LESSON **4**

Seasons on Earth

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On Earth, orange and red autumn leaves stand out against the blue sky.

INTRODUCTION

Nearly every place on Earth has four distinct seasons: winter, spring, summer, and fall. Both the Northern and Southern Hemispheres experience seasons, but they experience different seasons at the same time. When it is summer in the Northern Hemisphere, it is winter in the Southern Hemisphere, and vice versa. The shape and tilt of Earth on its axis affects the angle at which the Sun's rays pass through the atmosphere, and the length of daylight that an area experiences.

In this lesson, you will read about seasons and observe how the relative positions of the Sun and Earth change throughout the year. You will investigate the tilt of Earth's axis as it orbits the Sun, and you will see how the tilted Earth's orbit relates to seasons and changing shadows. You also will return to the software program you used in Lesson 3 to analyze the position of the North Star, as well as sunrise and sunset data over the year at different latitudes. You will

OBJECTIVES FOR THIS LESSON

Model Earth's orbit.

Identify Polaris as the current North Star.

Compare sunrise and sunset times at different latitudes throughout the year.

Relate changes in the apparent path of the Sun and the length of daylight to Earth's orbit on its tilted axis.

Create a working definition of the term "revolution." Identify "orbit" as its synonym.

explore what the apparent path of the Sun at different latitudes tells us about Earth's position relative to the Sun. Why does Earth's revolution around the Sun cause seasons? Let's find out.

Getting Started

1. Examine the shadow data from Lesson 3. Why do you think winter and summer shadows are different? Do you think that the shadows in June are the same everywhere on Earth? Discuss your ideas with the class.

2. What do you already know about seasons? What questions do you have about seasons? Share your ideas with the class.

3. Look at the two mounted globes. What observations can you make about the globes? Discuss your ideas as a class.

MATERIALS FOR LESSON 4

For you

- 1 copy of Student Sheet 4.3a: Sunrise and Sunset Data for Different Latitudes
- 1 copy of Student Sheet 4.3b: Graphing the Ecliptic at Different Latitudes
- 1 copy of Student Sheet 4: Review: Lessons 1-4

For your group

- 1 transparency copy of Student Sheet 4.3a: Sunrise and Sunset Data for Different Latitudes
- 1 transparency copy of Student Sheet 4.3b: Graphing the Ecliptic at Different Latitudes
- 1 set of fine-point transparency markers
- 1 Sun-Earth-Moon Board™
- 1 globe of Earth, 12 cm
- 1 rod labeled "E"
- 1 toothpick, 1 cm of tip
- Modeling clay, bead-sized amount
- 1 Mini Maglite®
- 2 AA batteries
- 5 removable dots
- 1 protractor
- 1 foam sleeve (optional)

4. Watch as your teacher demonstrates how Earth's axis can be "fixed" on one star as it orbits the Sun, as shown in Figure 4.1.

5. Read "The Reasons for Seasons" in this lesson. Discuss the questions with the class.

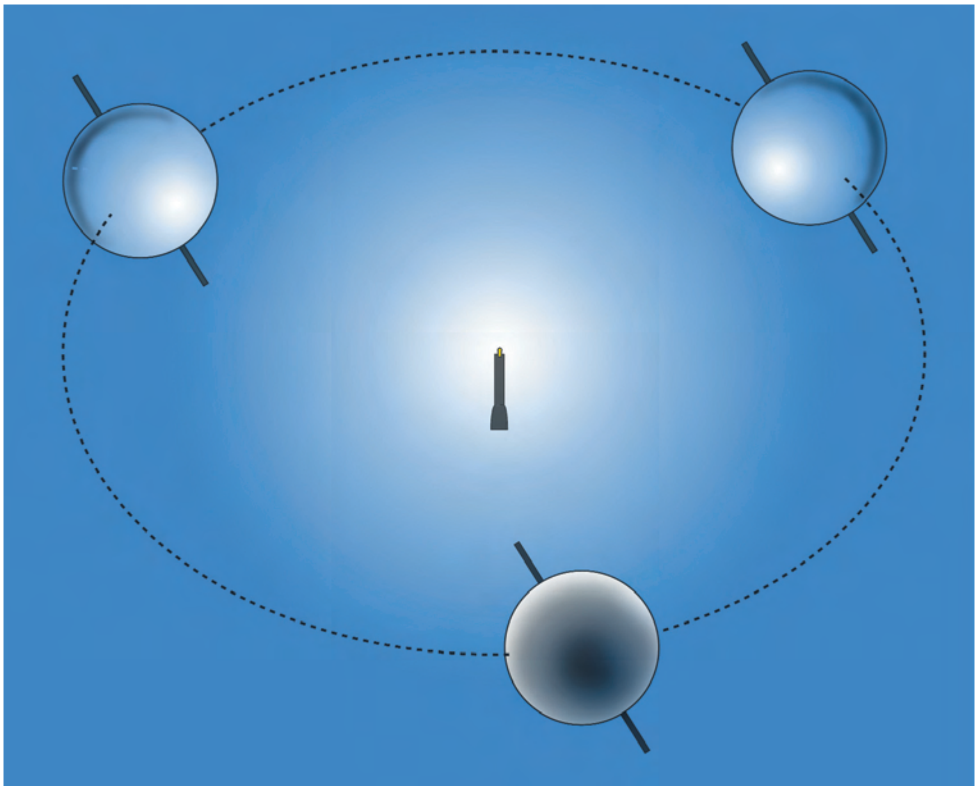

Figure 4.1 *The axis of this globe is "fixed" on the same point in the room as it orbits the Mini Maglite®.*

Inquiry 4.1
Investigating Seasons on Earth

PROCEDURE

1. Insert the rod labeled "E" through your globe to form an axis.

2. Stick the rod of your globe into the center hole of Side B of the SEM Board. If you have a protractor, measure the degree to which the axis is tilted. It should tilt approximately 23.5 degrees, as shown in Figure 4.2.

3. Mark your home location on the globe using a small bead-sized amount of modeling clay and the tip of your toothpick, as in Lesson 3 (see Figure 3.7). This will serve as a miniature shadow stick.

4. How can you use these materials to recreate winter and summer shadows on your globe? Discuss your ideas with your group.

Figure 4.2 *Setting up the Sun-Earth-Moon Board*

5. Place a removable dot in the center of your workspace. Place four additional removable dots approximately 30 cm from that dot to form a cross. Label the center dot "S." Label the outside dots "A," "B," "C," and "D" for the four seasons, as shown in Figure 4.3.

6. Position the SEM Board so that the rod of your globe is approximately over the dot labeled "A." Position the board so that the hole on the board marked "1" is closest to your "S" dot, as shown in Figure 4.4.

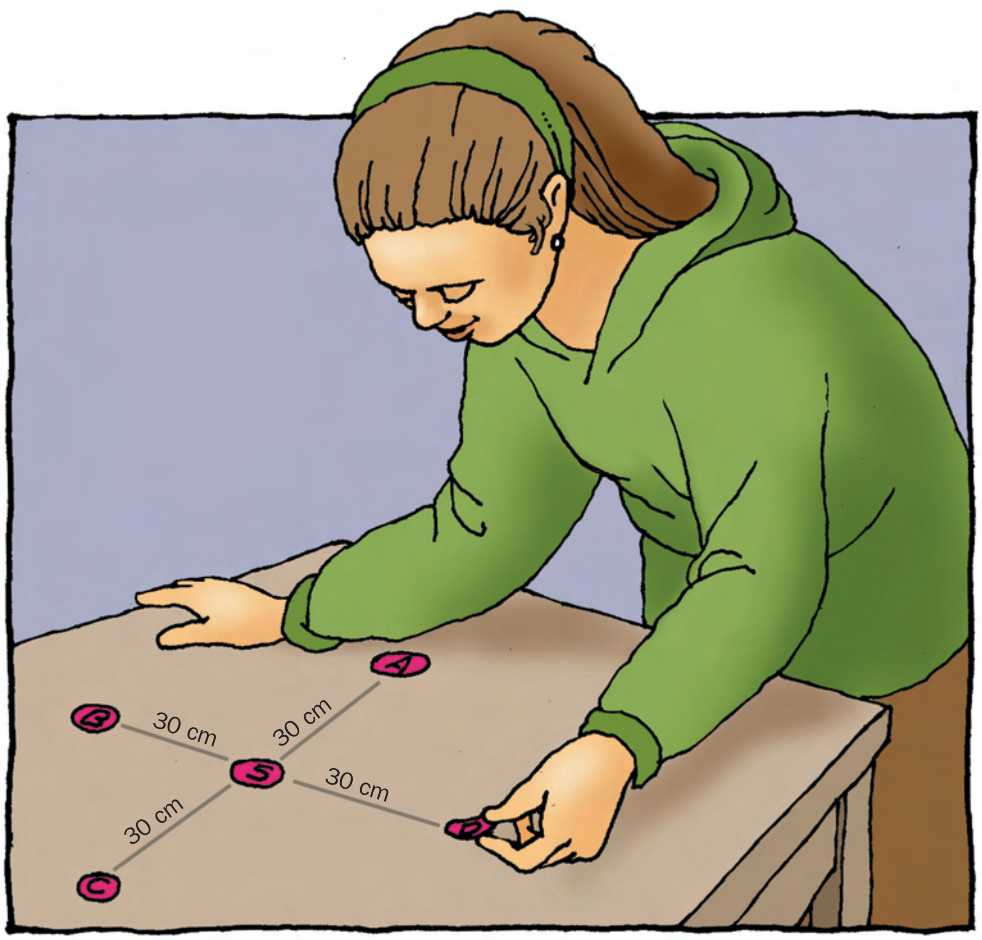

Figure 4.3 *Place the removable dots on your table, floor, or desk. Position and label them as shown. If the dots were a compass, the "A" would be north, the "B" would be west, the "C" would be south, and the "D" would be east. The "S" would be the center of the compass.*

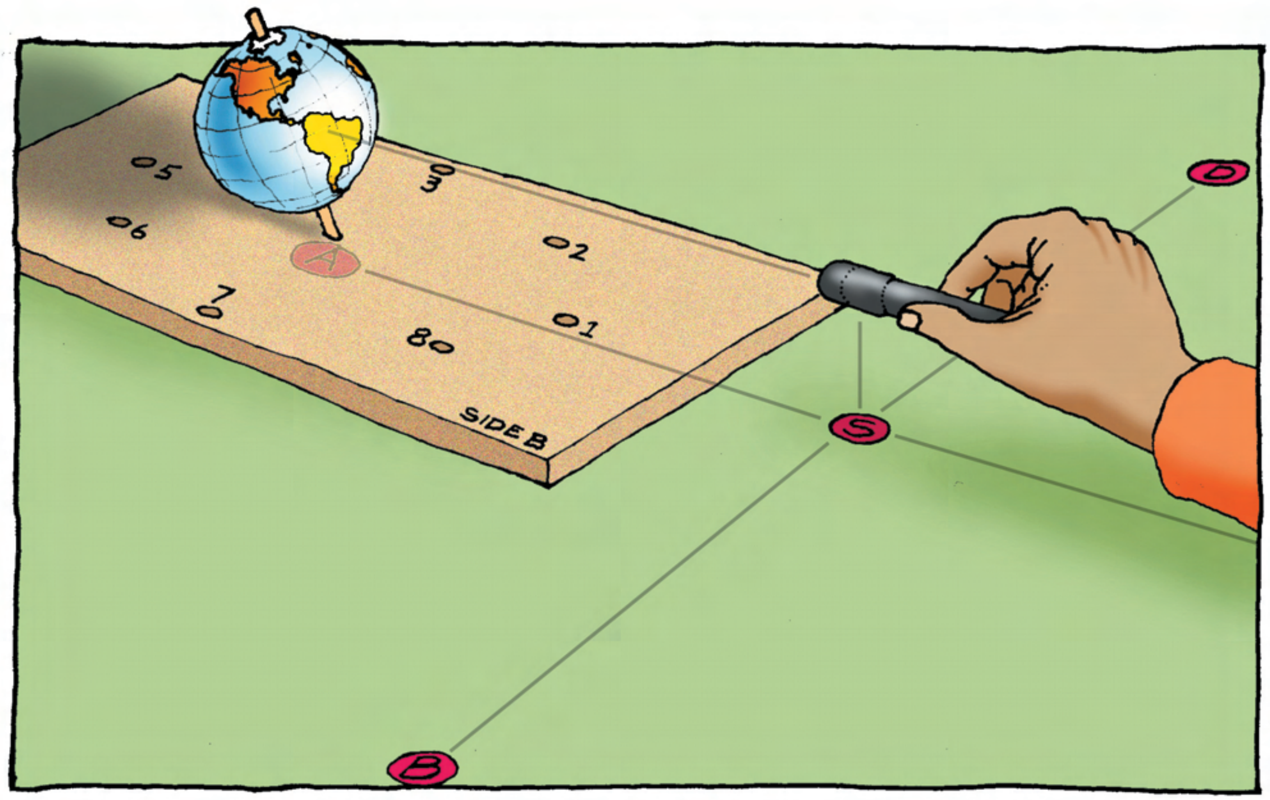

Figure 4.4 *Set up your model as shown. Shine the Mini Maglite® on the equator of your globe. Keep the head of the light over the "S" at all times.*

7. Hold the Mini Maglite over the "S" so that the light shines on the equator of your globe. Slowly rotate the globe counterclockwise so that your toothpick experiences day and then night. Observe the shadows that form near the toothpick. Do this several times. Discuss your observations with your group.

8. Record a description of your observations in your notebook. Label your observations "A." You may want to draw a picture as well.

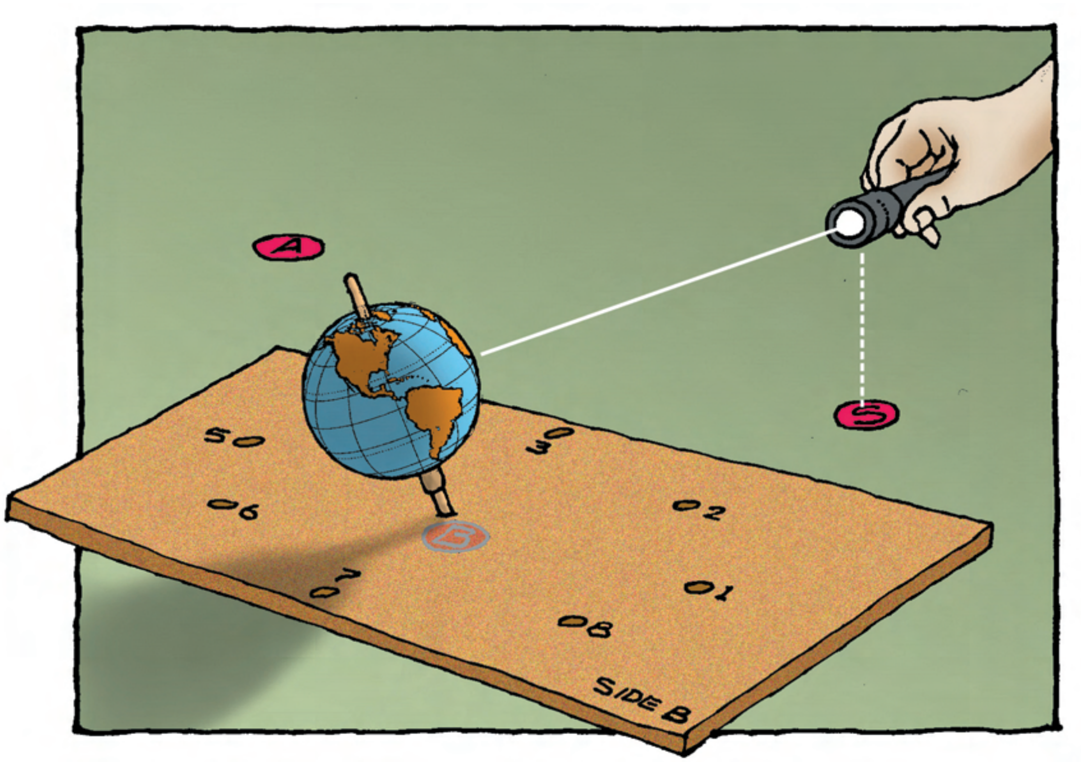

Figure 4.5 *Move your Sun-Earth-Moon Board counterclockwise around your Mini Maglite® to dot "B." Keep the axis of the globe pointing in the same direction each time.*

9. Now slide your SEM board counterclockwise around your Mini Maglite until the axis of your globe rests approximately over the dot labeled "B," as shown in Figure 4.5. Keep the axis of your globe facing the same direction as it was in Step 6. This means that the hole on the board marked "3" should now be closest to your "S" dot and your globe is still leaning toward the hole marked "5."

10. Examine the new position of your board. How many months would it take Earth to move one-fourth of its orbit around the Sun (from dot "A" to "B")? Discuss your ideas with your group.

11. Keep your Mini Maglite over the dot labeled "S," but shine it on your globe. Rotate your globe counterclockwise on its axis. What shadows does the toothpick cast as your globe rotates on its axis? Discuss your observations. Record them in your notebook. Label your observations "B."

12. Repeat Step 11 with the dot labeled "C." Keep the axis of your globe facing the hole on the board marked "5," which should now be closest to the "S" dot. Keep the Mini Maglite over the dot labeled "S" but face it toward the globe. Discuss, record, and label your observations.

13. Repeat Step 11 with the dot labeled "D." The hole on the board marked "7" should now be closest to your "S" dot.

14. Now move your clay and miniature shadow stick to a place in the Southern Hemisphere (such as South Africa). Repeat Steps 6–13. Record your observations in both words and pictures. Label your observations (for example, "Southern Hemisphere").

REFLECTING ON WHAT YOU'VE DONE

1. Share your group's results. Your teacher may ask you to demonstrate what you did.

2. Answer the following questions in your science notebooks, and then discuss them with your class:

   A. Describe and draw the position of the Sun and Earth during winter in the Northern Hemisphere.

   B. Describe and draw the position of the Sun and Earth during summer in the Northern Hemisphere.

   C. Why are summer and winter 6 months apart?

   D. What is happening in the Southern Hemisphere when it is winter in the Northern Hemisphere?

   E. Earth travels in a slightly elliptical orbit around the Sun. Therefore, Earth is closer to the Sun in December than it is in June. If Earth is closer to the Sun in December, why is December in the Northern Hemisphere colder than June?

   F. What did you learn in this lab that helps you to describe one reason why winter is colder than summer?

Inquiry 4.2
Observing the North Star

PROCEDURE

1. Read "Steering by the Stars." Discuss the questions at the end of the reading selection.

2. Review the steps of the inquiry, in which you will observe the North Star during four different times of the year. Create a table in your notebook to record your observations.

3. Using *Starry Night Backyard™*, set the computer program to your Home Location (use today's date and your nearest city). Record the latitude of your Home Location.

4. Select <Celestial Poles> from <Guides> on the menu bar. Set the <Time Step> to 003 minutes.

5. Click and drag the cursor around the screen until you find the labeled North Celestial Pole.

6. Put the screen in motion by clicking on the <Flow Time Forward> arrow. Stop it when you see the night sky. Move your cursor over the North Celestial Pole to see the name of the star nearest the pole. Can you find the North Star? What is its name? Use this name in the title of your table.

7. Measure the angle of separation between the North Star and the horizon. Do this by moving the cursor over the North Star, turning the cursor into an arrow, and then clicking and dragging the arrow to the horizon. Record the date and the angle of separation in your observation table.

8. Set the sky in motion again by clicking on the <Flow Time Forward> arrow. What observations can you make about the apparent motion of the stars? Record your observations in your table. Explain what you see and why you think it is happening.

9. Change the date on the screen to 3 months from the date of the lesson. Repeat Steps 6–8. Do this for all four seasons by advancing the dates in 3-month intervals. What observations can you make about the North Star and the motion of the other stars throughout the year? What observations can you make about the star's angle of separation each time? Record the date, angle of separation, and your observations in your table each time.

10. Visit another location (latitude) in the Northern Hemisphere. What observations can you make about the relationship between latitude and the location of the North Celestial Pole? What does the apparent motion of the stars tell you about Earth? In your notebook, write a short paragraph describing the conclusions you can make from this inquiry.

11. Visit a country in the Southern Hemisphere. Find the South Celestial Pole. Find the "South Star." What do you observe? Discuss your ideas with your group.

Inquiry 4.3
Investigating Seasonal Variations at Different Latitudes

PROCEDURE

1. How can you use *Starry Night Backyard* to learn more about sunrise and sunset and seasons at various latitudes? Your group will be assigned one of the following places to investigate using the computer:

   - Home location (nearest city)
   - Anchorage, Alaska
   - Quito, Ecuador
   - Antarctica (anywhere along 75° S latitude)

2. Record your assigned location on both Student Sheets 4.3a and 4.3b.

3. Using *Starry Night Backyard,* set your <Home Location> to the place to which your group was assigned. Record the longitude and latitude of that place onto Student Sheets 4.3a and 4.3b.

4. Set the date on the computer program to March 21 of this year.

5. Set the time on the program to 4:00 A.M.

6. Put the screen in play by clicking on the <Time Forward> button. Stop the screen when the Sun begins to rise (that is, the first moment you see a shadow appear). You may have to rewind or go forward to stop the screen at the exact time of sunrise.

7. Record the sunrise time in Table 1 of Student Sheet 4.3a. (If you do not see the Sun rise at all on March 21, record "0" in Table 1.) Where along the horizon is the Sun rising? Record the compass direction of the rising Sun in Table 1.

8. Put the screen into play again. At solar noon (when the shadows are the shortest for that day), stop the screen. Find the Sun in the sky. Put your cursor on the Sun, turn the cursor to an arrow, click, and drag the arrow down to the horizon. What is the Sun's angle of separation (its "height" above the horizon)? Record the angle of separation and its time in Table 1. (Record "0" if the Sun does not rise.)

9. Put the screen in play again. Stop the screen when the Sun begins to set (the minute you see the shadow disappear). Record the sunset time. Record the compass direction as well.

10. How many hours elapsed from the time of sunrise until the time of sunset? Calculate the total daylight hours and minutes. Record the total daylight hours in Table 1.

11. Reset your date to June 21. Repeat Steps 5–10 and record your data in Table 1. Then do the same for September 21 and December 21.

12. Use the data in Table 1 to complete the graph on Student Sheet 4.3b. Connect the sunrise, sunset, and angle of separation points using an arc (curved line). Use your key to color code each month's curve. A sample of what the ecliptic looks like in June at the equator is shown in Figure 4.6.

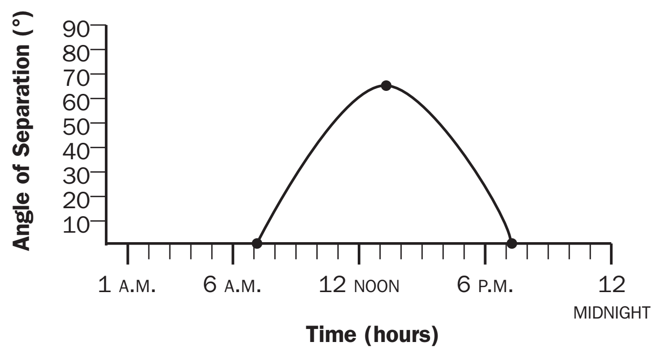

Figure 4.6 *Sample drawing of the ecliptic for Quito, Ecuador, on June 21*

REFLECTING ON WHAT YOU'VE DONE

1. Be prepared to share your group's data from Table 1 on Student Sheet 4.3a and Graph 1 on Student Sheet 4.3b with the class.

2. Answer the following questions in your science notebook, and be prepared to discuss your answers with the class:

   A. Describe the pattern of sunrise and sunset times for the equator. Why do you think this is so?

   B. How do sunrise and sunset times at the Antarctic compare to those in Alaska?

   C. How does the apparent path of the Sun across the sky during summer change as you move closer to the North Pole?

   D. How might the apparent height of the Sun in the sky and the length of daylight affect the temperature for a particular latitude?

   E. What do you think is responsible for the differences in the path of the Sun and in the sunrise and sunset times for different latitudes throughout the year?

3. In your own words, record a working definition for the term "revolution" in your notebook. Compare your definition to the definition of the term "orbit" in the glossary.

4. With your class, return to the Question B folder (from Lesson 1) and its accompanying photo card. Review the self-stick responses about what causes seasons. As a class, remove any postings that now seem incorrect. Add any new ideas you may have to the folder.

The Reasons for Seasons

Like all the planets in our solar system, Earth orbits around the Sun. Earth also rotates on its axis, which is currently tilted 23.5 degrees to the plane of its orbit. While the tilt of Earth's axis will change very little over your lifetime, the part of Earth that is exposed to the most solar energy—energy from the Sun—does change, and on a regular basis. This is because the tilted Earth orbits the Sun.

What do you think causes the seasons? Many people believe that seasons depend on the distance between Earth and the Sun. That might seem logical, but consider this: Earth travels in an ellipse, or oval, around the Sun. Due to this ellipse, Earth is slightly closer to the Sun in December than in June. If the distance from the Sun were responsible for how warm Earth is, it would mean that everyone on Earth would have summer in December. You know this is not true if you live in the Northern Hemisphere.

It is Earth's atmosphere and the tilt of its axis that are responsible for the changes in seasons. These factors affect the amount of solar energy that reaches each part of Earth at any time. The tilt of Earth on its axis affects the angle at which the Sun's rays pass through the atmosphere and strike Earth's surface. The higher the Sun's angle, the more intense the solar radiation and the less atmosphere the rays must pass through. The lower the Sun's angle, the less intense the solar radiation and the more atmosphere the rays must pass through (see the illustrations).

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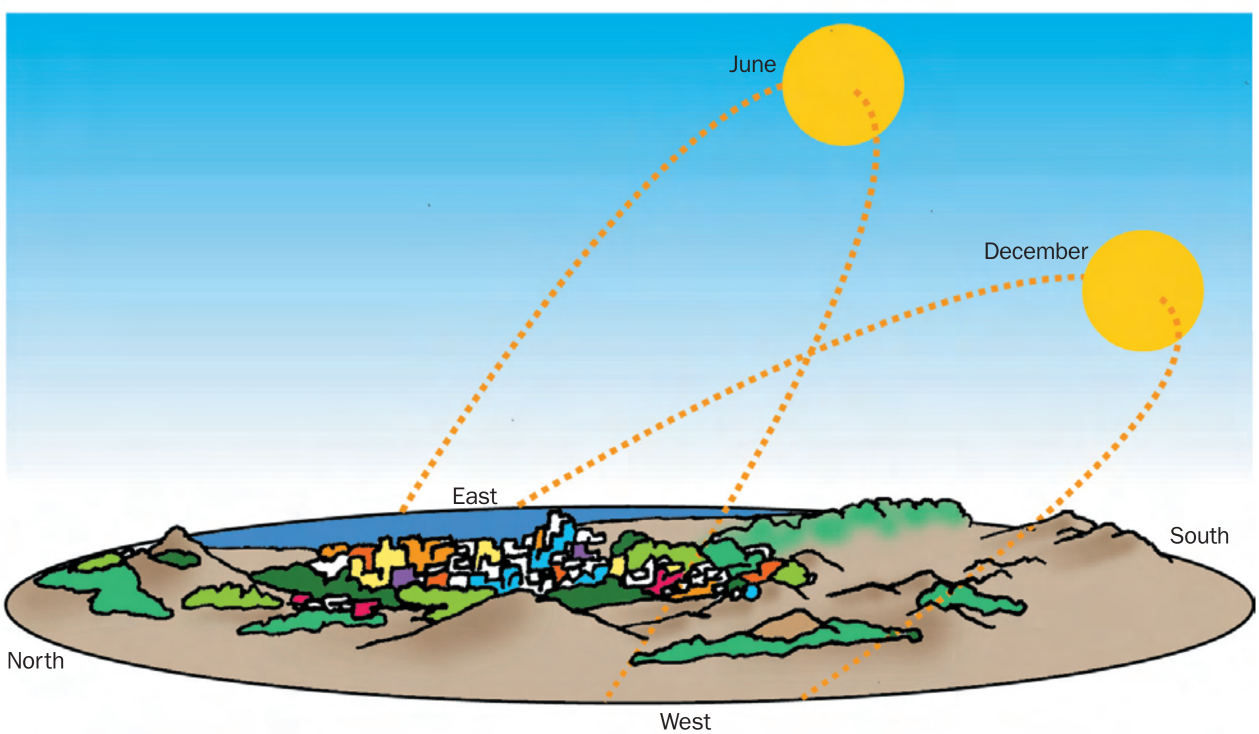
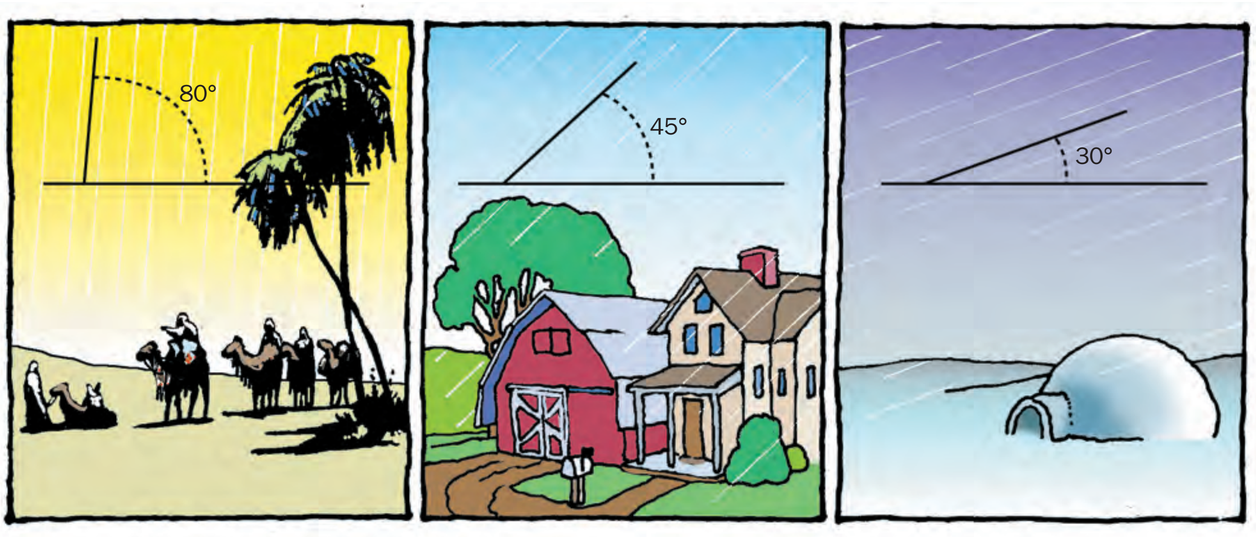
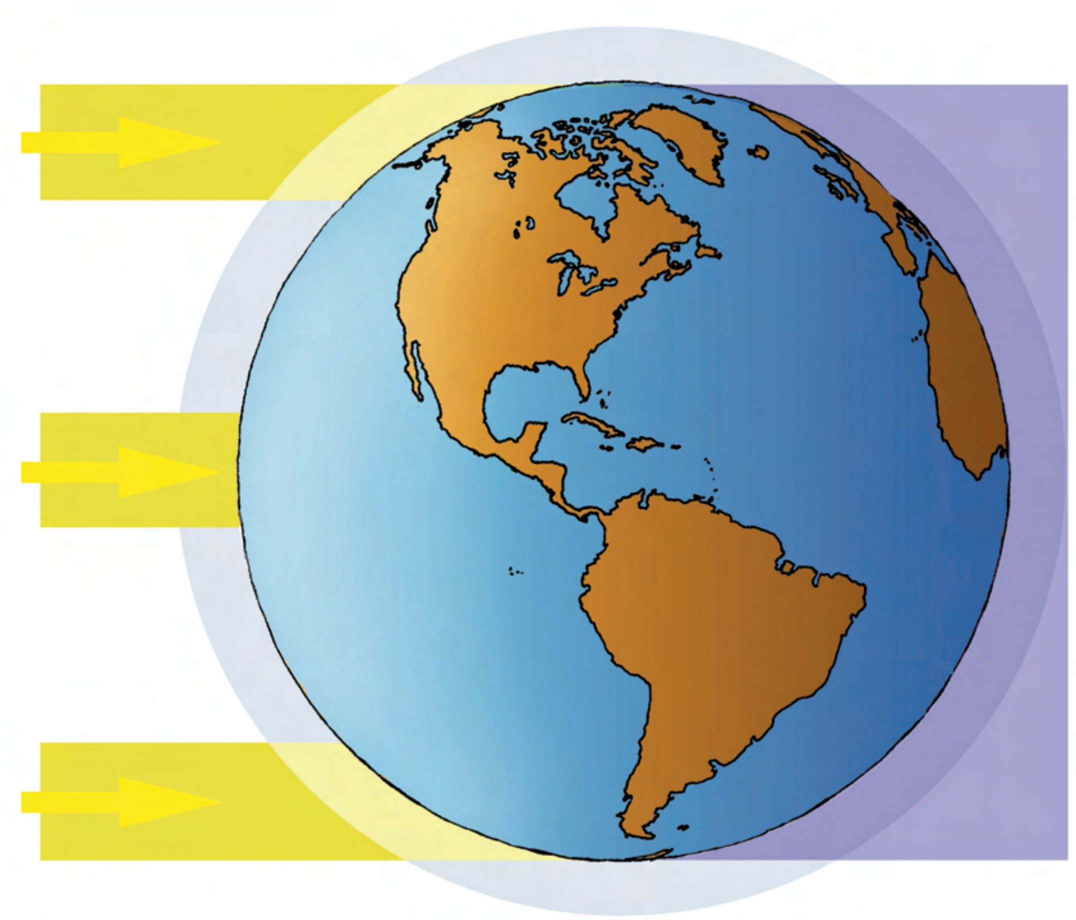


The angle of the Sun above the horizon is much greater in the summer than in the winter.



The higher the angle, the more intense the solar radiation.

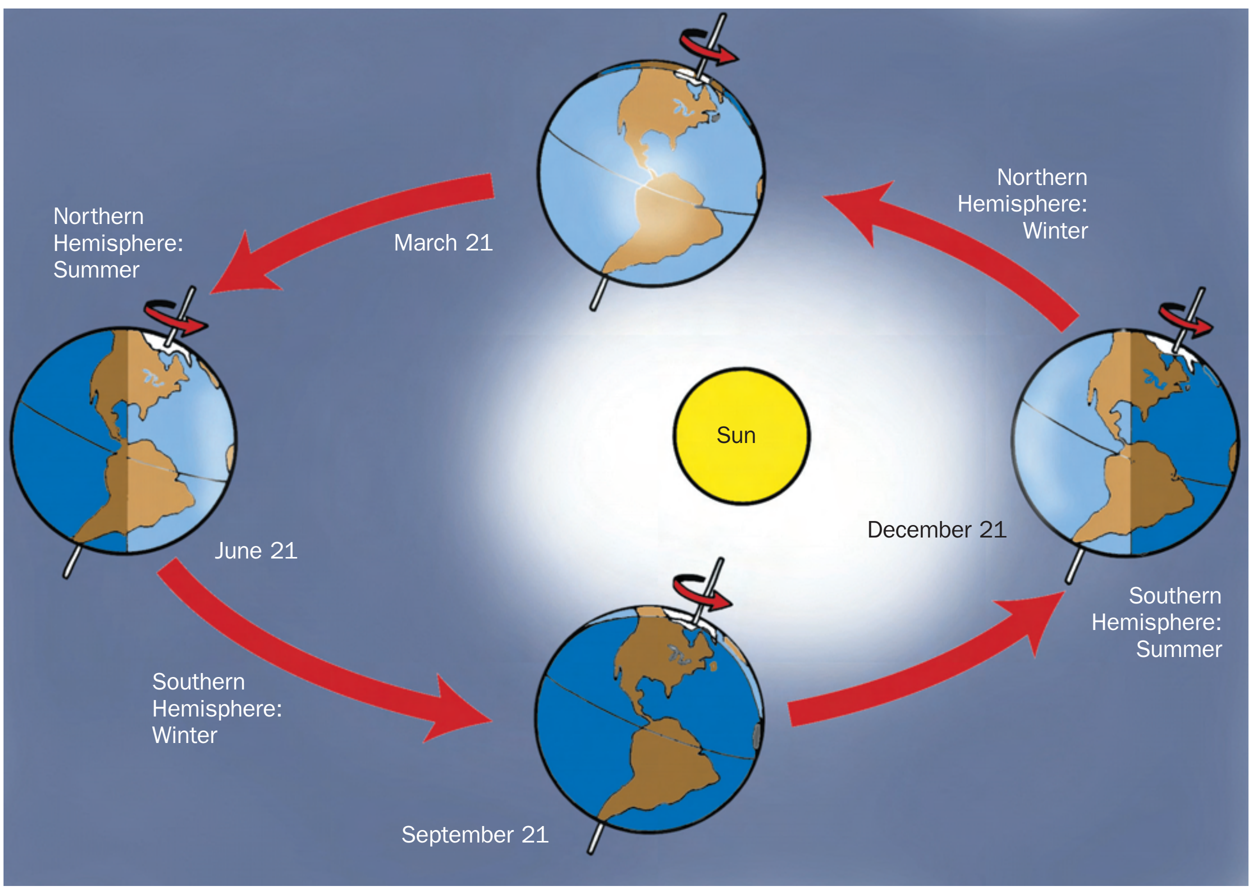


Because of the curvature of Earth, sunlight strikes the poles at a low angle. Rays striking Earth at a low angle must pass through more atmosphere. Earth's atmosphere absorbs and reflects solar energy. The more atmosphere the rays have to pass through, the less solar energy reaches Earth's surface. This is one reason the poles are colder than other parts of Earth.

The tilt of Earth also affects the length of daylight in any particular area. Between March 21 and September 21 on average, the Northern Hemisphere tilts toward the Sun. During this period the surface of Earth in the Northern Hemisphere receives longer periods of daylight than the surface of Earth in the Southern Hemisphere. More direct sunlight for longer periods causes warmer weather. However, between September 21 and March 21, the Southern Hemisphere tilts toward the Sun and has warmer weather. On December 21 (or December 22, depending on the year), the Southern Hemisphere celebrates the first day of summer—called the summer solstice; on that same day, the Northern Hemisphere experiences its first day of winter—the winter solstice!

On two days of the year (somewhere around March 21 and September 21), the Sun is over Earth's equator and neither hemisphere tilts toward the Sun. On those two days, the surface of Earth in both hemispheres receives equal amounts of energy from the Sun. Night and day are almost equal in length all over the world except at the poles. These two days are called the equinox. (To remember this term, think of "equal night.") Equinoxes occur midway between the solstices.

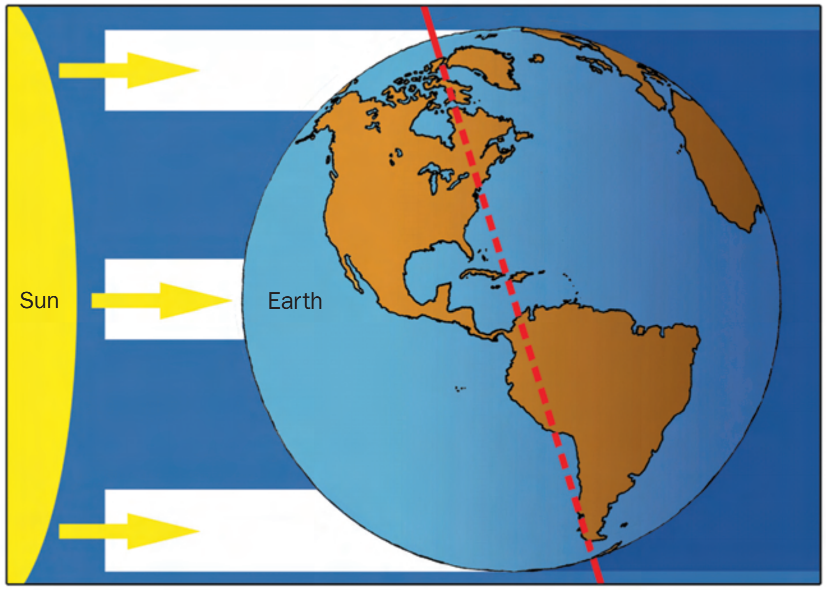
On average, December 21 has the shortest period of daylight in the Northern Hemisphere. But December 21 is not usually the coldest day of the year because it takes several weeks in fall and early winter before the atmosphere and oceans cool off. There is a lag, or delay, in seasonal temperatures, and the coldest period in



Between March 21 and September 21, the Northern Hemisphere tilts toward the Sun and has spring and summer. During that same time, the Southern Hemisphere tilts away from the Sun and has fall and winter. The equator is warm all year round. (Diagram is not drawn to scale.)

the Northern Hemisphere therefore may not arrive until early February. The same seasonal temperature delay occurs in spring and summer.

The amount of solar energy that reaches each hemisphere affects the temperature of the Earth's surface. Even though the Sun is closer to Earth in winter than in summer in the Northern Hemisphere, the Sun's rays do not hit Earth directly. The rays hit it at an angle after passing through the atmosphere. During winter, there are also fewer hours of daylight, which accounts for some of the chill of winter.



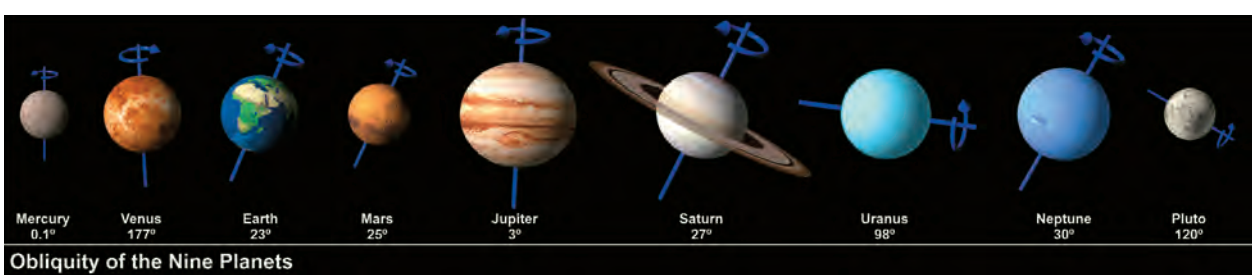
Seasons are the result of uneven heating of Earth's surfaces.

Seasons on Other Planets

Did you know that other planets also have different seasons? The spin axis of Uranus, for example, points to the Sun. That means that Uranus is tilted about 98 degrees to the plane of the ecliptic (the plane along which the Sun exists), compared to Earth's current tilt of 23.5 degrees. With Uranus completely on its side, one hemisphere always has summer during half of Uranus's 84-year orbit around the Sun, while the other hemisphere doesn't experience summer until the second half of its 84-year orbit! This pattern creates 42-year seasons of warmth and cold on each end of Uranus. Other planets also have interesting relationships to the Sun that cause different seasonal characteristics. You will learn about them in Part 2 of this module. ☐

QUESTIONS

1. What is the winter solstice, and when does it occur in the Northern Hemisphere?
2. Draw a picture of Earth's position relative to the Sun when the Southern Hemisphere is experiencing summer.
3. How long is winter on Uranus? Why?



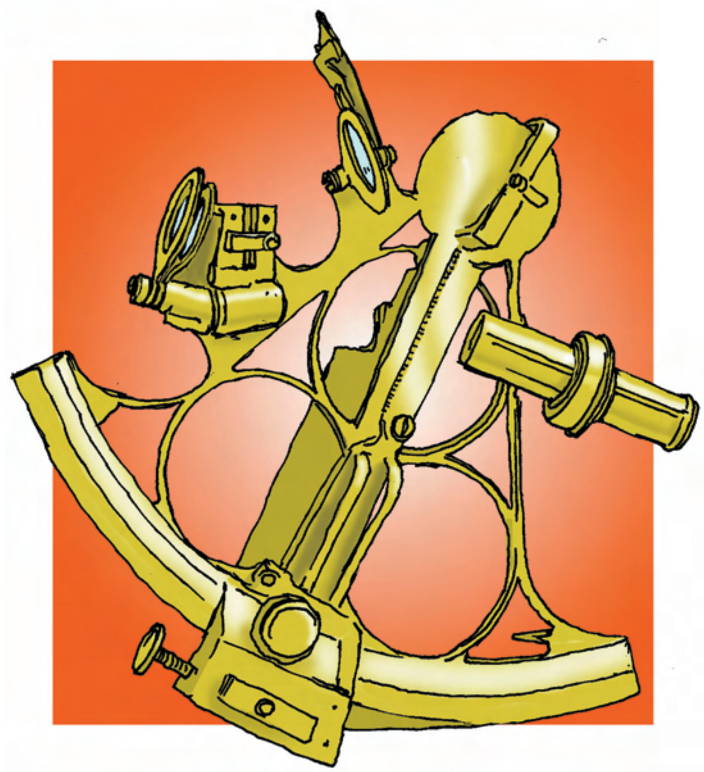
Each planet is tilted slightly differently. Notice how Uranus is tilted 98 degrees on its axis as it revolves around the Sun. What other planet might have an unusual pattern of seasons?

Steering by the Stars

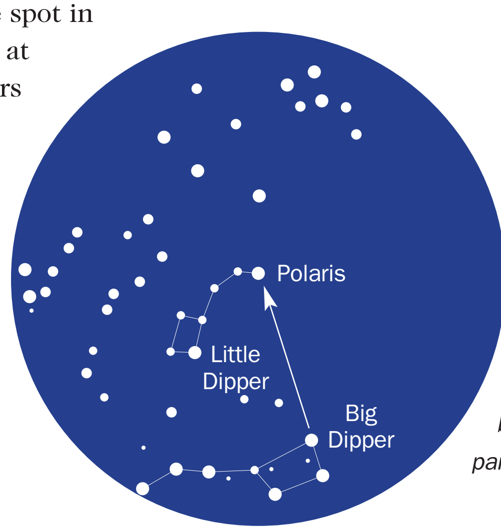
How did sailors of centuries past find their way across the seas before the invention of the compass and the sextant? The earliest sailors followed the coastline as far as they could, using features on land to mark their location. But when their journey took them far from land, they relied on the sky.

Early sailors knew that the Sun rises in the east and sets in the west, and they used that knowledge to guide them. So if they sailed into the rising Sun, they knew they were heading east. If they turned to the right, putting the rising Sun on their left side, they knew that they were heading south.

At night, these ancient mariners steered by the stars. The North Star proved a stable marker in the Northern Hemisphere because Earth's northern axis points to the North Celestial Pole (*celestial* means "dealing with the sky; heavenly"). The North Star, Polaris, is the star currently closest to the North Celestial Pole. As Earth rotates on its axis, the stars in the night sky seem to move in a circle, because they are fixed relative to Earth. But the North Star remains in one spot in the Northern Hemisphere sky at all times, and all the other stars seem to rotate around it. The farther north a sailor traveled in the Northern Hemisphere, the higher the North Star appeared in the sky. The farther south one sailed in the Northern Hemisphere, the lower the star appeared in the sky.



Sailors looked at stars and other celestial bodies through the telescope of this sextant. The angular distance of a star above the horizon was read off the sextant's scale. This way, sailors could calculate their positions.



Polaris, the current North Star, is at the tip of the handle of the Little Dipper. You can also find it by connecting the two stars in the pan of the Big Dipper.

Many sailors of old used a handy tool to help measure precisely how high or low a star was in the sky: their fingers! By holding his arms straight out in front of him, a mariner laid his fingers on top of each other to measure the "height" of a star such as the North Star from the horizon. Because the height of Polaris above the horizon is equal to the latitude at a particular location, sailors could use the star to estimate their location. They would, for example, turn west or east once a particular star selected for navigation was two finger-widths above the horizon. Very clever!

Although the skies are still important in guiding ships, today's sailors use computer and satellite technology—such as the Global Positioning System—to guide their travels. Navigators have come a long way since the days of steering by the stars. □

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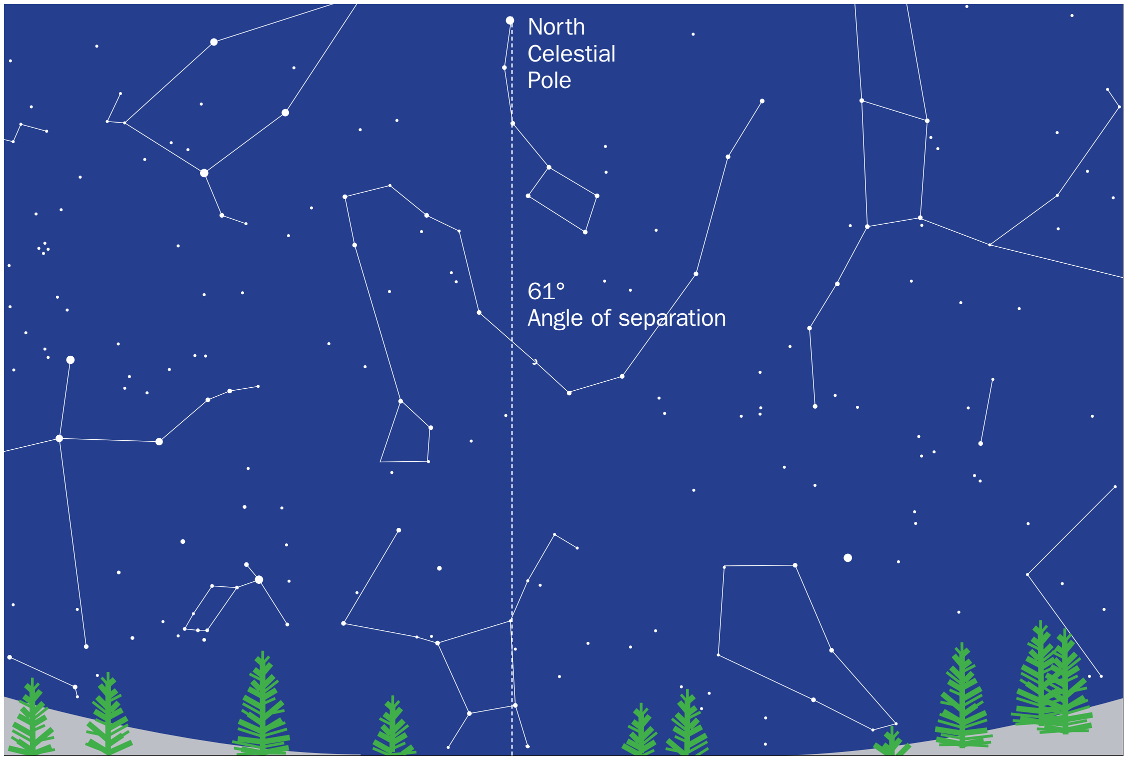
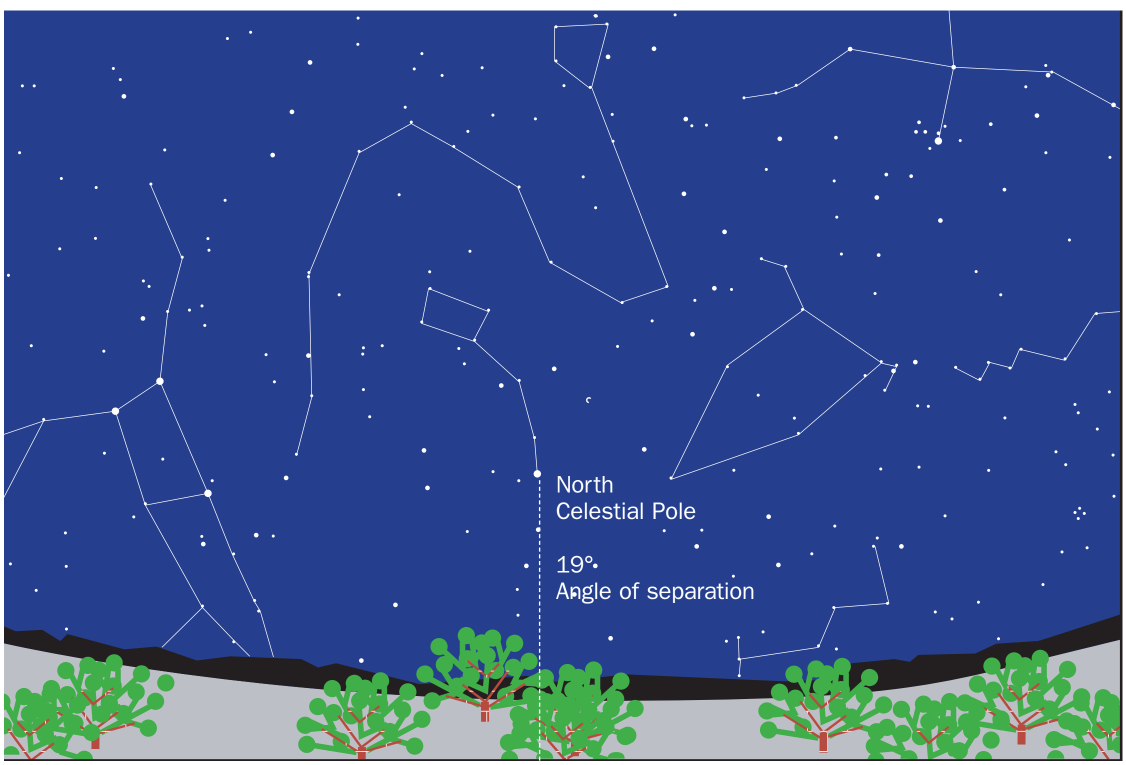
This time exposure shows star trails that mirror Earth's rotation. It was taken with a camera aimed at the North Star over Kitt Peak National Observatory in Arizona.



This illustration shows what the North Star looks like from Anchorage, Alaska (latitude 61° N).



This illustration shows what the North Star looks like from Mexico City, Mexico (latitude 19° N).

Constant as the North Star

As constant as it seems, Polaris, the North Star that we see in our night sky, has not always been our North Star. This is because Earth wobbles on its axis as it rotates, like a spinning top. While a top can make one complete wobble in a second, it takes Earth 26,000 years to complete one wobble—or precession. This means that Earth's axis points to different stars over the centuries. For example, around 3000 B.C., the North Celestial Pole pointed to Thuban, not Polaris.

QUESTIONS

1. Before the invention of the compass, how did sailors determine if they were sailing east or west?
2. Why is Polaris called the North Star?
3. Why is Polaris a stable sky marker today?
4. What handy tool did sailors use to help them navigate? How did this tool work?
5. What is the relationship between the position of the North Star and latitude?