Analyzing an Earth-Sun Model to Explain the Stars Seen in the Sky

A group of stars that form a pattern is called a *constellation*. The constellation Ursa Major also has an inner pattern known as the Big Dipper. But if you look for the Big Dipper, you will see that it is not always in the same position in the night sky. In addition to the movement of the stars across the sky every night, their rising times change throughout the year. So the constellations visible in the early evening are different in winter, spring, summer, and fall.


The Big Dipper is one of the most familiar star patterns in the northern sky. It looks like a ladle used to scoop water.

3. Discuss When you look at the night sky, what do you see?

Changes in Stars Seen in the Night Sky

Just as the sun appears to move in a path across the sky, stars in the night sky also appear to move. They seem to change locations nightly.

4. Why do the stars appear to move across the sky every night?

- **A.** Because Earth orbits the sun once a year.
- **B.** Because Earth tilts on its axis.
- **C.** Because Earth rotates once every 24 hours.

5. Act With your class, investigate why star patterns change yearly.

- Several students form a large circle. They represent the stars in the night sky. One student represents the sun and stands in the center. One student represents Earth and stands between the stars and the sun. The head of the student who is Earth represents the North Pole of Earth.
- Earth will move around the sun in a counterclockwise direction. The sun and stars do not move.
- Earth stands facing away from the sun. Earth looks straight ahead, to the left, and to the right. Note which stars Earth can see. This is the night sky in summer.
- Earth moves to a position one-fourth of the way around the sun. Note which stars Earth can see. This is the fall night sky.
- Earth moves to a winter position and finally a spring position. Note how the stars seen in the night sky change.

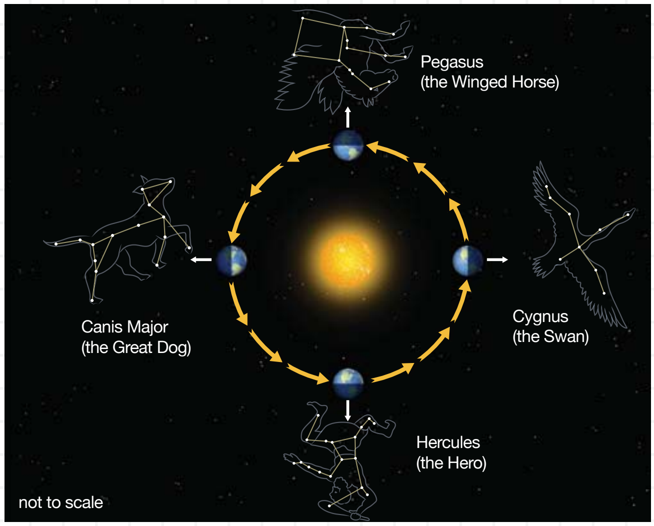
6. In the activity, if the student playing Earth turns to face the sun, what time of day is it for people who live on that side of Earth? ______________________
If the person now turns halfway around and looks at the stars, what time of day is it for the same people? ______________________

7. The student who represents Earth sees different stars from different positions in the circle. How does this model suggest evidence that Earth circles the sun once a year?

Seasonal Star Patterns

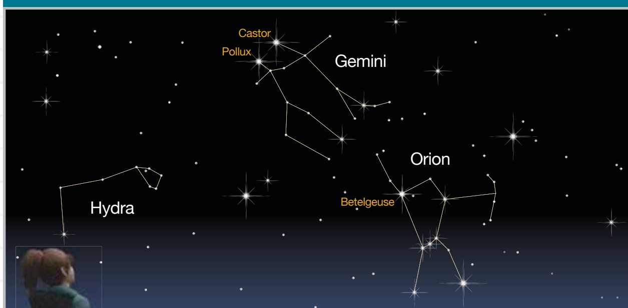
Earth's place in its orbit affects which stars can be seen during different seasons. The location of stars in the night sky changes as Earth moves along its orbit. During the year, you will be able to see all the stars visible from one specific place on Earth.

On a given day, you will only be able to see the stars that are in the opposite direction of the sun. The stars seen from the Northern Hemisphere may be different from the stars seen from the Southern Hemisphere. If you are on the North or South Pole, the stars will appear to rotate around a point directly above your head because of Earth's rotation. The sky seen from the North Pole is completely different than the sky seen from the South Pole. As you move from the North Pole toward the South Pole, the sky will change. The sky seen by someone in Florida may have some of the same stars in the sky seen by someone in Brazil, but the whole pattern of stars seen is not the same.

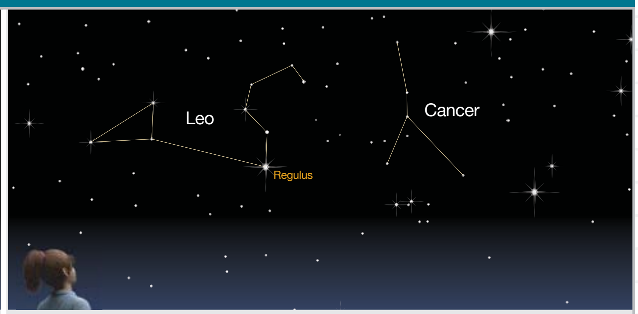


Earth's place in its orbit affects which stars are seen at different times of the year. For example, Cygnus is seen in the night sky of the Northern Hemisphere in summer.

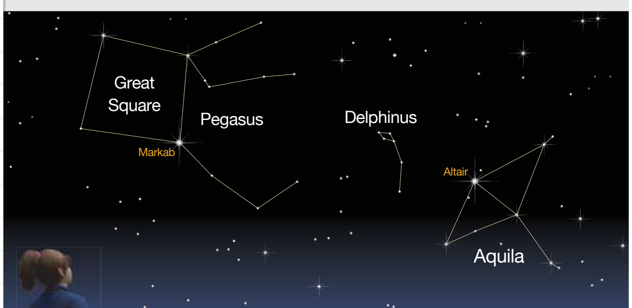
Some Stars Are Seen in Different Seasons



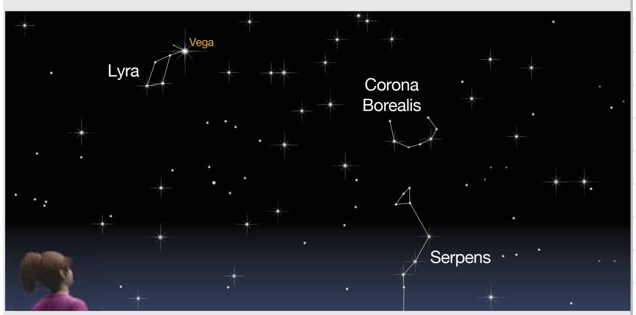
These are some of the constellations visible in the night sky of the Northern Hemisphere during **winter**. During the day, the sun blocks summer constellations from sight.



As Earth continues its orbit around the sun, winter changes to **spring**. Earth faces a different direction during the night and new constellations become visible.



In **fall**, Earth is three-fourths of the way through its orbit around the sun and new constellations are visible. Soon, winter constellations will start to be seen once more.

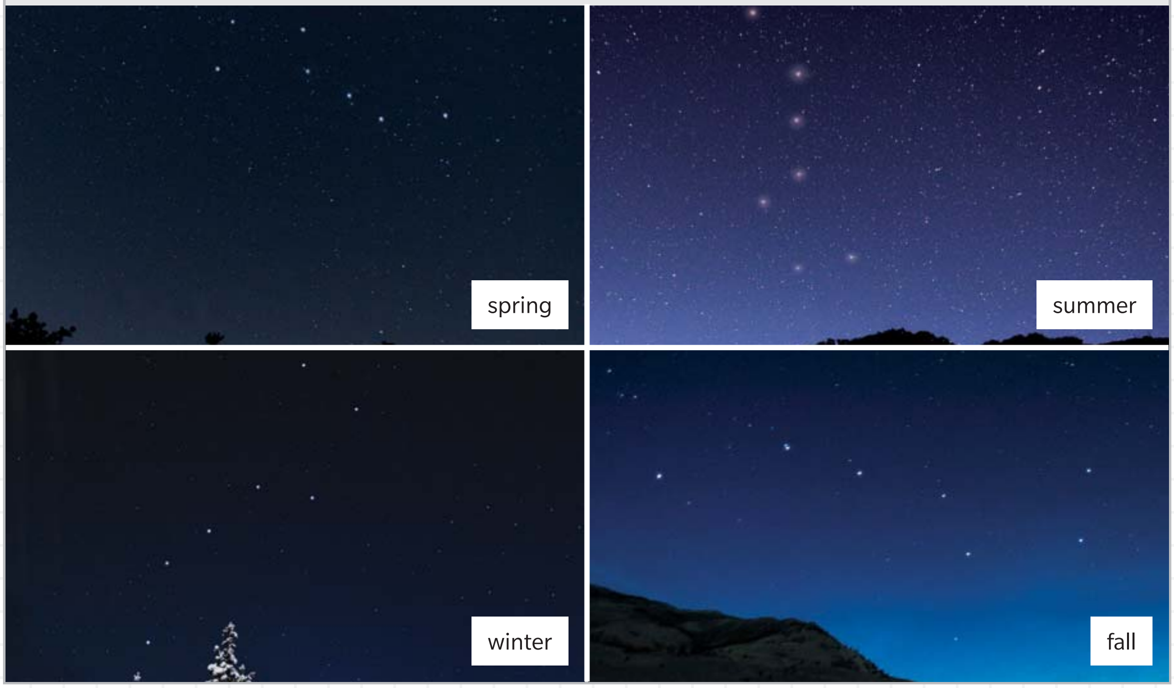


Earth's **summer** position brings new constellations into view. Now the winter constellations are opposite the sun and cannot be seen.

8. Why do you see different stars in spring's night sky than in fall's night sky? Explain.

Some Stars Are Seen All Year

These photos, taken at about the same time of night, show the position of the Big Dipper from season to season in the Northern Hemisphere.



Earth's place in its orbit determines which stars can be seen during different seasons, but depending on how far north or south of the equator you are, there are some stars that can be seen in the sky all year. Your location on Earth determines which stars stay visible all year.

9. Circle the correct words to explain what you observe in the photos above.

The Big Dipper appears to keep / change its position from season to season.
The Big Dipper seems to move in a circular pattern as the seasons / years change.

Navigation Using the Stars

In the Northern Hemisphere, the North Star's position remains fixed in place throughout the year because Earth's north axis points to it.

Because it does not shift position, the North Star became a guide by which sailors could navigate the northern seas at night. At the North Pole, the North Star is seen directly overhead. At the equator, the North Star is seen at the horizon. By taking a measure of the angle of elevation of the North Star, you can determine your latitude on Earth.

Time-lapse photography was used to capture this image over the course of one night. The sky is photographed at regular intervals to show the slow, continuous movement of other stars around the North Star.

10. Could a person at the South Pole see the North Star? Explain.

Relating Seasons to Energy from the Sun

During a year, many places on Earth experience four seasons. *Winter* is generally cold and may bring snow and ice. As temperatures warm, snow melts and *spring* begins. Next comes *summer*, the warmest season. *Fall* (also called *autumn*) follows, temperatures get cooler, and then winter begins again.

11. What seasonal changes do you see where you live?


Early blooms announce that spring is on the way and winter is ending.

Seasons of the Year

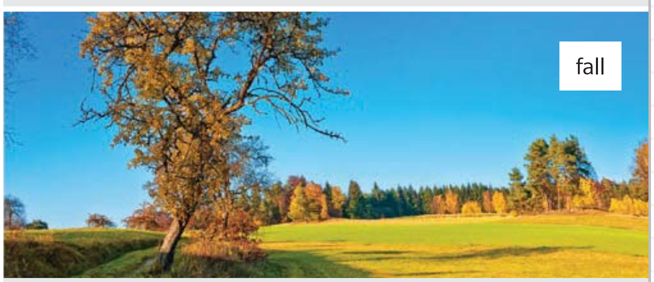
A **season** is a division of the year that is associated with particular weather patterns and daylight hours. Weather conditions and daily temperatures at any location on Earth follow a predictable cycle throughout the year. Winter may be cold. Summer may be hot. Spring and fall temperatures are warmer than winter's but colder than summer's. The farther north you go, the greater the differences in the seasons. For example, areas closer to the equator have milder weather in winter than areas closer to the poles have.

The Four Seasons of the Year

In the Northern Hemisphere, spring begins In March. The sun moves higher across the sky and the number of daylight hours increases. Temperatures gradually rise.

Summer is the warmest season, beginning in June in the Northern Hemisphere. The sun is in the sky for a greater part of the day.

In December, the Northern Hemisphere begins its coldest season—winter. Freezing temperatures and snowfall are associated with winter months. The sun sets early in the day.



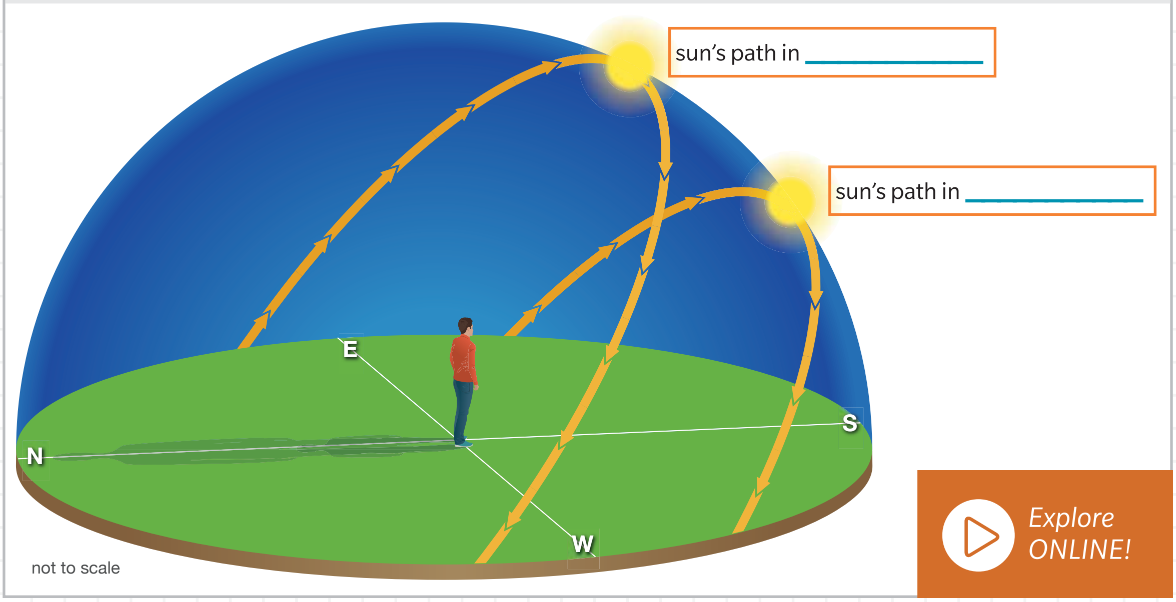
Fall begins in September in the Northern Hemisphere. The number of daylight hours decreases as the sun's path across the sky moves lower. Temperatures gradually cool.

Changes across the Seasons

Because of Earth's rotation, we see the sun appear to move across the sky. For people living on the equator, the path of the sun in the sky does not change very much throughout the year. The sun rises on the eastern horizon, goes nearly overhead, and then sets on the western horizon. The sun reaches its highest point in the sky at about noon. Daytime lasts about 12 hours all year long, and the weather is nearly always warm. But as you move north or south away from the equator, the sun's path in the sky changes during the year. For example, in the Northern Hemisphere, the sun rises north of east in the summer. In winter, the sun rises south of east. Sunsets follow the same pattern. Summer sunsets in the Northern Hemisphere are north of west, while winter sunsets are south of west. The sun's path changes as seasons change.

The Path of the Sun in Summer and Winter in the Northern Hemisphere

12. Write *summer* or *winter* to label each path of the sun.



Explore ONLINE!

Daylight Hours

In winter, it may be dark when you wake up for school and dark again soon after school ends. The sun does not go very high in the sky so its path across the sky is shorter. Because the sun is not up in the sky very long, there is less daylight time during this time of year. There is less time for the sunlight to heat up Earth during the daytime and more time for Earth to cool during the longer nighttime hours. The shortest amount of daylight time is on December 21 or 22 in the Northern Hemisphere.

In summer, the sun goes higher in the sky. Days are longer because it takes more time for the sun to complete its longer path across the sky. It is warmer in summer than in winter because the sun is up for a longer period of time. There are more hours of daylight to warm Earth during daytime, and fewer nighttime hours for Earth to cool. The day with the greatest amount of daylight time is June 20, 21, or 22 in the Northern Hemisphere.

13. How is the number of daylight hours of sunlight related to the seasons?

Hands-On Lab

Model Sunlight Distribution

Do the Math You will explore what happens when light is spread out compared to when it is not spread out.

MATERIALS
- flashlight
- graph paper
- metric ruler
- pencil
- protractor

Procedure

STEP 1 Work with a partner. One partner shines a flashlight straight down on graph paper from a height of 15 cm. Using a protractor, the second partner makes sure the light strikes the paper at a 90° angle. The second partner then traces around the lit area on the paper with a pencil. Label it *90°*.

STEP 2 Switch holding the flashlight between partners. Keep the flashlight at the same height as it was in STEP 1 (15 cm). Using the protractor, one partner guides the other to change the position of the flashlight so that the angle of the light striking the paper is 60°. That partner traces the lit area and labels it *60°*.

STEP 3 Next, using the protractor, change the angle so that the light striking the paper is 30°. Trace the lit area and label it *30°*.

STEP 4 Calculate the total area of each lit area using this method:

a. Count and record the number of full squares in each area.
Example: 4 full squares

b. Count the number of partial squares and divide the number by 2.
Example: 12 partial squares ÷ 2 = 6

c. Add the number of full squares to the number calculated for partial squares to find the total area. Example: 4 + 6 = 10

Angle of light	4a. Full squares	4b. Partial squares	4c. Total area
90°			
60°			
30°			

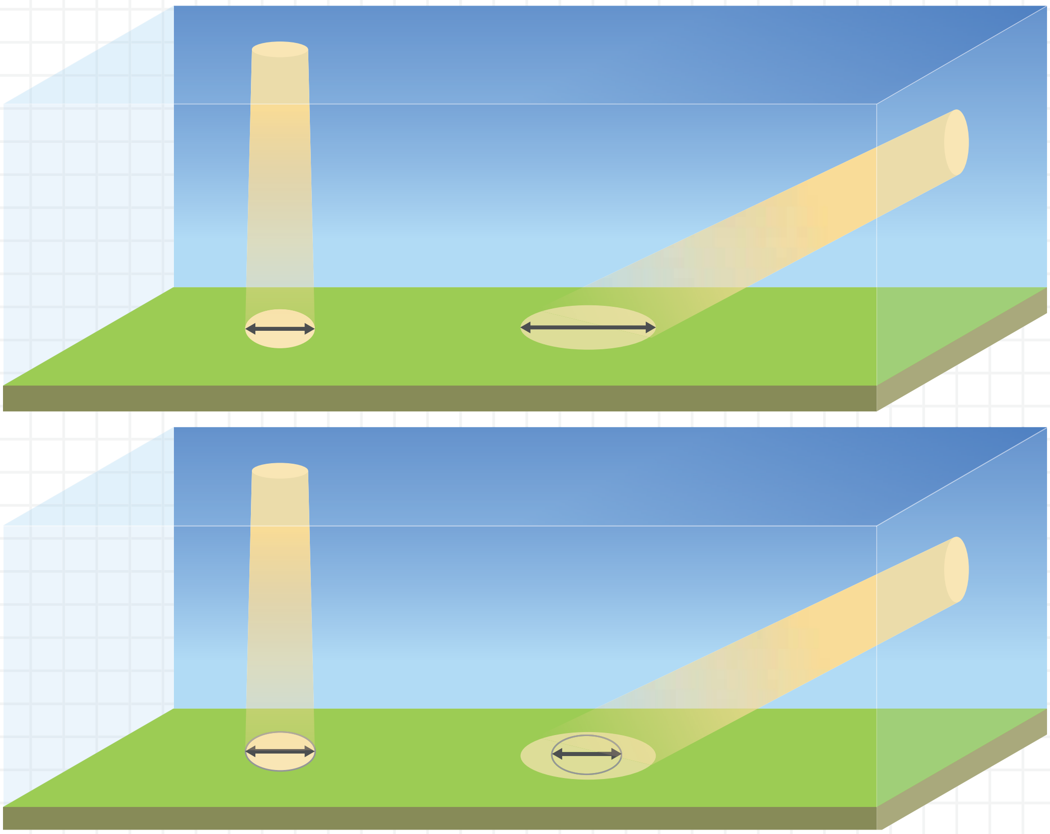
Analysis

STEP 5 Compare the total areas. What do you think the data mean?

Energy from the Sun

There are two reasons why we receive different amounts of the sun's energy in summer and winter: changes in the length of the sun's path across the sky and changes in the height of the sun in the middle of the day. In the summer, the sun has a longer path across the sky, which means the sun is in the sky for a longer period of time. There are more hours of daylight, so there is more time for Earth to absorb the solar energy.

The height of the sun in the sky determines the angle at which the sunlight strikes Earth. As shown in the activity, when the sun is overhead, the energy on each square meter is more intense—the light is less spread out. The amount of energy striking a smaller area will result in warmer temperatures than the same amount of energy striking a spread-out area. In summer, when the sun is higher in the sky, the solar energy is more intense. In winter, when the sun is lower in the sky, the sun's energy reaches Earth at a lesser angle. Solar energy passes through more atmosphere when it strikes Earth at a lesser angle, making the sun's rays striking Earth less intense. The angle at which sunlight strikes Earth influences Earth's temperatures, making it hot in summer and cold in winter. These changes in the sun's path across the sky and the angle at which sunlight strikes Earth affect the changes in temperature that occur across the seasons.



As the sun moves lower in the sky, the energy from sunlight is spread over a larger and larger area. The same amount of ground gets all of the light when the sun is directly overhead, but gets only a part of the light when the sun strikes at an angle.

14. Discuss Together with a partner, talk about the amount of solar energy that falls on a given area. What happens when light is not spread out? What happens when the light is more spread out? Relate this idea to the sun's energy and Earth.

15. Language SmArts On a separate sheet of paper, write a short essay to compare what you observed in your investigation to what you saw in the image and what you read about the angles of sunlight striking Earth.

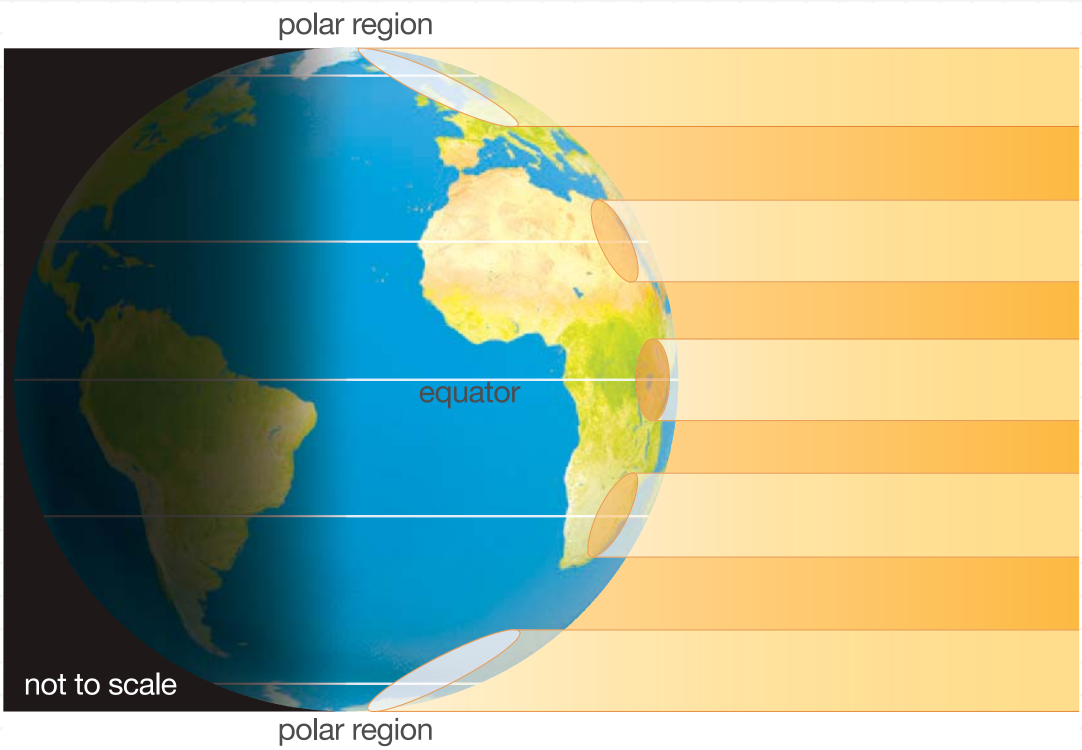
EVIDENCE NOTEBOOK

16. How do the length of days and the path of the sun across the sky help to explain why winter is cold with shorter days? Record your evidence.

Patterns of Sunlight and Latitude

Light comes from the sun. The rays of sunlight move in straight lines. Because the sun is so far away, the rays that strike Earth are very nearly parallel. Because of Earth's spherical shape, these parallel rays strike Earth most directly at the equator. As you move from the equator to the poles, the rays strike at lesser angles.

The diagram shows Earth lit by the sun on a day in the spring or fall. The diagram shows that the sun appears overhead as viewed from the equator. So, people who live on or near the equator feel the intense energy of the sun. People who live at the North Pole would see the sun on this same day as very low in the sky. This helps to illustrate why it is nearly always warm near the equator and cold at the poles.



Due to the shape of Earth, sunlight strikes different latitudes on Earth's surface at different angles.

17. Think about a person at the equator, a person at the North Pole, and a person somewhere in between. Each person points toward the sun. Describe where in the sky they are pointing.

18. Which of these describes the differences in sunlight striking Earth at different latitudes? Circle all that apply.

A. The intensity of the sun's energy received at the equator is greater than the intensity of the energy received at the poles.

B. Sunlight strikes at a greater angle at the equator, which spreads out the sunlight.

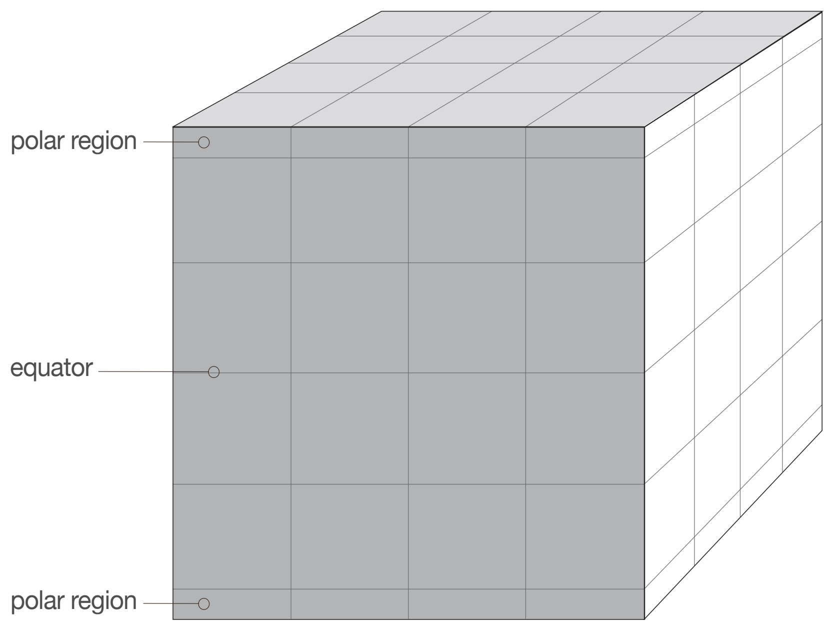
C. As you move away from the equator, the rays of sunlight striking Earth are no longer parallel.

D. Sunlight passes through less atmosphere at the equator, so more sunlight gets through, which makes locations around the equator hotter.

Analyze How Earth's Shape Affects Patterns of Sunlight

19. If Earth were flat instead of curved, how would that affect temperatures from pole to pole? Explain how the range of temperatures at noon at different latitudes on a cube-shaped planet would compare to temperatures on our spherical Earth.

20. Draw To the right of the cube, draw a model of the way the sun's rays would strike a cube-shaped planet.



Analyzing an Earth-Sun Model to Explain Seasons

Earth orbits the sun in a predictable pattern. The pattern of Earth's seasons depends on how much sunlight reaches different areas of Earth as the planet moves around the sun. One complete orbit around the sun is called a *revolution*. One complete revolution takes one year.

Earth-Sun Models

Earth has a nearly circular orbit around the sun. Earth also rotates around its north-south axis, an imaginary line passing through Earth from pole to pole.

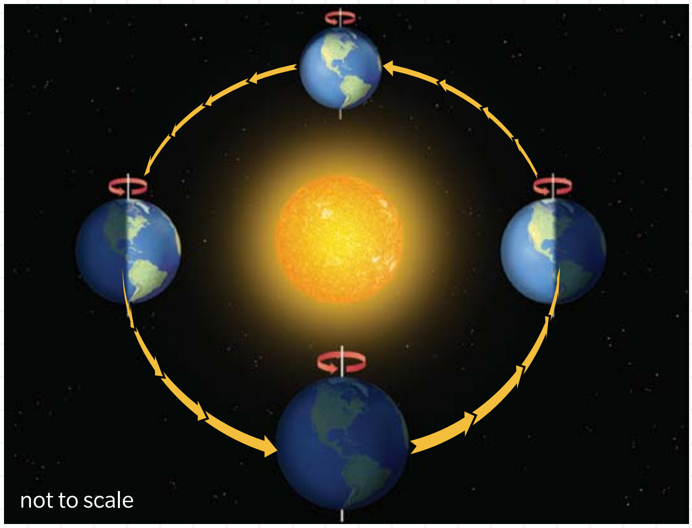
21. Examine the image. What does this model show? Circle all that apply.

A. Every place on the planet gets 12 hours of light and 12 hours of dark each day.

B. Temperature conditions on the planet change depending on distance from the sun.

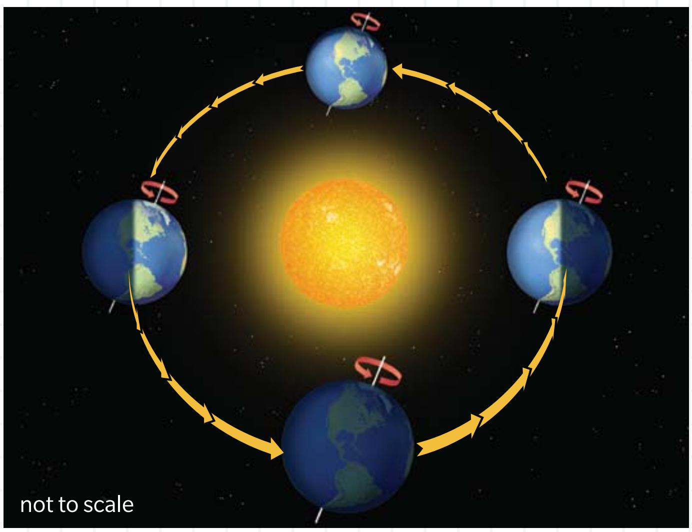
C. There are colder temperatures at the poles and warmer temperatures at the equator, but no temperature changes during the year.

22. Does this first model explain the seasons that happen on Earth? Give at least one example to support your answer.



Earth has a nearly circular orbit around the sun. This model of a fictional Earth shows an axis that is not tilted.

Unlike the planet in the first model, Earth's axis is not perpendicular to the plane of Earth's orbit around the sun. Earth's axis is tilted 23.5° from perpendicular to the plane of its orbit. This tilt remains the same throughout Earth's orbit. Earth's axis is pointed in the same direction no matter where Earth is in its orbit around the sun.



This model shows Earth with its axis tilted 23.5°.

Hands-On Lab

Model Patterns of Sunlight throughout Earth's Revolution

You will model the tilt of Earth. You will show the way different areas of Earth receive more or less sunlight throughout the year.

MATERIALS

- construction paper
- foam ball, 1″
- light source
- marker
- metric ruler
- modeling clay, non-drying
- protractor
- toothpick

Procedure

STEP 1 Use clay to make a base for your foam ball sphere.

STEP 2 With the marker, mark both poles and draw an equator on the sphere. Push the toothpick carefully through the sphere from pole to pole.

STEP 3 Insert the toothpick into the base. Using the protractor, set the tilt of the axis at 23.5° from vertical.

STEP 4 Cut the construction paper so that it is a square and then fold it exactly in half. Draw a line along the fold. Use the protractor to mark 90° on both sides of the line and connect those marks. Label the four connected folds beginning with *Spring* and moving counterclockwise to label *Summer*, *Fall*, and *Winter*.

STEP 5 Place the light source on the center where the lines cross. This is your sun.

STEP 6 Set the sphere directly on *Summer*. The North Pole (top of the toothpick) should tilt toward the light. Observe where the sphere is light and dark. Record your data by drawing and shading to show your *Summer* sphere in the table below.

STEP 7 **Keep the angle and direction that the sphere is pointing the same.** Move the sphere to *Fall*. Observe where the light falls. Record your data in the table for *Fall*.

STEP 8 Repeat STEP 7, moving the sphere to *Winter* and then *Spring*.

Summer	Fall	Winter	Spring

Analysis

STEP 9 What did you observe about sunlight on Earth in winter? Why does the Northern Hemisphere have lower temperatures in winter? Use what you observed to explain.

STEP 10 Look at the sphere. When the Northern Hemisphere tilts away from the sun, what season would you expect to experience in the Southern Hemisphere? Why?

The Tilt of Earth

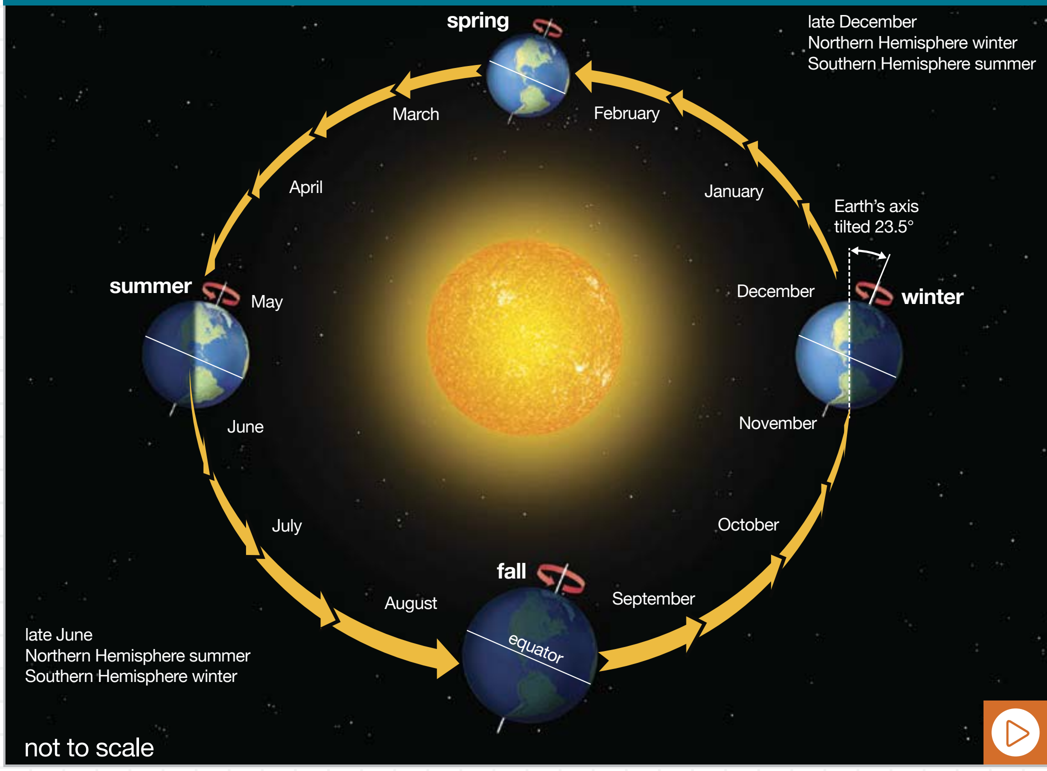
The spherical shape of Earth explains why it gets colder as you get closer to the poles, and why the height of the sun appears lower in the sky as you get closer to the poles. But these ideas alone do not completely explain why it is warmer in summer than in winter.

What did you learn as your model Earth moved around the model sun? Because Earth's tilt did not change, the amount of sunlight reaching a specific area of Earth did change. As Earth orbits the sun, the area of Earth that is pointed more toward the sun changes because Earth is always tilted in the same direction. So, the reason we have seasons is because of a combination of Earth's tilt and Earth's revolution.

When the Northern Hemisphere points toward the sun, the Southern Hemisphere points away from the sun. Seasons in the Southern Hemisphere are opposite from those in the Northern Hemisphere. In December, it is winter in Canada and summer in Australia.

23. Do the North and South Poles always stay in the same position relative to the sun? Explain your reasoning.

Earth's Revolution around the Sun



The northern tip of Earth's axis sometimes points toward the sun and sometimes points away from the sun. This tilt causes Earth's seasons.

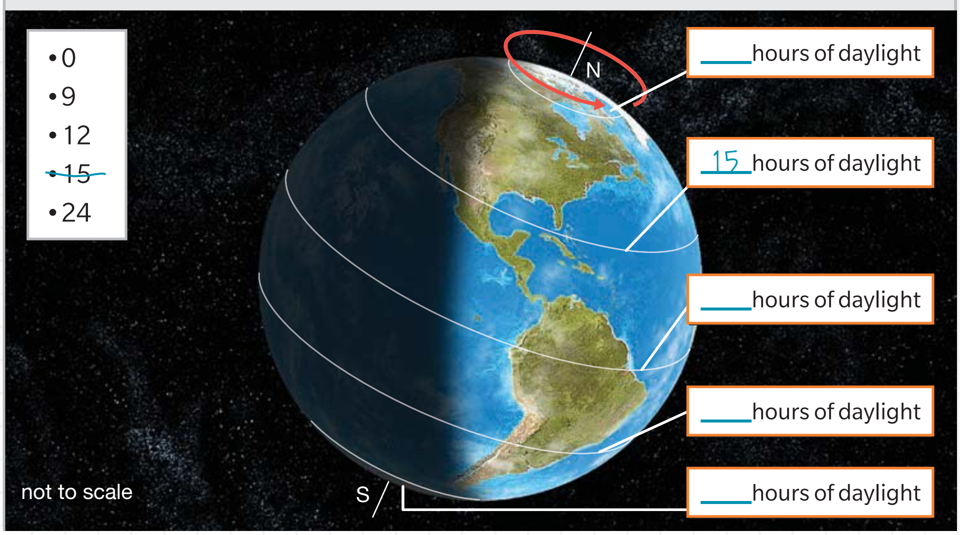
24. It is summer in the hemisphere tilted away from / toward the sun. It is winter in the hemisphere tilted away from / toward the sun. The seasons are the same / reversed in the Northern and Southern Hemispheres.

The Effect of Earth's Tilt on Daylight Hours

The number of hours of daylight increases as spring changes to summer. This change is the result of Earth's tilt. If Earth had no tilt, days and nights would last about 12 hours each day everywhere. Because of the tilt, areas pointed toward the sun have more hours of daylight than those areas pointed away.

Hours of Daylight by Latitude

25. Complete the labels to show how much daylight an area at each latitude would have with Earth in this position.



The Solstices and Equinoxes

On the June solstice, there are 24 hours of daylight at the North Pole, 12 hours of daylight at the equator, and 24 hours of darkness at the South Pole.

Solstices mark the two days of the year when Earth's axis is tilted directly toward or away from the sun. The June solstice, also called the summer solstice, occurs when Earth's north axis is tilted toward the sun, between June 20 and June 22. The June solstice is the day of the year with the greatest number of daylight hours in the Northern Hemisphere. This longest day of the year in the Northern Hemisphere is at the same time as the shortest day of the year in the Southern Hemisphere.

The December solstice, also called the winter solstice, occurs when Earth's north axis is tilted away from the sun, around December 21. The December solstice is the day with the fewest number of daylight hours in the Northern Hemisphere. In the Southern Hemisphere, the December solstice is the longest day of the year.

The days that begin spring and fall are marked by the equinoxes. Earth's axis does not tilt directly toward or away from the sun. The word *equinox* means "equal night." On an equinox, there are equal hours of day and night at all locations on Earth.

26. The solstices / equinoxes mark the dates on which Earth's axis is tilted directly toward or away from the sun. The days get shorter / longer as you move from the June solstice to the December solstice in the Northern Hemisphere.

The Tilt of Earth Affects the Energy Received from the Sun

Earth's tilt affects the temperatures at different locations on Earth. Because of Earth's tilt, some parts of Earth receive more solar energy than others. At the North Pole, Earth's tilt means that the sun rises above the horizon in mid-March and continues to shine until mid-September. The sun does not completely set during that time. But since the sun shines on the North Pole at a lesser angle instead of striking from directly overhead, less energy is received in a given area at the North Pole than at the equator. When sunlight strikes at a lesser angle, the light spreads out. So, although daylight lasts longer at the North Pole than at the equator, the temperature is not as warm.

The angle at which sunlight strikes a particular location on Earth changes as Earth revolves around the sun. Areas are warmer when sunlight is not as spread out, such as in those areas around the equator.

27. When the South Pole is tilted toward / away from the sun, the Southern Hemisphere experiences winter. The amount of the sun's energy that strikes the area increases / decreases as compared to the sun's energy in the summer. The daylight hours are longer / shorter, and the area temperatures increase / decrease.

So, Earth's distance from the sun is not what determines the seasons. In fact, Earth is closest to the sun around January 3 and farthest from the sun around July 4. It is Earth's tilt that determines the seasons.