it becomes yellow, and when it is extremely hot it may appear white. Just as the color of the metal depends on its temperature, the color of a star also depends on its temperature. You might be able to see colors in some stars. For example, Sirius [SIHR ee us], one of the brightest stars in the sky, is white. Betelgeuse [BET el jooz], a bright star in the constellation Orion [oh RYE un], is redish. Some stars have an orange or a yellow tint.
Temperature and Wavelengths Emitted

Every object emits energy in the form of electromagnetic radiation. The wavelength of the radiation emitted depends upon the temperature of the object. Objects at human body temperature emit mainly long, infrared waves. As temperature rises, however, the wavelengths of the emitted radiation become shorter. Recall that a heated metal object turns red and then yellow. The reason for this is that the wavelength of yellow light is shorter than that of red light.

Likewise, the wavelengths of light emitted by a star depend on the star’s temperature. This means that yellow stars are hotter than red stars. The hottest stars appear bluish because blue light has an even shorter wavelength. Table 2 gives the surface temperature for different color stars. Note that the Sun’s temperature makes it appear yellowish.

The Brightness of Stars

Why are some stars brighter than others? The brightness of a star is due to two things. One is the amount of energy the star emits. The other is the star’s distance from Earth. All stars, except the Sun, are so far away that they look like tiny points of light in the night sky.

Brightness and Distance

The headlights of a distant car at night might seem like tiny points of light when the car is far away. But as the car gets closer, the headlights appear brighter. The brightness of a source of light, such as a headlight, depends on how far away it is. As Figure 6 shows, a light source looks brighter when it is closer to you. The same is true for stars. The closer a star is, the brighter it looks.
**Luminosity**

One lightbulb in Figure 7 appears brighter than the other. This brightness is called luminosity. **Luminosity** is the amount of light energy emitted per second. Energy is expressed in joules. One joule per second is called a watt. The brighter lightbulb in Figure 7 emits 100 watts of energy, compared to 30 watts for the other bulb. The 100-W bulb has a higher luminosity because it emits more energy each second. Stars have different luminosities too—some emit more energy than others.

**Apparent Magnitude**

Luminosity is only partly responsible for how bright a star appears from Earth. If a very luminous star is far enough away, it appears dim. **Apparent magnitude** is the observed luminosity of a celestial body, such as a star, as observed from Earth. The apparent magnitude of a star depends on luminosity and distance. The smaller the magnitude number, the brighter the star.

A star of magnitude 1 is brighter than one of magnitude 2 but not just twice as bright. Each unit of magnitude is brighter by a factor of 2.5. A star of magnitude 1.0 appears 2.5 times as bright as a star of magnitude 2.0. Thus, a star of magnitude 1.0 appears about 100 times brighter than a star of magnitude 6.0. The faintest objects visible to the unaided eye have an apparent magnitude of about +6. A bright, full moon has a magnitude of about –12.6.

**Absolute Magnitude**

A better way to compare the brightness of stars is to calculate their absolute magnitudes. **Absolute magnitude** is the apparent magnitude a star would have if it were 32.6 ly away from Earth. Table 3 compares the apparent and absolute magnitudes of several stars with those of the Sun.

**Table 3** Based on absolute magnitude, how much brighter than the Sun is Antares?

<table>
<thead>
<tr>
<th>Star</th>
<th>Distance (light-years)</th>
<th>Apparent Magnitude</th>
<th>Absolute Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>0.0</td>
<td>–26.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Sirius</td>
<td>8.7</td>
<td>–1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Canopus</td>
<td>98.0</td>
<td>–0.7</td>
<td>–0.3</td>
</tr>
<tr>
<td>Antares</td>
<td>520</td>
<td>0.9</td>
<td>–5.1</td>
</tr>
</tbody>
</table>

**Figure 7** These bulbs are at the same distance, but one appears brighter because it emits more energy per second. The 100-watt light bulb emits 100 joules per second, compared to 30 joules per second for the other bulb.
Table 4

<table>
<thead>
<tr>
<th>Star</th>
<th>Apparent Magnitude</th>
<th>Distance (ly)</th>
<th>Absolute Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betelgeuse</td>
<td>0.45</td>
<td>427</td>
<td>–7.2</td>
</tr>
<tr>
<td>Bellatrix</td>
<td>1.64</td>
<td>243</td>
<td>–4.2</td>
</tr>
<tr>
<td>Saiph</td>
<td>2.07</td>
<td>720</td>
<td>–4.66</td>
</tr>
<tr>
<td>Rigel</td>
<td>0.18</td>
<td>773</td>
<td>–8.1</td>
</tr>
</tbody>
</table>

Looking at Stars

Although some stars might appear close or far to the unaided human eye, analysis of starlight might yield different information. Table 4 lists and shows four major stars that make up the constellation of Orion. Even though the stars might look similar to your eye, they are all very different. What can you learn about these stars from their data? Recall that a smaller magnitude means brighter.

Although Bellatrix is the closest of these stars to Earth, Betelgeuse and Rigel appear brighter. This is because Betelgeuse, a red supergiant, and Rigel, a blue supergiant, have much greater luminosities and therefore, smaller absolute magnitudes.

Classifying Stars—The H-R Diagram

Early in the twentieth century, two astronomers independently developed diagrams of how absolute magnitude, or luminosity, is related to the temperature of stars. Hertzsprung and Russell found that stars fell into certain regions of the diagram. About 90 percent of stars seemed to fall on a roughly diagonal, curved line, called the main sequence. Figure 8 shows a Hertzsprung-Russell (H-R) diagram.

The Sun, like 90 percent of all stars, is a main sequence star. The rest of the stars seem to fall into three regions of the diagram based on luminosity and temperature. Two of these star groupings lie above the main sequence line. The group closest to the main sequence has large-diameter stars with lower temperatures. They are called red giants. The stars in the group at the top of an H-R diagram are very large and have varying temperatures. They are known as supergiants. The third group, which lies below the main sequence, includes the white dwarfs. These are very hot stars and have small diameters relative to most main sequence stars.

Figure 8 On which end of the y-axis—top or bottom—are stars the brightest? On which end of the x-axis—left or right—are stars the hottest?
Figure 8  The H-R diagram indicates the temperature and luminosity of stars, but does not indicate their frequency. In fact, supergiant stars at the top right of the diagram are very rare with fewer than one star in 10,000 fitting this category.
Understanding Variations Among Stars

Stars are the source of all light in the universe. The amount of light a star emits per second is known as its luminosity. This light is emitted as a continuous spectrum, although some wavelengths are absorbed by elements in a star’s atmosphere, producing dark lines on its spectrum. The color of a star is related to its temperature; hotter stars tend to be blue while cooler stars are yellow or red. The distance between stars is so great that it is measured by how many years it takes light to travel between them. How bright a star appears in the night sky depends both upon its luminosity and its distance from Earth. Astronomers compare the brightness of stars using a scale, called absolute magnitude, which eliminates differences caused by distance.
Can you identify elements in a star?

Astronomers study the composition of stars by observing their absorption spectra. Each element in a star’s outer layers produce a set of lines in the star’s absorption spectrum. From the pattern of lines, astronomers can determine what elements are in a star. You will examine the spectra patterns of four elements and use the information to interpret the elements present in the Sun and in a mystery star.

Procedure
1. Study the spectra for the four elements.
2. Examine the spectra for the Sun and the mystery star.
3. Use a ruler to help you line up the spectral lines.
4. Compare the spectral pattern of the known elements to those of the Sun and the mystery star.

Analysis
1. Identify Which elements are present in the part of the absorption spectrum shown for the Sun?
2. Identify Which elements are present in the absorption spectrum shown for the mystery star?

Science Content Standards
4.d Students know that stars are the source of light for all bright objects in outer space and that the Moon and planets shine by reflected sunlight, not by their own light.
Brightness of Stars

The apparent magnitude of a star is a measure of how bright a star appears in the sky. As the stars appear brighter, their magnitudes become smaller. Use the following table of apparent magnitudes of stars to determine how much brighter one star is than another.

<table>
<thead>
<tr>
<th>Star</th>
<th>Apparent Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vega</td>
<td>0.03</td>
</tr>
<tr>
<td>Capella</td>
<td>0.08</td>
</tr>
<tr>
<td>Procyon</td>
<td>0.38</td>
</tr>
<tr>
<td>Achernar</td>
<td>0.46</td>
</tr>
<tr>
<td>Acrux</td>
<td>0.76</td>
</tr>
</tbody>
</table>

If each 1-unit change in magnitude corresponds to a brightness change by a factor of 2.5, you can use the expression $2.5^x$ to find the change in magnitude of the star if $x$ is the difference in the apparent magnitudes.

**Example**

How much brighter is Vega than Acrux? Recall that the smaller the apparent magnitude, the brighter the star appears.

**Use this equation:**

\[
\text{Difference in brightness} = 2.5^x
\]

Where $x = \text{larger apparent magnitude value} - \text{smaller apparent magnitude value}$

**Solve for $x$:**

larger apparent magnitude (Acrux) — smaller apparent magnitude (Vega) = 0.76 — 0.03 or 0.73.

**Substitute $x$ Into the Equation:**

\[
2.5^{0.73} = 1.95
\]

Use your calculator to solve.

**Answer:** Vega is nearly two times brighter than Acrux.

**Practice Problems**

1. Which star is brighter, Capella or Acrux? By how many times brighter is one star than the other?
2. How much brighter is Vega than Achernar?

[For more math practice, visit Math Practice at ca8.msscience.com.]
How Stars Shine

Main Idea Stars generate light from energy released in nuclear fusion.

Real-World Reading Connection Have you ever wondered how the Sun and other stars generate light? Perhaps you have heard of exploding stars, known as supernovas. How are stars formed? What determines a star’s lifetime?

How Stars Form

Initially, the universe consisted of light elements such as hydrogen, helium, and a smaller amount of lithium. These elements were produced in the big bang, or origin of the universe. Stars are formed in a nebula, which is a large cloud of gas and dust in space. Nebulae are also known as interstellar clouds and can be millions of light-years across.

Matter in a Nebula

The space between stars is called interstellar space. Interstellar space contains mostly gas and dust. The density of matter is so low in interstellar space that there is only one atom per cubic centimeter. In a nebula, the density of gas and dust is hundreds of times higher. In some regions of a nebula, dust particles are close enough to form dust clouds. These dust clouds can be dense enough to block the light emitted by nearby stars, as shown in Figure 9.

Figure 9 Dust and gas in an interstellar cloud completely block the stars in the center of this photo. Because this gas includes high concentrations of molecules, it is called a molecular cloud.
Components of Nebulae

The dust in nebulae is not like house dust. It is made up of much smaller particles, and might include clumps of carbon and silicate molecules. Hydrogen and helium are the most common gases in nebulae. However, some nebulae contain small quantities of gaseous molecules, and so these are called molecular clouds. One of these is shown in Figure 9 on the previous page.

If the molecules in a nebula block light from stars contained within it, the nebula is called an absorption nebula. If the nebula’s molecules become excited by energy from the stars within it, they emit their own light. These are called emission nebulae.

Contraction and Heating

The gravitational force between particles can cause clumps of matter to form in a nebula. Each particle in the clump exerts an attractive force on all the other particles. Even though this force is very weak, it causes the atoms in the clump to move closer together toward the center. As the particles move closer together, they move faster. Because the particles in the clump of matter are moving faster, the temperature of the matter increases. This means that as the clump of matter contracts, it heats up.

Protostars

As the clump contracts, it becomes spherical. When the mass of the clump of matter reaches a few percent of one solar mass, it is called a protostar. As the protostar continues to contract, its temperature continues to increase. Higher temperatures mean that particles move faster and the sphere begins to rotate. Then, it flattens into a disk that is denser and hotter at the center, such as the disk shown in Figure 10. After millions of years, the temperature in the center of the protostar becomes hot enough for nuclear fusion to occur. When the central mass reaches 8 percent that of the Sun, fusion begins and a new star is born. Figure 11 shows the process of star formation.
Visualizing the Formation of Stars

Figure 11
Stars form in clouds of dust and gas where the density of matter is hundreds of times higher than in interstellar space. In some parts of these clouds, dust and gas have clumped together to become even more dense.

The attractive force of gravity causes the particles in the clump to move closer together. As the particles move closer together, they move faster, and the temperature of the matter increases.

As the clump contracts even more, it begins to take the shape of a sphere. The matter continues to become hotter as the clump continues to contract. The spherical mass begins to spin and becomes a disk that is hottest in the center.

Finally the temperature at the center of the disk becomes hot enough for nuclear fusion to occur. Then a new star begins to glow. The material in the outer part of the disk can contract and possibly form planets, asteroids, and comets.

Contributed by National Geographic
How Stars Produce Light

Stars emit enormous amounts of energy, part of which is seen as visible light. When the temperature in the core of a protostar becomes high enough, a process called nuclear fusion occurs. Energy released during fusion passes through the star and is emitted from its photosphere.

Nuclear Fusion

In a nuclear fusion reaction, two atomic nuclei combine to form a larger nucleus with a higher mass. The energy from the Sun and other stars that can be seen as visible light is caused by nuclear fusion reactions that occur deep inside the stars’ hot cores. This energy flows from the interior to the exterior of the star, where it is radiated into space. Most of the energy emitted into space by the Sun is in the form of visible light and infrared radiation.

Figure 12 shows the nuclear reactions in a star’s core that change hydrogen nuclei into helium nuclei and release energy. Recall that isotopes of an element have the same number of protons, but different numbers of neutrons. The nuclear reactions shown in Figure 12 involve isotopes of hydrogen and helium.

Figure 12 This three-step fusion reaction is one way energy is produced in the cores of stars.

Infer In what form is most of the energy released during fusion in the Sun’s core?
The Balance Between Pressure and Gravity

There are two major forces at play in stars. Fusion reactions produce an outward pressure, which tends to push the matter in a star outward. However, the attractive gravitational force between all particles in a star pulls these particles inward toward each other. The force of gravity tends to make the star contract. As the fusion reactions occur, the outward pressure becomes large enough to balance the inward pull of gravity. When these two opposing forces balance each other, the star stops contracting.

State what forces determine whether a star expands or contracts.

Expansion and Contraction

As seen in Figure 13, a star will begin to expand if its rate of fusion increases. This is because the force produced by nuclear fusion within the star is greater than the force of gravity. Figure 13 also shows how a star contracts if its rate of fusion decreases. As the rate of fusion decreases, the force exerted by fusion from within the star also decreases. This means gravity can begin to pull matter back toward the star’s core.

How Stars Come to an End

As fusion continues in a star’s core, the star eventually converts all its hydrogen into helium. In stars with masses about the same or greater than that of the Sun, nuclear fusion will convert helium into carbon, nitrogen, and oxygen. In very massive stars, fusion reactions involving these elements form even heavier elements. When fusion stops, there is no longer any force balancing the inward pull of gravity and a star will continue to contract. Depending on the initial mass of the star, the result could be a white dwarf, a supernova, a neutron star, or a black hole.
The Life Cycle of Low-Mass Stars

When a low-mass star runs out of hydrogen to fuse into helium, gravity can make its core contract rapidly. This is followed by an expansion to a red giant stage. Finally, the star contracts again to a white dwarf stage. This process is illustrated in Figure 14 below.

Red Giants  When Sun-sized (about one to eight solar masses) stars use up their fuel, they become red giants. When the hydrogen in the core is converted to helium, the core contracts rapidly. This rapid contraction is often called a collapse. The temperature rises and hydrogen fusion begins outside the core. Carbon, oxygen, and other elements may be produced in the helium core during this next fusion stage. Fusion causes expansion, and this results in cooling. The cooler star emits reddish light—it is now a red giant.

White Dwarfs  Red-giant stars lose mass from their surfaces, until eventually only the core remains. Because fusion in the core has ceased, gravity causes it to contract until it is about the size of Earth. Such stars are known as white dwarfs. A white dwarf is the small, dense core of a giant star that remains after the star has lost its exterior matter. Some are so hot that they emit blue light. The Sun will become a dwarf star in billions of years.

The Life Cycle of High-Mass Stars

High-mass stars begin the end of their life cycle much like low-mass stars do. Their greater mass, however, means that the collapsed core can continue to fuse nuclei into heavier and heavier elements until the element iron is formed.
Supernova

A supergiant star can explode before it dies. When a supergiant star explodes before dying, it is called a supernova. The debris of a great supernova explosion still is visible as an interstellar cloud, known as the Crab Nebula, shown in Figure 15. Chinese astronomers observed this explosion in 1054. Supergiants are stars with initial masses greater than ten solar masses. They develop like red giants at first. However, fusion reactions continue to make elements heavier than oxygen.

**Fusion Rates Increase** The formation of each heavier element involves a cycle of expansion and contraction, and these cycles take place at an ever increasing rate. For example, a very massive star might burn carbon for 1,000 years, oxygen for one year, and silicon for a week. When iron is made, the star has less than a day to live.

**Fusion Stops** At this point, the fusion process stops, because the iron nucleus does not undergo nuclear fusion reactions. Iron accumulates in the star’s core and gravity compresses it producing temperatures of several billion K. Finally, as shown in Figure 16, the core collapses in on itself, releasing a huge amount of energy. This explosive collapse is called a supernova. So much energy is released in this explosion that the star brightens greatly, making it suddenly visible from Earth. It appears to be a new star.

An important feature of this supernova explosion is that its force blasts apart the star’s outer layers dispersing all the heavy elements in its outer layers throughout space. Eventually, these elements become part of new stars, like our Sun. This is how the heavier elements found on Earth and in our bodies were created.

Distinguish between a star and a supernova.
Neutron Stars

A neutron star is a star composed mainly of neutrons. Neutron stars are what remain of stars after supernova explosions. A neutron star is very small. It is about as large as a city. Because so much matter is packed into a small volume, it is very dense—so dense that one teaspoon would weigh billions of kilograms. Neutron stars form from the cores of supergiant stars after the iron core stage. The pressures in these massive stars is great enough to fuse protons and electrons, forming neutrons.

The term neutron star is misleading, however, because these objects are not stars, according to the definition you have learned. They do not shine as stars do. However, they can be detected. Two properties make this possible: they rotate rapidly and have strong magnetic fields. This results in pulses of radiation, usually in the radio portion of the electromagnetic spectrum. Some pulsars radiate in the visible, X-ray, and gamma-ray regions too. Such pulsating neutron stars are termed pulsars.

Black Holes

If a neutron star has an original mass between 10 and 1,000,000 times that of the Sun, contraction will continue. The neutron star contracts until its mass is concentrated into a single point called a black hole. A black hole is a region of space from which no matter or radiation can escape.

Because light cannot escape from black holes, they usually cannot be seen directly. However, black holes can be detected when they are located near some other object in space. Often a black hole passes through a cloud of interstellar matter, or is located close to another “normal” star. This allows the black hole to draw matter from such objects into itself, as illustrated in Figure 17. How can you “see” black holes if they do not emit light?
Star Evolution

Stars form when gravity causes matter in a nebula or an interstellar cloud to clump together. Then it contracts, causing temperature and pressure at the center to increase, and the clump becomes spherical and begins to rotate. Once enough matter accumulates, the temperature becomes high enough to trigger nuclear fusion, and becomes a star. Stars release much of their energy in the form of light. Eventually, stars run out of elements to fuel the fusion reaction. Smaller stars, like the Sun, become red giant stars and then white dwarfs. More massive stars undergo periods of expansion and contraction until iron accumulates in their cores. Iron resists further fusion, and these stars collapse in supernova explosions. The core remaining after such an explosion may form a neutron star or a black hole. Supernova explosions release sufficient energy to produce heavier elements, which are dispersed throughout space and can be incorporated in new stars.
Galaxies

Gravitational attraction causes stars to group together into galaxies.

Real-World Reading Connection Maybe you have seen a picture of a galaxy. If you have seen the bright band of stars that span a dark sky, then you have seen part of a galaxy. It is the Milky Way galaxy, where our solar system is.

Stars Cluster in Galaxies

Some of the fuzzy points of light in the sky that originally were thought to be stars or nebulae now are known to be distant galaxies. Stars are not uniformly distributed throughout the universe but are unevenly clustered into groups. Massive systems of stars, dust, and gas held together by gravity are called galaxies. Within galaxies are smaller groups of stars known as star clusters. One of these star clusters is shown in Figure 18.

Gravity is the fundamental force responsible for the formation and motion of stars. It also causes stars to group together into galaxies. Some galaxies contain billions of stars. The gravitational forces between stars and other types of matter hold the enormous numbers of stars together in a galaxy.

Figure 18 This cluster, known as M13, is within our galaxy and can be viewed using binoculars. Although it appears to the unaided eye as one fuzzy star, it is over 100,000 stars.

Infer What force caused these stars to cluster into a sphere?
Types of Galaxies

Galaxies can have different sizes and different shapes. The most common shapes are spiral, elliptical, and irregular, as shown in Figure 19. Spiral galaxies tend to be more luminous than elliptical galaxies.

Spiral Galaxies

There are two kinds of spiral galaxies: regular and barred. For both types, when seen from a top view, spiral arms can be seen. They have three components, as shown in Figure 20. These are the nucleus (or central bulge), the spiral arms, and the halo. The spiral arms contain star-forming regions. They are outlined by young blue stars. The halo is relatively free of dust and gas, and contains mostly old star clusters. Viewed on edge, spiral galaxies are relatively flat with a central bulge. Some spiral galaxies contain a bar of stars, dust, and gas that passes through the center of the galaxy. These are called barred spirals.

WORD ORIGIN

galaxy

galax—from Greek galaxis; means milky. (The first known galaxy was the Milky Way.)
The Milky Way Galaxy—Our Sun’s Home

The Sun is one of billions of stars in the Milky Way galaxy—a typical spiral galaxy. The Milky Way is 90,000 light-years in diameter. All the stars we can see from Earth without a telescope are located in the Milky Way. The bright band of stars cutting across the night sky is the Milky Way as seen from Earth. Figure 21 shows the location of the solar system in the Milky Way galaxy. Earth lies within the disk of the galaxy. The Sun is located about mid way from the center of the Milky Way and orbits the galactic center. In similar spiral galaxies, this galactic center appears as a bulge of stars in the heart of the disk.

Elliptical and Irregular Galaxies

Elliptical galaxies have an oval shape. They vary greatly in size and numbers of stars. Old, reddish stars tend to populate elliptical galaxies. They contain little interstellar gas or dust. There are no spiral arms. Irregular galaxies include all those that are neither elliptical nor spiral. They have a patchy appearance and are difficult to classify. Examples of elliptical and irregular galaxies are shown in Figure 22.

How do the three types of galaxies differ?

Figure 21  Our solar system is located 28,000 ly from the center of the Milky Way and takes about 240 million years to complete one orbit. From above you can see that it lies within one of the spiral arms.

Figure 22  The elliptical galaxy shown on the left has a strongly defined spherical shape compared to that of the irregular galaxy shown on the right.
The Distances Between Galaxies

Galaxies are so far away that, to the unaided eye, even the closest ones appear as faint, fuzzy patches of light. Recall that the distance between stars usually is expressed in terms of light-years. One light year is 9.5 trillion km, which is the distance light travels in one year. The closest galaxy to Earth is about one million light-years away. The Andromeda galaxy in Figure 23 is about two million light-years away. This means that light from the Andromeda galaxy takes two million years to reach Earth. When you look at Figure 23, you are seeing the Andromeda galaxy as it was two million years ago.

The Local Group

Galaxies are not scattered randomly throughout the universe. They group together in clusters, which are parts of larger groupings called superclusters. Gravity causes galactic clusters to form. There is a lot of almost empty space between those clusters called voids. Our galaxy is part of a cluster of galaxies called the Local Group. Figure 24 shows the galaxies that are part of the Local Group.

ACADEMIC VOCABULARY

randomly (RAN dom lee) (adverb) lacking a definite plan or pattern

The data points were distributed randomly over the graph, so no trend was obvious.
Superclusters

Looking beyond our Local Group, there are other groups of galaxies, some very large and in the shape of ribbons or clumps. We belong to the Virgo supercluster with thousands of galaxies spread across 100 million light-years. Part of the Virgo supercluster is shown in Figure 25.

The farthest galaxies from Earth are about 14 billion light-years away. Looking at those galaxies shows the universe as it was 14 billion years ago. Figure 26 gives some idea of the large number of galaxies that are seen in a small region of the sky.

In what supercluster is the Milky Way located?

The Big Bang Theory

In the late 1920s, the astronomer Edwin Hubble discovered that most of the galaxies he observed were moving away from Earth. He found that the farther away a galaxy was from Earth, the faster it was moving. Hubble’s discovery could be explained only if the entire universe was expanding. Then galaxies would be moving away from each other with a speed that increased as they got farther apart.
The Expanding Universe and the Big Bang

According to the big bang theory, this expansion of the universe began about 14 billion years ago. At that time, the universe was the size of a tiny point. This point contained all the matter and energy in the universe and was extremely hot. Then the universe began to expand rapidly, and as it grew, it began to cool.

For several hundred thousand years, the universe was too hot for elements to form from subatomic particles. So the universe consisted of a mix of radiation and subatomic particles. As the universe continued to expand, it cooled, and hydrogen and helium atoms began to form.

The Formation of Galaxies

Galaxies began forming several hundred million years after the big bang. Astronomers do not completely understand how galaxies formed. One hypothesis is that as space expanded, clouds of hydrogen and helium in some regions of space became more dense than in other regions. The matter in these denser regions began to clump together due to the pull of gravity. In these regions stars began to form. As more stars continued to form, gravity gradually pulled them together to form galaxies, as illustrated in Figure 27.

Dark Matter and Dark Energy

Based on the way galaxies rotate and move through space, astronomers can calculate how much mass it should contain. However, when they add up all the matter they can detect, they find that it does not equal the needed amount. They call this missing matter dark matter.

Similarly, additional energy is needed to explain the fact that the expansion of the universe is accelerating. They call this missing energy dark energy.
Evolution of the Universe

Stars are not distributed evenly through space, but grouped in large units called galaxies that are millions of light-years apart and contain billions of stars. Within galaxies are clumps of stars known as star clusters that contain from a dozen to a million stars. Galaxies themselves are grouped in clusters. Galaxies are divided into three types: spiral, elliptical, and irregular. The Milky Way galaxy is a spiral type and our solar system is about halfway between the center and the edge on one arm of the spiral. Galaxies are moving apart from each other, and those farthest from us are moving the fastest. According to the big bang theory, all the matter and energy in the universe was the size of a tiny point about 14 billion years ago. Then it expanded rapidly and cooled. Radiation and subatomic particles formed as it expanded followed by atoms, and eventually stars and galaxies.
How fast is the universe expanding?

The distances between galaxies are large and are measured in megaparsecs. A megaparsec (Mpc) is about 3,260,000 light-years or 9.5 trillion km. Scientists measure how fast galaxies are moving away from Earth by measuring the light they emit. Similar to how the sound of a train changes when it is moving toward or away from you, the wavelength of light gets shorter or longer when it is moving toward or away from Earth. The table shows the speeds and distances from Earth of 12 galaxies.

### Analysis

1. Plot distance on the x-axis and speed on the y-axis.
2. Draw a line of best fit through the graphed points.
3. Find the slope of the line. The slope is Hubble’s constant. It tells you how fast the space between the galaxies is expanding.

### Data Analysis

1. Compare your result expressed in km/s/Mpc with the known value of Hubble’s Constant.
2. Combine your result with those obtained by other students and find the average value. How does this compare with the known value? Why is it better or worse than your original value?

### Science Content Standards

- **4.e** Students know how to use astronomical units and light years as measures of distance between the Sun, stars, and Earth.
- **9.d** Recognize the slope of the linear graph as the constant in the relationship \( y = kx \) and apply this principle in interpreting graphs constructed from data.
Model and Invent: A Star is Born

**Problem**

The universe is made up of matter and energy. You have learned that stars are different colors and sizes because of their distance, the amount of energy, and the type of matter they contain. Many questions remain about the universe, however. For example, how was it formed? The most popular theory right now is that the universe formed in a massive expansion from a single point called the “big bang.” Use this Design-Your-Own Lab to learn more about a topic involving energy and matter. You might want to learn more about what stars are made of, how they are born, or their life cycles. You might want to study the big bang, black holes, neutron stars, or the next-nearest galaxy to Earth.

**Form a Hypothesis**

- First, brainstorm a list of topics that interest you. You must choose a topic that involves stars, matter, and energy.
- Create a large concept web of topics.
- Then, narrow down your interest to one topic. Decide what you want to research.
- Write a question and predict what the answer to your question will be by writing a hypothesis.

**Materials**

- Field guides about stars and galaxies
- Star chart of constellations
- Pair of binoculars or small telescope
- Computer with internet access

**Science Content Standards**

4.b Students know that the Sun is one of many stars in the Milky Way galaxy and that stars may differ in size, temperature, and color.

4.d Students know that stars are the source of light for all bright objects in outer space and that the Moon and planets shine by reflected sunlight, not by their own light.
Collect Data and Make Observations

1. Decide how you will research the answer to your question.
2. Make a list of possible resources.
3. Make a list of search terms that you will use to research. List at least ten search terms. Remember that the more specific your terms, the better information you will find. Put stars beside the terms you think will work best.
4. Make sure your teacher has approved your experiment before you proceed further.
5. When you have gathered enough data to answer your question, create a poster, diorama, or computer presentation to share your findings.

Analyze and Conclude

1. **State** the answer to your question.
2. **Evaluate** How much matter and energy does your object of study have compared to other celestial objects?
3. **Describe** How do scientists measure the energy given off by your star or other object?
4. **Explain** What have scientists learned about the universe from their studies of these objects?
5. **Identify** When did scientists start to study these objects? What technology did they need to develop to do these studies?
6. **Recognize** What basic science principles are behind the behavior of these objects?
7. **Error Analysis** Explain difficulties you had answering your question. Would you change your question or hypothesis? Could you improve your research methods? Explain.

Communicate

**WRITING in Science**

**Make a Presentation** Display the poster that answers your question on a bulletin board, or give your presentation to the class. After you have listened to or read your classmates’ questions and answers, write two paragraphs about what you learned from others’ projects.
Stephen Hawking: An Extraordinary Mind

Stephen Hawking is widely regarded as the greatest mind in physics since Albert Einstein. A mathematics professor at Cambridge University, he is best known for discovering that black holes emit subatomic particles, called Hawking Radiation. His work allows astronomers to study black holes in detail. Hawking’s book *A Brief History of Time: From the Big Bang to Black Holes* explains complicated concepts in language nonscientists can understand.

Visit Careers at ca8.msscience.com to learn more about Stephen Hawking. Write a newspaper article focusing on an aspect of Hawking’s life, such as his research, books he has published, or his family history.

Adapting Optics

Powerful Earth-based telescopes must view the sky through Earth’s atmosphere. The problem? The atmosphere distorts light, blurring the image of faraway stars and galaxies. Today, some telescopes obtain crisp images using “rubber mirrors.” These deformable mirrors can be manipulated faster than the atmosphere can change. The technology, called adaptive optics, removes the atmosphere’s blurring effect. These two images of binary star IW Tau show a blurry mass taken without adaptive optics and a clearer image using adaptive optics.

Visit Technology at ca8.msscience.com to view objects photographed with adaptive optics. Create a catalog of images with brief captions. Present your photo gallery to the class.
Kepler's Supernova

On October 9, 1604, observers in Europe and Asia saw a bright object appear on the horizon. Though they did not know it, the men were witnessing the death of a star. Within days, the object became the brightest object in the sky. Johannes Kepler studied the object for over a year until it was no longer visible. While the unusual object remained a mystery to Kepler, astronomers ultimately rewarded his perseverance by naming the supernova after him. Kepler's supernova is one of only six stellar explosions seen in our galaxy in the past 1,000 years.

Visit History at ca8.msscience.com to learn about these six supernovae. Create a time line of these events which includes details about the historical record supporting each.

Watching the Heat

Since 1996, the Solar and Heliospheric Observatory (SOHO) has stood watch between Earth and the Sun. From its vantage point 930,000 miles from Earth, SOHO stares at the Sun 24 hours a day, sending back a steady stream of solar data. While helping astronomers uncover the Sun's mysteries, SOHO also acts as an early warning system, alerting Earth engineers to periodic, high-energy shockwaves produced by the Sun that affect astronauts and satellites in space and communication systems on Earth. Thanks to SOHO, space weather forecasters have up to three days to prepare for incoming disturbances caused by unusual solar activity.

Visit Society at ca8.msscience.com to view solar data. Use the information provided to create a “space weather forecast” for astronauts on the International Space Station. Include charts and graphs in your forecast.
The Milky Way galaxy, which is composed of billions of stars, is one of the billions of galaxies in the universe.

**Lesson 1 Stars**

- **Main Idea** Although the Sun is considered to be a fairly typical star, analysis of starlight indicates that stars vary greatly in size, temperature, and color and are composed primarily of hydrogen and helium.
  - Stars are large balls of mostly hydrogen gas that emit energy.
  - Large distances between stars are measured in light-years.
  - A spectroscope is used to identify the elements in stars.
  - The color of a star depends on its temperature.
  - Luminosity measures the intrinsic brightness of stars.
  - Both luminosity and distance affect how bright stars appear.
  - The H-R diagram relates temperature to luminosity of stars.

- absolute magnitude (p. 513)
- apparent magnitude (p. 513)
- light-year (p. 509)
- luminosity (p. 513)

**Lesson 2 How Stars Shine**

- **Main Idea** Stars generate light from energy released in nuclear fusion.
  - Stars form as matter in interstellar clouds is drawn together by gravity and is heated enough to start nuclear fusion.
  - Energy produced at a star’s core is emitted at its surface as light.
  - The fate of a star depends on its initial mass.
  - Stars having an initial mass similar to that of the Sun become red giants and then white dwarfs.
  - More massive stars may undergo supernova explosions and become neutron stars or black holes.

- black hole (p. 526)
- nebula (p. 519)
- neutron star (p. 526)
- nuclear fusion (p. 522)
- red giant (p. 524)
- supernova (p. 525)
- white dwarf (p. 524)

**Lesson 3 Galaxies**

- **Main Idea** Gravitational attraction causes stars to group together into galaxies.
  - Galaxies are star groups containing billions of stars held together by gravitational attraction.
  - Galaxies are divided into three types: spiral, elliptical, and irregular.
  - The Sun is located in one arm of the spiral galaxy called the Milky Way.
  - The big bang theory states that the universe began about 14 billion years ago when all matter and energy was concentrated at a single, tiny point.

- big bang theory (p. 533)
- galaxy (p. 528)
According to the **11.** , all matter and all energy in the universe originated from a single point. First, matter was spread evenly, but soon clumps of dust and gas began to form stars. A large group of stars numbering in the billions is called a(n) **12.** . The space between stars contains clouds of gas and dust. Such a cloud is called a(n) **13.** . The distances between stars and galaxies are so great that astronomers measure them using a unit called a(n) **14.** .
Understanding Main Ideas

Choose the word or phrase that best answers the question.

1. What color star has the highest surface temperature?
   A. blue
   B. red
   C. white
   D. yellow 4.b

2. Which means the same as luminosity?
   A. apparent brightness
   B. absolute brightness
   C. brightness
   D. intrinsic brightness 4.d

3. Which is not part of a spiral galaxy?
   A. halo
   B. supercluster
   C. nucleus
   D. spiral arms 4.a

4. The photograph below is of the Sombrero galaxy.

Which unit of measurement is most appropriate for measuring distances within the group of stars shown above?
   A. astronomical unit
   B. kilometer
   C. light-year
   D. mile 4.c

5. What is the most important factor that causes matter in a nebula to form clumps?
   A. gravitational attraction
   B. heating
   C. molecular motion
   D. rotation 2.g

6. What is measured on the y-axis?
   A. diameter
   B. color
   C. luminosity
   D. temperature 4.b

7. Which type of star is located in the bottom center of the diagram?
   A. giant
   B. supergiant
   C. white dwarf
   D. main sequence star 4.b

8. What type of star is topmost in the diagram?
   A. giant
   B. Sun-like
   C. supergiant
   D. white dwarf 4.b

9. Which magnitude describes the brightest star?
   A. 2.5
   B. 1.3
   C. −0.5
   D. −2.5 4.b
Applying Science

10. **Explain** why a low-mass star contracts to form a white dwarf.  

11. **Describe** how absorption spectra are formed.

12. **Examine** the nuclear fusion reaction that begins star formation. Include the number and type of particles that take part, the particles formed, and the type of energy released.

13. **Identify** the layers of the Sun-like star shown in the illustration below and indicate where light energy is emitted.

14. **Hypothesize** A new galaxy has just been discovered using a powerful new telescope. Astronomers report that it is composed mostly of older reddish stars and that it has little interstellar dust or gas. What type of galaxy is it most likely to be?

15. **Explain** how the wavelengths of light emitted by a star depend on the star’s temperature.

Cumulative Review

17. **Explain** why astronomers measure distances of planets and their moons using astronomical units instead of kilometers or light-years.

18. **Compare** a total lunar eclipse with a total solar eclipse.

19. **Infer** Based on what you have learned about the asteroids, what type of planet might have formed in the orbit occupied by the asteroid belt? Would it be more like the inner or outer planets?

Applying Math

Use the table below to answer questions 20–24.

<table>
<thead>
<tr>
<th>Star</th>
<th>Apparent Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vega</td>
<td>0.03</td>
</tr>
<tr>
<td>Capella</td>
<td>0.08</td>
</tr>
<tr>
<td>Procyon</td>
<td>0.38</td>
</tr>
<tr>
<td>Achernar</td>
<td>0.46</td>
</tr>
<tr>
<td>Acrux</td>
<td>0.76</td>
</tr>
</tbody>
</table>

20. How much brighter is Procyon than Capella?  

21. How much brighter is Procyon than Vega?  

22. How much brighter is Acrux than Achernar?  

23. How much brighter is Acrux than Capella?  

24. How much brighter is Acrux than Vega?

16. **Write** a brief biography of a star about the size of the Sun. Describe the role of gravity in its formation and in maintaining its stable existence while on the main sequence.
1. The illustration below shows part of the Sun.

In which layer of the Sun is energy produced?
A V
B X
C Y
D Z

2. About how long does it take light from the Sun to reach Earth?
A 8 seconds
B 8 minutes
C 8 hours
D 8 days

3. The most massive stars end their lives as which type of object?
A black hole
B white dwarf
C neutron star
D black dwarf

4. Which is a group of stars, gas, and dust held together by gravity?
A constellation
B supergiant
C black hole
D galaxy

Use the graph below to answer questions 5 and 6.

5. Which is the most abundant element in the Sun?
A helium
B hydrogen
C oxygen
D carbon

6. How will this circle graph change as the Sun ages?
A The hydrogen slice will get smaller.
B The hydrogen slice will get larger.
C The helium slice will get smaller.
D The circle graph will not change.
7. Which do astronomers use to determine what elements are present in stars?
   A. gyroscope
   B. microscope
   C. spectroscope
   D. telescope

8. Which is produced in the nuclear fusion reaction between four hydrogen nuclei?
   A. carbon
   B. helium
   C. oxygen
   D. neutrons

9. In which of the following choices are the objects ordered from smallest to largest?
   A. stars, galaxies, galaxy clusters, universe
   B. galaxy clusters, galaxies, stars, universe
   C. universe, galaxy clusters, galaxies, stars
   D. universe, stars, galaxies, galaxy clusters

10. The illustration below shows a side view of the Milky Way galaxy.

   Where is the Sun located?
   A. W
   B. X
   C. Y
   D. Z

11. The Milky Way is an example of which stellar object?
   A. an elliptical galaxy
   B. a spiral galaxy
   C. an irregular galaxy
   D. a star cluster

12. The illustration below shows the distance between Earth and the nearest star other than the Sun, Proxima Centauri.

   How far away from Earth is Proxima Centauri?
   A. 8.4 AUs
   B. 8.4 light-years
   C. 4.2 AUs
   D. 4.2 light-years

13. Why do stars and other large celestial objects have a spherical shape?
   A. All objects become spherical when they melt.
   B. Atomic and molecular forces cause all objects to become spherical.
   C. Gravity attracts matter within these objects toward a central point.
   D. Multiple collisions cause these objects to become rounded.
Are you interested in stars, galaxies, and the universe? If so, check out these great books.

**Nonfiction**

**The Universe**, by Seymour Simon, is a study of the vastness of the universe. Full-color photographs show nebulas and galaxies and support the topics discussed, including the big bang and theories about the future of the universe. The content of this book is related to Science Standard 8.4.

**Nonfiction**

**Sun**, by Steve Tomecek, introduces readers to the physics of the Sun. This book gives readers an in-depth look at our closest star, explaining the Sun’s size, distance from Earth, composition, temperature, sunspots, and solar flares. The content of this book is related to Science Standard 8.4.

**Nonfiction**

**Big Bang: The Story of the Universe**, by Heather Couper, begins with hydrogen atoms and explains the origins and formation of the elements that are now commonplace in the universe. This book gives clear explanations of a complicated subject. The content of this book is related to Science Standard 8.4.

**Nonfiction**

Choose the word or phrase that best answers the question.

Use the figure below to answer questions 1–3.

1. Which season is it in the southern hemisphere when Earth is in this position?
   A. spring
   B. summer
   C. autumn
   D. winter

2. Which part of Earth receives the greatest total amount of solar radiation when Earth is in this position?
   A. northern hemisphere
   B. south pole
   C. southern hemisphere
   D. equator

3. In what month is Earth closest to the Sun?
   A. March
   B. September
   C. July
   D. January

4. Which is the closest star to Earth?
   A. Sirius
   B. the Sun
   C. Betelgeuse
   D. the Moon

5. What unit is often used to measure distances between stars and galaxies?
   A. kilometer
   B. astronomical unit
   C. light-year
   D. meter

Write your responses on a sheet of paper.

6. **Compare and contrast** the different types of galaxies.

7. **Discuss** what an astronomical unit is and why it is useful.

8. **Explain** how a moon remains in orbit around a planet.

9. **Sequence** the phases of the Moon starting and ending with a new moon. Explain why we can see only these lighted portions of the Moon. Consider the fact that the Sun lights one half of the Moon at all times.

10. **Explain** how eclipses of the Sun occur only occasionally despite the fact that the Moon’s rotation causes it to pass between Earth and the Sun every month.

11. **Define** constellation and give three examples of a constellation.

The figure below shows Earth and the star Proxima Centauri. Use the figure below to answer questions 12 and 13.

12. **Identify** How many light-years from Earth is the star Proxima Centauri?

13. **Infer** how many years it would take for light from Proxima Centauri to reach Earth.

14. **Sketch and label** the Sun and the four parts of a comet as it moves away from the Sun.