Before You Read

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

Read to Learn

Constellations

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

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

What are some common constellations?

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

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

![Constellation Diagram](image)

**Why do constellations appear to move?**

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

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

**Absolute and Apparent Magnitudes**

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

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

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

How is parallax measured?

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

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

Properties of Stars

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

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

Mini Glossary

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

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

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

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

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

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

   - Stars
     - Absolute magnitude describes a star's _________.
     - The hottest stars are blue-white. Cooler stars are _________.
     - The distance between stars is measured in _________.
     - Stars seem to move in the night sky because Earth _________.
     - are a group of stars arranged in a pattern.
     - is often called the North Star.

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

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Visit glencoe.com to access your textbook, interactive games, and projects to help you learn more about stars.
section 2 The Sun

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

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The Sun's Layers

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

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

The Sun's Atmosphere

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

Surface Features

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

What is a sunspot?

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

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

What are prominences and solar flares?

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

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

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

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

The Sun—An Average Star

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

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

Think it Over

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

Reading Check

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

Mini Glossary

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

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

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

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

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

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

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is a huge ball of __________________.</td>
<td>Its light reaches Earth in __________________.</td>
</tr>
<tr>
<td>It produces energy in its __________________.</td>
<td>Life on __________________ depends on it.</td>
</tr>
<tr>
<td>It has an __________________ that has different layers. One is the corona.</td>
<td>It is not close to other __________________.</td>
</tr>
</tbody>
</table>

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

End of Section

ScienceOnline Visit glencoe.com to access your textbook, interactive games, and projects to help you learn more about the Sun.

206 Stars and Galaxies
section 2 Evolution of Stars

PS 1.1b Other stars are like the Sun but are so far away that they look like points of light. Distances between stars are vast compared to distances within our solar system. Also covered: PS 4.4a

● Before You Read

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

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● Read to Learn

Classifying Stars

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

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

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

How do scientists show this relationship?

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

What You’ll Learn

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

Study Coach

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

Foldables

Create a Foldable as shown below about evolution of stars. Label the three columns Star Classification, Star Temperature and Color, and How a Star Evolves.
What is the main sequence?

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

What are dwarfs?

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

What are giants?

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

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

What process creates the light that reaches Earth?

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

Evolution of Stars

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

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

How are stars formed?

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

The particles in the smaller pieces of nebula move closer together. This causes temperatures in each piece to rise. When the temperature in the core of a piece of nebula reaches 10 million K, fusion begins. Energy is released from the core and travels outward. Now the object is a star.
What is a giant?
After a star is formed, the heat created by fusion creates outward pressure. Without this pressure, the star would collapse from its own gravity. The star becomes a main sequence star. It continues to use its hydrogen fuel. The different stages in the life of a star are shown in the illustration on this page and the next page.

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

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

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

What are supergiants and supernovas?
The length of time it takes for a star to go through its stages of life depends on its mass. The stages happen more quickly and more violently in stars that are more than eight times more massive than the Sun. In massive stars, the core heats up to much higher temperatures. Heavier and heavier elements form in the core. The star expands into a supergiant. Finally, iron forms in the core. Iron can’t release energy through fusion. The core collapses violently. This sends a shock wave outward through the star. The outer part of the star explodes. This produces a kind of star called a supernova. A supernova can be millions of times brighter than the original star was.
What is a neutron star?
What happens next depends on the size of the supernova's collapsed core. If the collapsed core is between 1.4 and 3 times as massive as the Sun, the core shrinks until it is only about 20 km in diameter. In this dense core, there are only neutrons. This kind of star is called a **neutron star**. Because the star is so dense, one teaspoonful of a neutron star would weigh more than 600 million metric tons on Earth.

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

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

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

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

**Think it Over**

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

Mini Glossary

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

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

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

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

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

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

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

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

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

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

End of Section

Science online Visit glencoe.com to access your textbook, interactive games, and projects to help you learn more about the evolution of stars.
Before You Read

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

Read to Learn

Galaxies

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

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

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

What are the three major types of galaxies?

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

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

Irregular galaxies include all the galaxies that don’t fit into the other two groups. These galaxies have many different shapes.
The Milky Way Galaxy

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

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

Origin of the Universe

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

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

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

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

Does the Doppler shift affect light?

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

How do we know the universe is expanding?

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

The Big Bang Theory

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

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

Mini Glossary

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

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

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

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

![Diagram of the Universe with layers showing the Milky Way, Solar System, and Earth]

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

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