Section 1

Terms to Learn

astronomy
calendar
year
month
day
leap year

What You'll Do

- Identify the units of a calendar.
- Evaluate calendars from different ancient civilizations.
- Explain how our modern calendar developed.
- Summarize how astronomy began in ancient cultures and developed into a modern science.

Astronomy—The Original Science

Astronomy is the study of all physical objects beyond Earth. Before astronomy became a science, people in ancient cultures used the seasonal cycles of celestial objects to make calendars and organize their lives. Over time, some people began to observe the sky for less practical reasons—mainly to understand Earth's place in the universe. Today, astronomers all over the world are using new technologies to better understand the universe.

The Stars and Keeping Time

Most ancient cultures probably did not fully understand how celestial objects in our solar system move in relation to each other. However, they did learn the seasonal movements of these objects as they appeared in the Earth's sky and based their calendars on these cycles. People in ancient cultures gradually learned to depend on calendars to keep track of time. For example, by observing the yearly cycle of the sun's movement among the stars, early farmers learned the best times of year to plant and harvest various foods.

After learning the seasonal cycles of celestial objects many civilizations made calendars. One such calendar is shown in **Figure 1.** A **calendar** is a system for organizing time. Most calendars organize time within a single unit called a year. A **year** is the time required for the Earth to orbit the sun once. Within a year are smaller units of time called months. A **month** is roughly the amount of time required for the moon to orbit the Earth once. Within a month are even smaller units of time called days. A **day** is the time required for the Earth to rotate once on its axis.

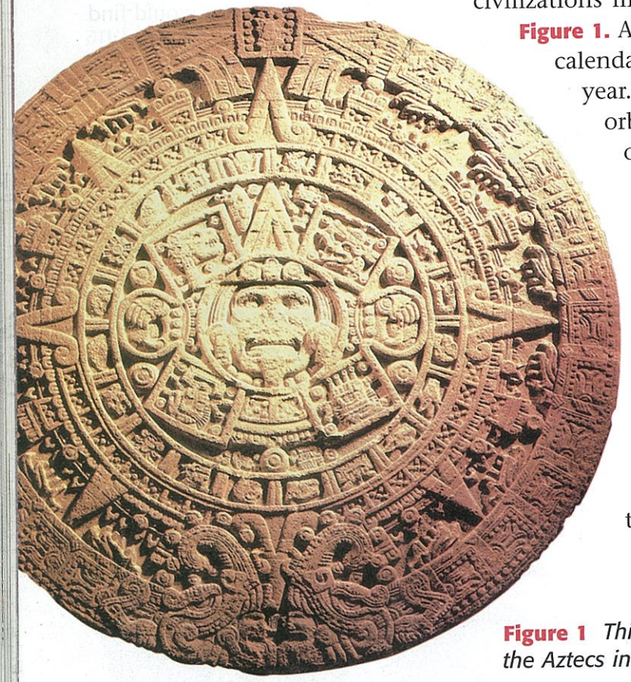


Figure 1 *This stone is a calendar used by the Aztecs in pre-colonial America.*

Ancient Calendars Ancient cultures based their calendars on different observations of the sky. Examine **Figure 2** at the top of the next page to see how different cultures around the world used objects in the sky differently to keep track of time.

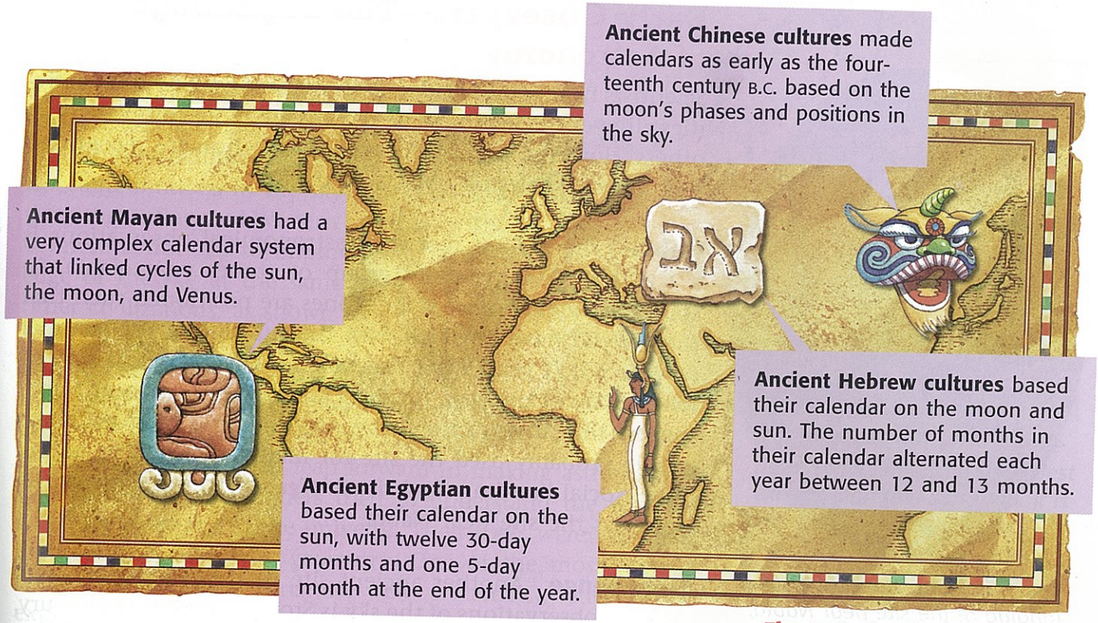


Figure 2 *People in ancient cultures based their calendars on different kinds of celestial cycles.*

Toward a Modern Calendar The early Roman calendar had exactly 365 days in a year and 7 days in a week. The calendar worked well at first, but gradually the seasons shifted away from their original positions in the year.

It was then determined that there are actually about 365.25 days in a year. To correct this, Julius Caesar created the *Julian calendar.* He began by adding 90 days to the year 46 B.C., which put the seasons back to their original positions. He then added an extra day every 4 years to keep them from shifting again. A year in which an extra day is added to the calendar is called a **leap year.**

In the mid-1500s, people noticed that the Julian calendar was incorrect. Pope Gregory XIII presented this problem to a group of astronomers who determined that there are actually 365.242 days in a year. To solve the problem, a new calendar—the *Gregorian calendar*—was created. The Pope dropped 10 days from the year 1582 and restricted leap years to years that are divisible by 4 but not by 100 (except for years that are divisible by 400). This lowered the number of leap years that occur and made the average length of 1 year closer to 365.242 days. Today most countries use the Gregorian calendar, which scientists calculate will be accurate for another 3,000 years.

LabBook

Julius Caesar and Pope Gregory XIII aren't the only ones who can decide when to have leap years—you can too! In fact, you can make your own calendar! Turn to page 706 in the LabBook to find out how.

Early Observers—The Beginnings of Astronomy

Scientists have found evidence for ancient astronomical activities all over the world. Some records are more complete than others. However, they all show that early humans recognized the cycles of celestial objects in the sky.

Figure 3 *Some stones are still standing at the site near Nabta, in the Sahara Desert.*

Nabta The earliest record of astronomical observations is a 6,000 to 7,000-year-old group of stones near Nabta, in southern Egypt. Some of the stones are positioned such that they would have lined up with the sun during the summer solstice 6,000 years ago. The *summer solstice* occurs on the longest day of the year. Artifacts found at the site near Nabta suggest that it was created by African cattle herders. These people probably used the site for many purposes, including trade, social bonding, and ritual. **Figure 3** shows some of the stones at the site near Nabta.

Stonehenge Another ancient site that was probably used to make observations of the sky is Stonehenge, near Salisbury, England. Stonehenge, shown in **Figure 4,** is a group of stones arranged primarily in circles. Some of the stones are aligned with the sunrise during the summer and winter solstices. People have offered many explanations for the purpose of Stonehenge as well as for who built and used it. Careful studies of the site reveal that it was built over a period of about 1,500 years, from about 3000 B.C. to about 1500 B.C. Most likely, Stonehenge was used as a place for ceremony and ritual. But the complete truth about Stonehenge is still a mystery.

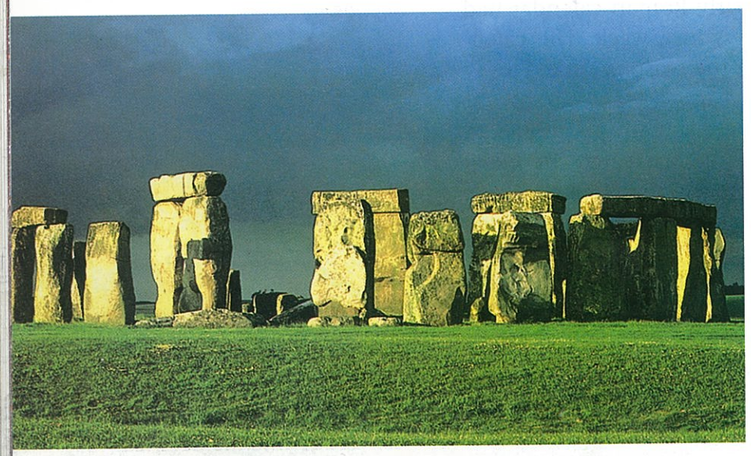


Figure 4 *Although its creators have long since gone, Stonehenge continues to indicate the summer and winter solstices each year.*

The Babylonians The ancient civilization of Babylon was the heart of a major empire located in present-day Iraq. From about 700 B.C. to about A.D. 50, the Babylonians precisely tracked the positions of planets and the moon. They became skilled at forecasting the movements of these celestial bodies, which enabled them to make an accurate calendar.

Ancient Chinese Cultures As early as 1000 B.C., ancient Chinese cultures could predict eclipses. *Eclipses* occur when the sun, the moon, and the Earth line up in space. The Chinese had also named 800 stars by 350 B.C. The Chinese skillfully tracked and predicted the same motions in the sky as the civilizations that influenced Western astronomy. The Chinese continued to improve their knowledge of the sky at the same time as many other civilizations, as shown in **Figure 5.**

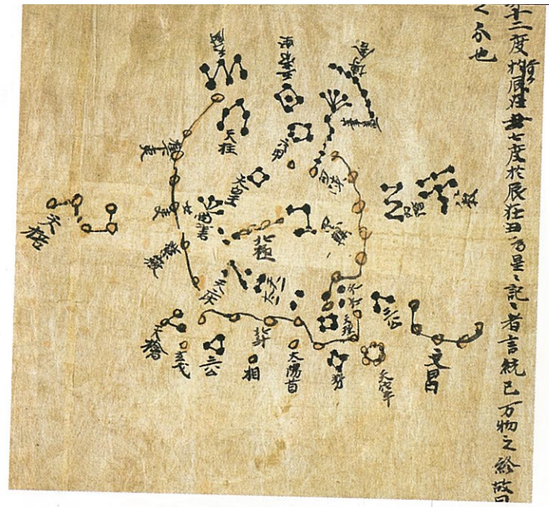


Figure 5 *This ancient Chinese manuscript is the world's oldest existing portable star map. It is more than 1,000 years old.*

The Ancient Greeks Like many other civilizations, the ancient Greeks learned to observe the sky to keep track of time. But the Greeks also took a giant leap forward in making astronomy a science. Greek philosophers tried to understand the place of Earth and humans in the universe. Their tools were logic and mathematics, especially geometry. One of the most famous Greek philosophers, Aristotle (ER is TAHT'L), successfully explained the phases of the moon and eclipses. He also correctly argued that the Earth is a sphere—an idea that was not very popular in his time.

Native Americans Archaeological records show that many of the pre-colonial civilizations in the Americas were skilled in observing the sky. Perhaps the most highly-skilled observers were the Maya, who flourished in the present-day Yucatan about 1,000 years ago. The Maya had complex systems of mathematics and astronomy. Many Mayan buildings, such as the one in **Figure 6,** are aligned with celestial bodies during certain astronomical events.

The Ancient Arabs After Greek, Roman, and early Christian civilizations weakened, the ancient Arabs inherited much of the Greeks' knowledge of astronomy. The Arabs continued to develop astronomy as a science while Europe fell into the Dark Ages. Today many stars have Arabic names. The Arabs also invented the astrolabe, algebra, and the number system that we use today.

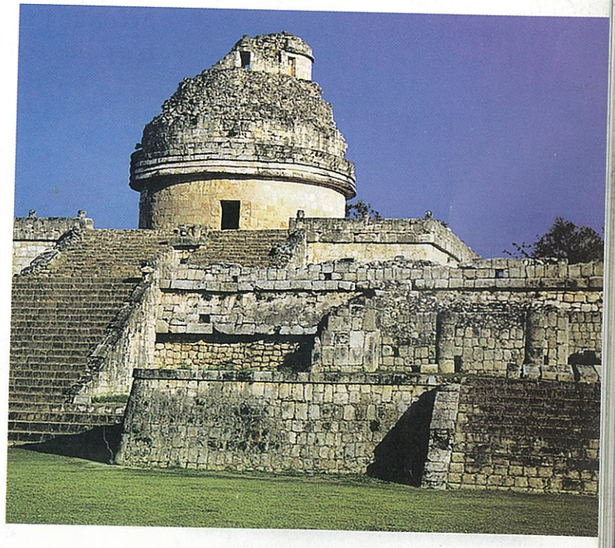


Figure 6 *This Mayan building is the Caracol at Chichén Itzá, in the Yucatán. Many parts of the building align with Venus and the sun on certain days.*

The Who's Who of Early Astronomy

The science of astronomy has come a long way since the early days. The earliest astronomers had no history to learn from—almost everything they knew about the universe came from what they could discover with their own eyes and minds. Not surprisingly, most early astronomers thought that the universe consisted of the sun, moon, and planets, with all the stars occupying the edge of the universe. While they could not have known that our solar system is a very small part of a much larger universe, they had to start somewhere.

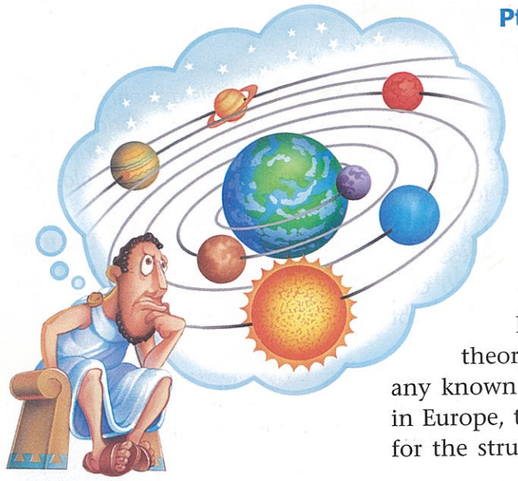


Figure 7 *According to the Ptolemaic theory, the Earth is at the center of the universe.*

Ptolemy In A.D. 140, a Greek astronomer named Claudius Ptolemy (KLAW dee uhs TAHL uh mee) wrote a book that combined all the ancient knowledge of astronomy that he could find. Ptolemy expanded Aristotle's theories with careful mathematical calculations in what was called the *Ptolemaic theory.* As shown in **Figure 7,** Ptolemy thought that the Earth is at the center of the universe—with the sun and the other planets revolving around the Earth.

Even though it was incorrect, the Ptolemaic theory predicted the motions of the planets better than any known method at that time. For more than 1,500 years in Europe, the Ptolemaic theory was the most popular theory for the structure of the universe.

Copernicus In 1543, a Polish astronomer named Nicolaus Copernicus (NIK uh LAY uhs koh PUHR ni kuhs) published a new theory that would eventually revolutionize astronomy. According to his theory, which is shown in **Figure 8,** the sun is at the center of the universe and the planets—including the Earth—orbit the sun. While Copernicus was correct about all the planets orbiting the sun, his theory did not immediately replace Ptolemy's theory.

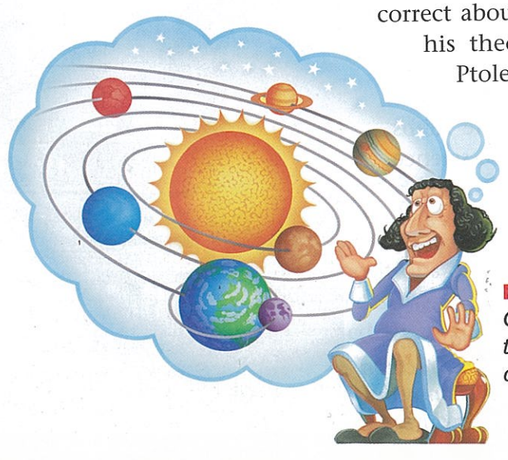


Figure 8 *According to Copernicus's theory, the sun is at the center of the universe.*

Tycho Brahe Danish astronomer Tycho Brahe (TIE koh BRAW uh) used several large tools, such as the one shown in **Figure 9,** to observe the sky. Tycho favored an Earth-centered theory that was different from Ptolemy's. Tycho believed that the other planets revolve around the sun but that the sun and the moon revolve around the Earth. While Tycho's theory was not correct, he did record very precise observations of the planets and stars for several years.

Johannes Kepler After Tycho died, his assistant, Johannes Kepler, continued Tycho's work. Kepler did not agree with Tycho's theory, but he recognized how precise and valuable Tycho's data were. In 1609, after analyzing the data, Kepler announced some new laws of planetary motion. Kepler stated that all the planets revolve around the sun in elliptical orbits and that the sun is not in the exact center of the orbits.

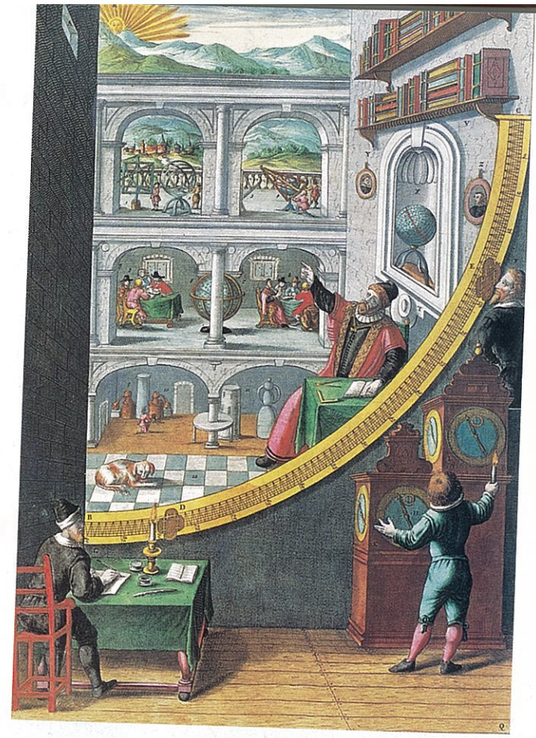
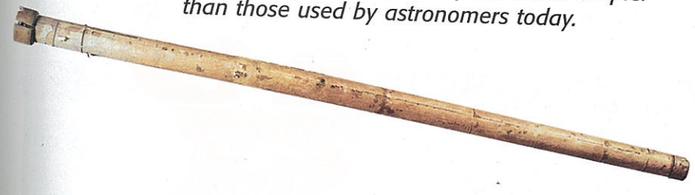


Figure 9 *Tycho used the mural quadrant, which is a large quarter-circle on a wall, to measure the positions of stars and planets.*

Galileo Galilei In 1609, Galileo became the first person to use a telescope to observe celestial bodies. His telescope is shown in **Figure 10.** Galileo discovered four moons orbiting Jupiter, craters and mountains on the moon, sunspots on the sun, and phases of Venus. These discoveries showed that the planets are not just dots of light—they are physical bodies like the Earth. Galileo favored Copernicus's theory over Ptolemy's.

Figure 10 *Galileo's telescope is much simpler than those used by astronomers today.*



Isaac Newton Finally, in 1687 a scientist named Sir Isaac Newton explained *why* planets orbit the sun and why moons orbit planets. Newton explained that the force that keeps all of these objects in their orbit is the same one that holds us on the Earth—gravity. Newton's laws of motion and gravitation completed the work of Copernicus, Tycho, Kepler, and Galileo.

Self-Check

Name two astronomers who favored an Earth-centered universe and two astronomers who favored a sun-centered universe. *(See page 726 to check your answer.)*

Modern Astronomy

With Galileo's successful use of the telescope and Newton's discoveries about planetary motion, astronomy began to become the modern science that it is today. Gradually, people began to think of stars as more than dots of light at the edge of the universe.

From Fuzzy Patches to an Expanding Universe William Herschel, who discovered Uranus in 1781, used a telescope to study the stars in our galaxy. As he studied these stars, he found small, fuzzy patches in the sky. Herschel did not know what these patches were, but he did record their positions in a catalog.

The invention of photography in the 1800s allowed astronomers to make even better observations of the sky. In 1923, Edwin Hubble used photography to discover that some of the patches Herschel had found are actually other galaxies beyond our own. Before this discovery, scientists thought that the Milky Way galaxy was the entire universe! Hubble also discovered that the universe is expanding. In other words, distant objects in space are moving farther and farther away from each other.

Figure 11 *Today computers and telescopes are linked together. Computers not only control telescopes, but they also process the information gathered by the telescopes so that astronomers may better analyze it.*

Larger and Better Telescopes Today astronomers still gaze at the sky, trying to assign order to the universe. Larger and better telescopes on Earth and in space, supercomputers, spacecraft, and new models of the universe allow us to study objects both near and far. Many questions about the universe have been answered, but our studies continue to bring new questions to investigate.

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REVIEW

1. Which ancient civilization's calendar gave rise to our modern calendar?
2. What advantage did Galileo have over the astronomers that went before him, and how did it help him?
3. **Analyzing Relationships** Is Copernicus's theory completely correct? Why or why not? How does his theory relate to what we know today about the sun's position in our solar system and in the universe?

Section 2

Mapping the Stars

Terms to Learn

constellation	celestial equator
altitude	ecliptic
right ascension	light-year
declination	

What You'll Do

- Describe constellations and explain how astronomers use them.
- Explain how to measure altitude.
- Explain right ascension and declination.
- Evaluate the scale of the universe.

Ancient cultures organized the sky by linking stars together in patterns. These patterns reflected the culture's beliefs and legends. Different civilizations often gave the stars names that indicated the stars' positions in their pattern. Today we can see the same star patterns that people in ancient cultures saw. Modern astronomers still use many of the names given to stars centuries ago.

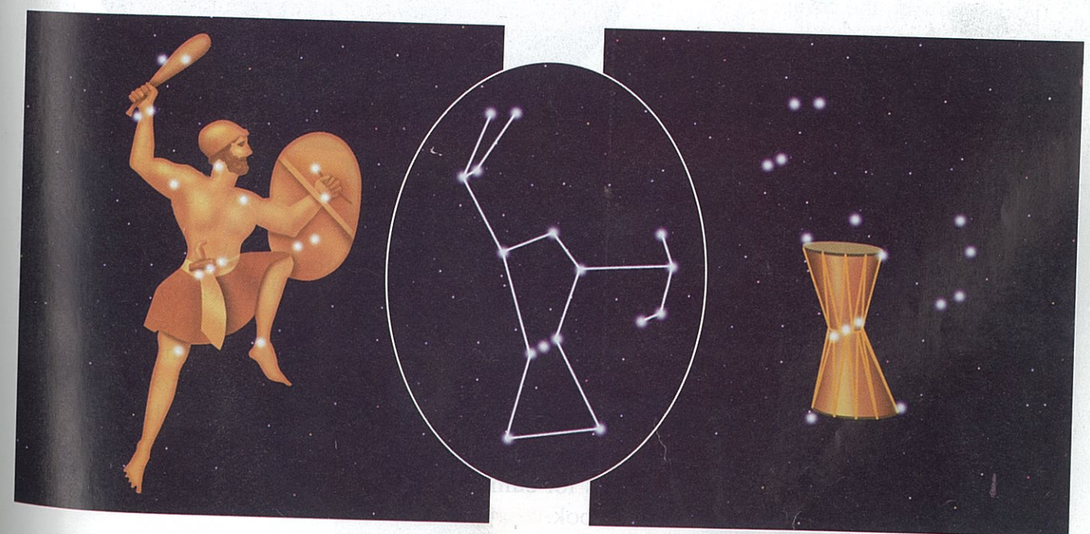
Astronomers can now describe a star's location with precise numbers. These advances have led to a better understanding of just how far away stars are and how big the universe is.

Constellations

When people in ancient cultures linked stars in a section of the sky into a pattern, they named that section of the sky according to the pattern. **Constellations** are sections of the sky that contain recognizable star patterns. Many cultures organized the sky into constellations that honored their gods or reflected objects in their daily lives. Constellations helped people organize the sky and track the apparent motions of planets and stars.

In the Eye of the Beholder . . . Different civilizations had different names for the same constellations. For example, where the Greeks saw a hunter (Orion) in the northern sky, the Japanese saw a drum (*tsuzumi*), as shown in **Figure 12.** Today different cultures still interpret the sky differently.

Figure 12 *The drawing at left shows that the ancient Greeks saw Orion as a hunter. The drawing at right shows that the Japanese saw the same set of stars as a drum.*



Self-Check

If a celestial object is said to be "in the constellation of Ursa Minor," does it have to be a part of the stick figure that makes up that constellation? Explain. *(See page 726 to check your answer.)*

Regions of the Sky When you think of constellations, you probably think of the stick figures made by connecting bright stars with imaginary lines. To an astronomer, however, a constellation is something more. As you can see in **Figure 13** below, a constellation is an entire region of the sky. Each constellation shares a border with its neighboring constellations. For example, in the same way that the state of Texas is a region of the United States, Ursa Major is a region of the sky. Every star or galaxy in the sky is located within a constellation. Modern astronomers divide the sky into 88 constellations. Around the world, astronomers use the same names for these constellations to make communication easier.

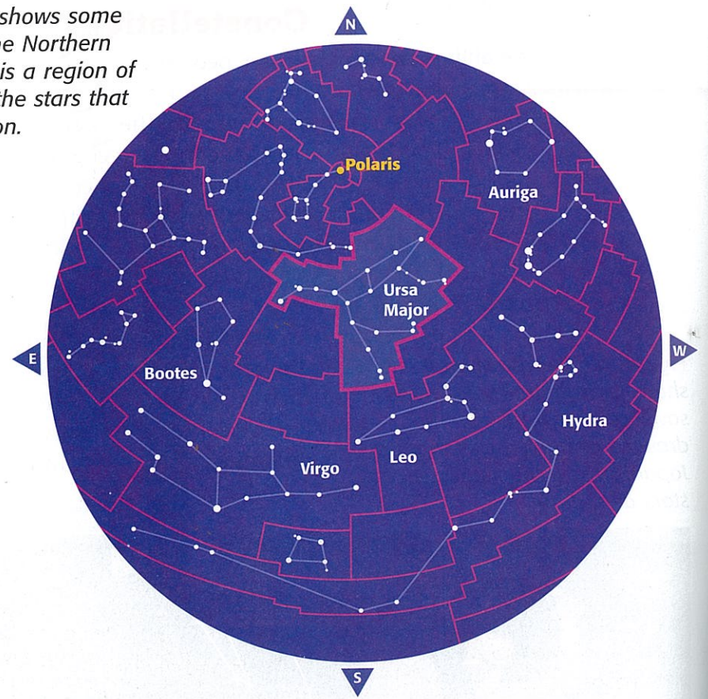


Figure 13 *This sky map shows some of the constellations in the Northern Hemisphere. Ursa Major is a region of the sky that includes all the stars that make up that constellation.*

QuickLab

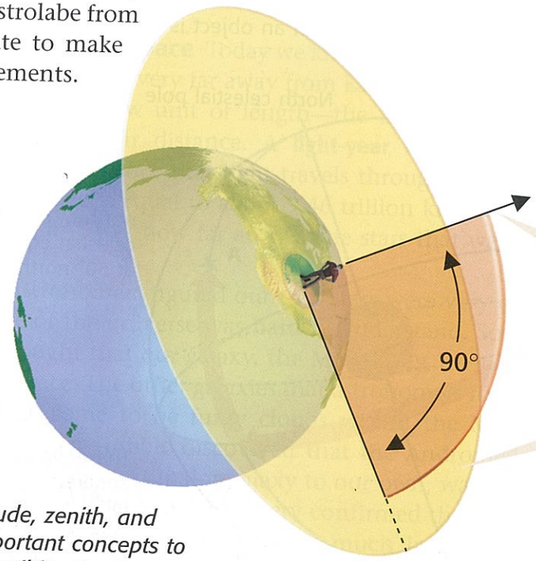
Using a Sky Map

1. Hold your **textbook** over your head with the cover facing upward. Turn the book so that the direction at the bottom of the sky map is the same as the direction you are facing.
2. Notice the location of the constellations in relation to one another.
3. If you look up at the **sky** at night in the spring, you should see the stars positioned as they are on your map.
4. Why are *E* and *W* on sky maps the reverse of how they appear on land maps?

Seasonal Changes As we go around the sun each year, the constellations change from season to season. This is one reason that people in ancient cultures were able to keep track of the right time of year to plant and harvest their crops. Notice that the sky map in Figure 13 shows the night sky as seen from the Northern Hemisphere in the spring. This map would not be accurate for the other three seasons. Sky maps for summer, fall, and winter are in the Appendix of this book.

Finding Stars in the Night Sky

You can use what you learned in the Investigate to make your own observations of the sky. Have you ever tried to show another person a star or planet by pointing to it—only to have them miss what you were seeing? With just a few new references, as shown in **Figure 14,** you can tell them exactly where it is. **Figure 15** shows how you can use the astrolabe from the Investigate to make such measurements.



In astronomy, **altitude** is the angle between the object and the horizon.

The **zenith** is an imaginary point in the sky directly above an observer on Earth. The zenith always has an altitude of 90°.

The **horizon** is the line where the sky and the Earth appear to meet.

Figure 14 *Altitude, zenith, and horizon are important concepts to know when describing the locations of celestial objects.*

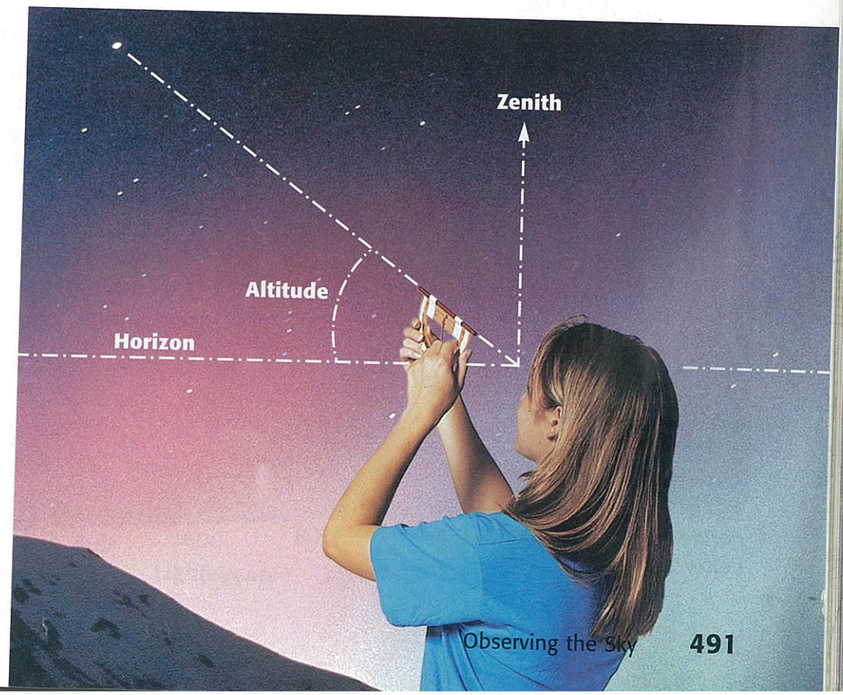


Figure 15 *With an astrolabe, you can measure the altitude of a star by measuring the angle between your horizon and the star. The altitude of any celestial object depends on where you are and when you look.*