

# **1** Earth and Sun

## **Objectives**

In this chapter you will learn that:

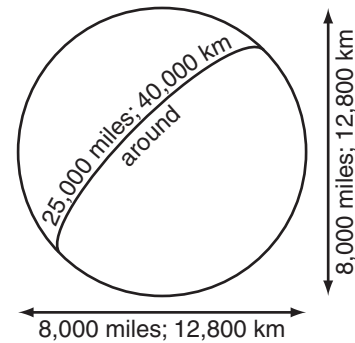
- Earth is approximately 25,000 miles around.
- Earth rotates on its axis, which generates night and day.
- Latitude is an angle measurement used to identify a location on the surface of Earth.
- It takes Earth one year to revolve around the Sun.
- Seasons are caused by how the tilt of Earth's axis affects the orientation of the planet as it revolves around the Sun.
- Hours of daylight are determined by Earth's orientation with the Sun.

## **Size and Shape of Earth**

Earth is a planet—it is a large body that moves around the Sun. It is not a perfect sphere, but Earth is a spherically shaped object. Earth has these approximate dimensions:

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**Figure 1.1.** Earth is about 4,000 miles from its center to the surface (8,000-mile diameter) and approximately 25,000 miles around.



- Radius: 4,000 miles (6,400 km)
- Diameter: 8,000 miles (12,800 km)
- Circumference: 25,000 miles (40,000 km)

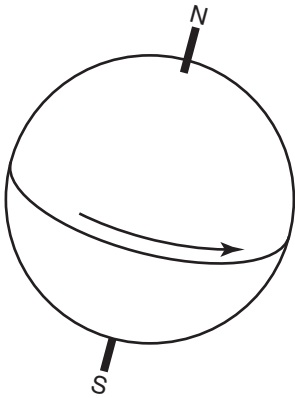
These values can vary slightly due to differences in surface topography and because Earth is not an exact sphere. If you could drive nonstop around the equator at 60 mph it would take seventeen days to make the trip.

What is the approximate distance around Earth (its circumference)?

*Answer:* 25,000 miles (40,000 km)

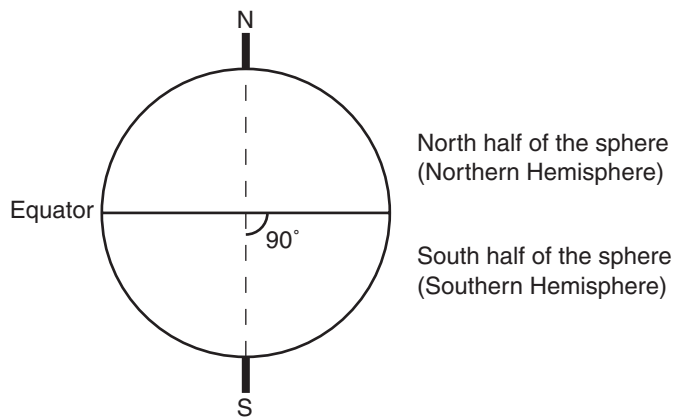
## Rotation, Poles, Equator

One feature of this planet is its rotation—it spins. It takes one day for Earth to rotate on its axis (one day exactly, because that is the definition of a day: one spin on its axis). Spinning leads to a reference system based on the axis of rotation. The North and South Poles are at the ends of the axis of rotation and thus can be used as unique reference points. If Earth did not spin (and thus had no rotation axis), then any place would be as good as any other for describing location.



**Figure 1.2.** Because Earth rotates, we can identify the North Pole and the South Pole as special spots. A place on Earth will rotate once around and find itself back in the same position a day later.

Rotation also produces another feature of interest: the equator. The equator is in a plane perpendicular to the axis of rotation, and it divides the spherical Earth into halves. All of the points on one side of the equator are closer to the North Pole than to the South Pole. All of the points on the other side are closer to the South Pole. The half of Earth closest to the North Pole is called the Northern Hemisphere (half a sphere). The half of Earth closest to the South Pole is the Southern Hemisphere.



**Figure 1.3.** The equator is in a plane perpendicular to the axis of rotation, and it separates Earth into two halves: the Northern Hemisphere and the Southern Hemisphere.

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What is the line that divides Earth into a half that is closer to the North Pole and another half that is closer to the South Pole? \_\_\_\_\_

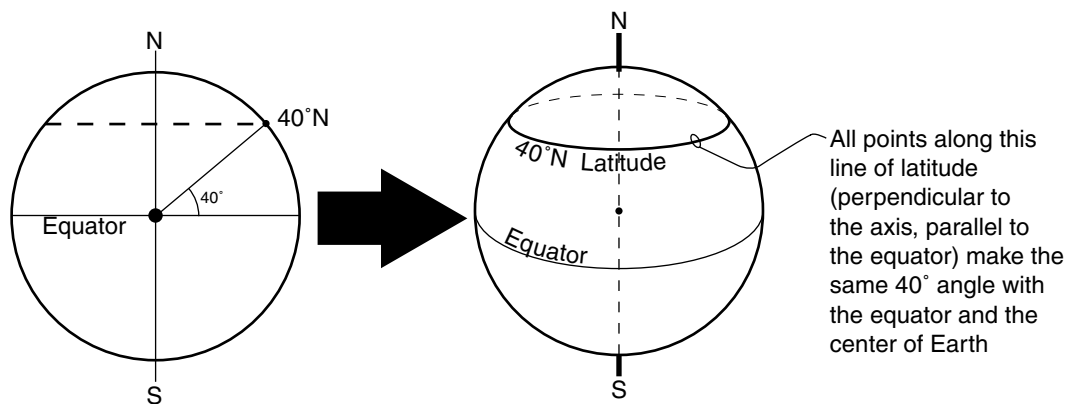
*Answer:* the equator

## Latitude

Once the two poles and the equator have been identified, then a system of measurement called latitude can be established. Latitude is an angle measurement from the equator to a point on Earth's surface. The angle is measured from the center of Earth at the point where the rotation axis intersects the plane of the equator.

The latitude system has some simple qualities:

- All points on the equator are  $0^\circ$  away from the equator.
- The North Pole is  $90^\circ$  away from the equator.
- The South Pole is  $90^\circ$  away from the equator.
- If the angle is measured toward the North Pole it is called north latitude.
- If the angle is measured toward the South Pole it is called south latitude.
- North and south are important! You must state whether a place has north or south latitude to properly identify it.



**Figure 1.4.** All points that are the same angle away from the equator and the center of Earth have the same latitude.

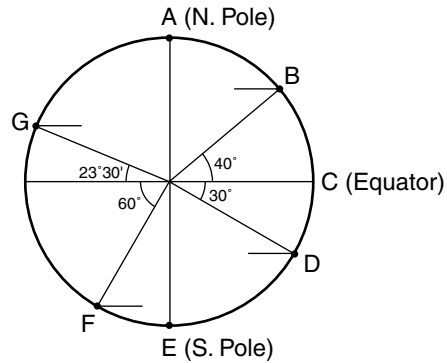


Figure 1.5.

What are the latitudes of points A, B, C, D, E, F, and G in Figure 1.5?

*Answer:* A = 90°N, B = 40°N, C = 0°, D = 30°S, E = 90°S, F = 60°S, G = 23°30'N

## Revolution around the Sun

At the same time that it is rotating on its axis, Earth also is following a path around the Sun. Earth is a planet that rotates on its axis and also revolves around the Sun.

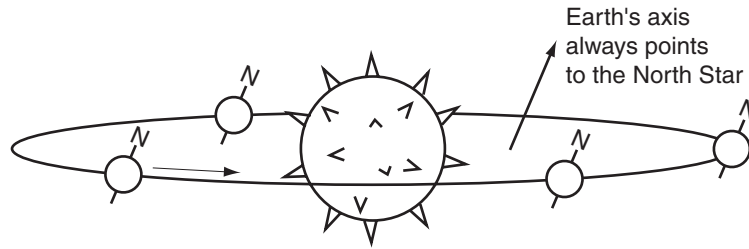
Rotate = axis = 1 day

Revolve = orbit = 1 year

It takes one year for Earth to revolve around the Sun (one year exactly, because that is the definition of a year: one trip around the Sun). This journey also takes 365¼ days (i.e., one year). So Earth will rotate on its axis 365¼ times in the time it takes for the planet to go around the Sun and return to its departing point.

The path that Earth travels along is an ellipse—but it is very close to being a circle. The nearly circular path is used to define a geometric feature called the plane of revolution. Although the planet orbits within the plane of revolution—this is going to affect almost everything on Earth—Earth's axis of rotation (the line running from the South Pole through the North Pole) always points toward the North Star.

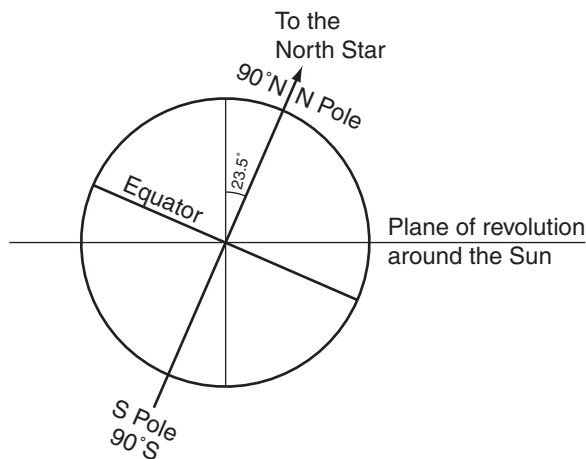
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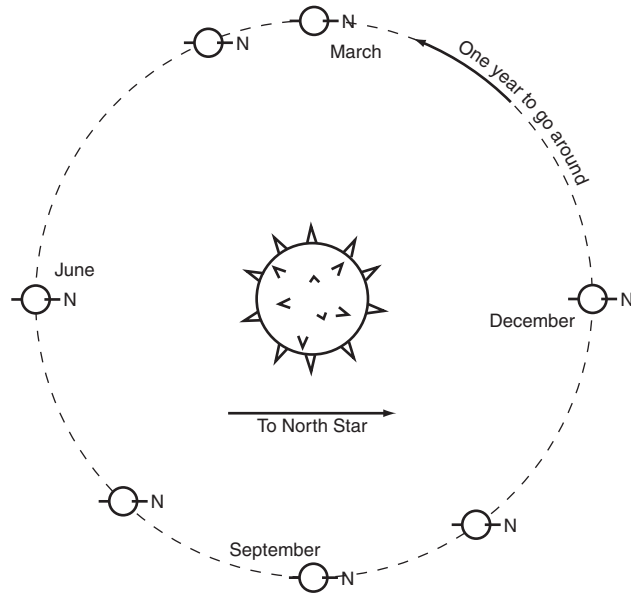
**Figure 1.6.** It takes Earth one year to complete its nearly circular revolution around the Sun. Earth's axis is always tilted toward the North Star.

For the North Pole to be continuously directed toward the North Star, Earth's axis has to be tilted  $23\frac{1}{2}^{\circ}$  away from perpendicular to its plane of revolution around the Sun. The direction and angle of the tilt will always be the same: the axis is always aligned toward the North Star. As a result of its constant aim to the North Star, the alignment of the axis with the Sun is always changing. For part of its revolution around the Sun, Earth's North Pole generally leans toward the Sun, and for the other part of a year it leans away from the Sun.

- In December, the North Pole leans away from the Sun.
- In June, the North Pole leans toward the Sun.



**Figure 1.7.** Earth's axis is tilted  $23\frac{1}{2}^{\circ}$  away from perpendicular to its orbit in the plane of revolution.



**Figure 1.8.** In this view from above Earth's plane of revolution you can see that the North Pole is always pointed toward the North Star. This causes the orientation of Earth with respect to the Sun to always be changing.

- In March and September, the line from Earth to the Sun is perpendicular to the South Pole–North Pole axis.

Because the North Pole is always pointing to the North Star, Earth's Northern Hemisphere is directed \_\_\_\_\_ the Sun in June and \_\_\_\_\_ the Sun in December.

*Answer:* toward; away from

## Tilt and Reference Latitudes

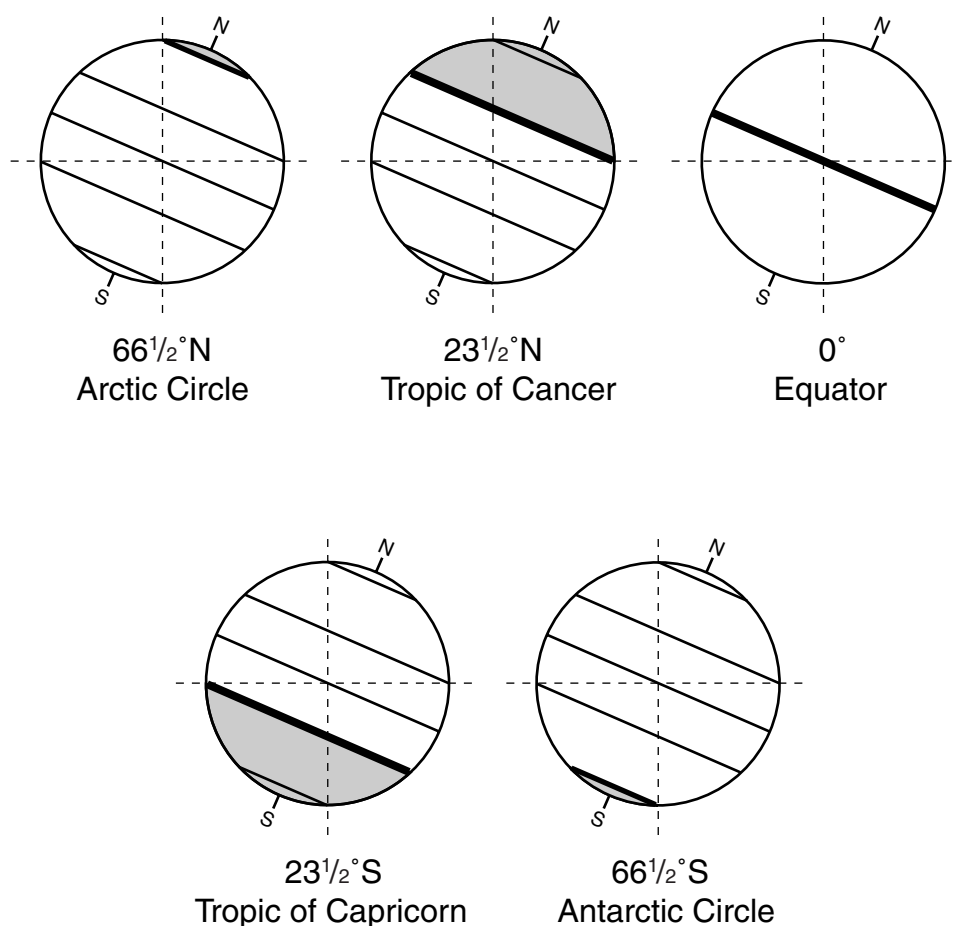
This tilt of Earth's axis creates five special latitude lines. These five lines are the equator, two "tropics," and two "circles." Because tropics and circles are lines of latitude, they are in planes that are perpendicular to Earth's rotation axis and parallel to the plane of the equator.

Tropics are located at  $23\frac{1}{2}^{\circ}\text{N}$  and  $23\frac{1}{2}^{\circ}\text{S}$ , and just touch the plane of

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revolution around the Sun. Circles are located at  $66\frac{1}{2}^{\circ}\text{N}$  and  $66\frac{1}{2}^{\circ}\text{S}$  ( $23\frac{1}{2}^{\circ} + 66\frac{1}{2}^{\circ} = 90^{\circ}$ ), and they just touch the line that passes through Earth's center and is perpendicular to the plane of revolution. The areas bounded by these five latitude lines (equator, two tropics, and two circles) react in different ways to the changing orientation of Earth and the Sun over the course of a year.

- $66\frac{1}{2}^{\circ}\text{N}$  is the Arctic Circle. As Earth rotates on its axis, all of the places on the North Pole side of this line will always be on the same side of perpendicular as the North Pole.



**Figure 1.9.** There are five special lines of latitude that are produced by Earth's  $23\frac{1}{2}^{\circ}$  angle of tilt to its plane of revolution around the Sun.

- $23\frac{1}{2}^{\circ}\text{N}$  is the tropic of Cancer. As Earth rotates on its axis, all of the places on the North Pole side of this line will always be above the plane of revolution around the Sun. No point that is north of this line will ever rotate to be directly on the plane of revolution.
- The equator is at  $0^{\circ}$  latitude. As Earth rotates on its axis, all points at the equator will spend half of each day above the plane of revolution and half below it, and half of each day on the North Pole side of perpendicular and half on the South Pole side.
- $23\frac{1}{2}^{\circ}\text{S}$  is the tropic of Capricorn. As Earth rotates on its axis, all of the places on the South Pole side of this line will always be below the plane of revolution around the Sun. No point that is south of this line will ever rotate to be directly on the plane of revolution.
- $66\frac{1}{2}^{\circ}\text{S}$  is the Antarctic Circle. As Earth rotates on its axis, all of the places on the South Pole side of this line will always be on the same side of perpendicular as the South Pole.

Which two lines mark the farthest places north and south that can be directly on Earth's plane of revolution around the Sun? \_\_\_\_\_

*Answer:* the tropic of Cancer ( $23\frac{1}{2}^{\circ}\text{N}$ ) and the tropic of Capricorn ( $23\frac{1}{2}^{\circ}\text{S}$ )

## Revolution, Alignment, and Day Length

As Earth travels around the Sun, Earth's tilt toward the North Star will create four days when Earth-Sun alignment is in a special condition. In June and December, there are solstices. A solstice is the moment when the Sun is directly overhead at one of the tropics. This is the farthest point north or south of the equator that the Sun can be directly overhead. A solstice also is the day when a hemisphere is aimed either most directly toward the Sun (summer solstice) or away from the Sun (winter solstice). In September and March, there are equinoxes. An equinox is the moment when the Sun is directly over the equator. Solstices and equinoxes mark the extremes of orientation and a changeover with respect to Sun conditions.

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### June Solstice

On the day of the June solstice, the North Pole is tilted as close as it gets toward the Sun and the South Pole is tilted as far away as it gets. It is summer in the Northern Hemisphere and winter in the Southern Hemisphere. On this day:

- The Sun will be directly overhead at  $23\frac{1}{2}^{\circ}\text{N}$  (tropic of Cancer), and it is strongest at that latitude.
- All points in the Northern Hemisphere will get more than 12 hours of sunlight; they spend more than half of the day rotating on the sunlit side of the planet. All points in the Southern Hemisphere will get fewer than 12 hours of sunlight.
- All points on the equator will spend 12 hours rotating on the sunlit side of Earth and 12 hours rotating on the dark side of Earth.
- All points north of the Arctic Circle ( $66\frac{1}{2}^{\circ}\text{N}$ ) will spend the entire 24-hour day rotating on the sunlit side of Earth.
- All points south of the Antarctic Circle ( $66\frac{1}{2}^{\circ}\text{S}$ ) will spend the entire 24-hour day rotating on the dark side of Earth.

### September Equinox

On the day of the September equinox, the Sun is directly overhead at the equator. It is the first day of autumn in the Northern Hemisphere and the first day of spring in the Southern Hemisphere. On this day:

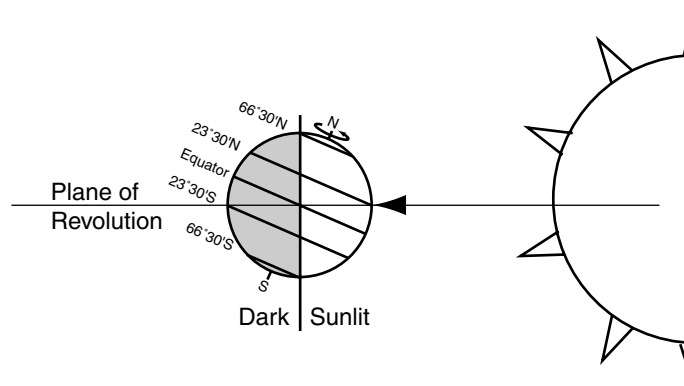


Figure 1.10. The June solstice.

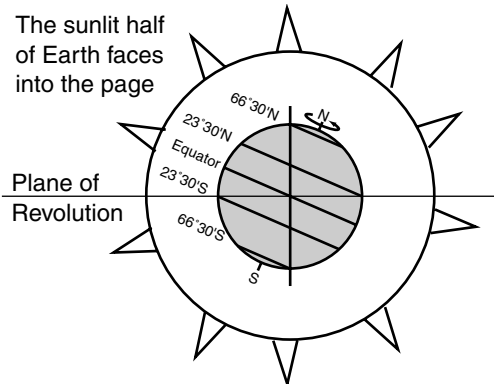


Figure 1.11. The September equinox.

- The Sun is most directly overhead at the equator.
- All points on Earth will rotate on the sunlit side of the planet for 12 hours and rotate on the side away from the Sun for 12 hours.

### December Solstice

On the day of the December solstice, the South Pole is tilted as close as it gets toward the Sun and the North Pole is tilted as far away as it gets. It is winter in the Northern Hemisphere and summer in the Southern Hemisphere. On this day:

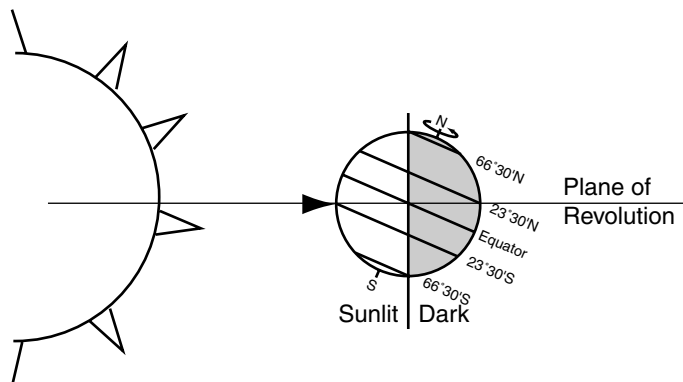


Figure 1.12. The December solstice.

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This classic photograph from December 7, 1972, was taken by a crew member on *Apollo 17* near the time of the December solstice. Note how the part of Earth that is sunlit and visible to the astronauts ranges from nearly all of Antarctica (at bottom) to the Mediterranean Sea (top) at about 40°N latitude. (Image AS17-148-22721 courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center.)

- The Sun will be directly overhead at 23½°S (tropic of Capricorn), and it is strongest at that latitude.
- All points in the Southern Hemisphere will get more than 12 hours of sunlight; they spend more than half of the day rotating on the sunlit

side of the planet. All points in the Northern Hemisphere will get fewer than 12 hours of sunlight.

- All points on the equator will rotate 12 hours on the sunlit side of Earth and rotate 12 hours on the dark side of Earth.
- All points south of the Antarctic Circle ( $66\frac{1}{2}^{\circ}\text{S}$ ) will spend the entire 24-hour day on the sunlit side of Earth.
- All points north of the Arctic Circle ( $66\frac{1}{2}^{\circ}\text{N}$ ) will spend the entire 24-hour day rotating on the dark side of Earth.

### March Equinox

On the day of the March equinox, the Sun is directly overhead at the equator. It is the first day of spring in the Northern Hemisphere and the first day of autumn in the Southern Hemisphere. On this day:

- The Sun is most directly overhead at the equator.
- All points on Earth will be on the sunlit side of the planet for 12 hours and on the dark side for 12 hours.

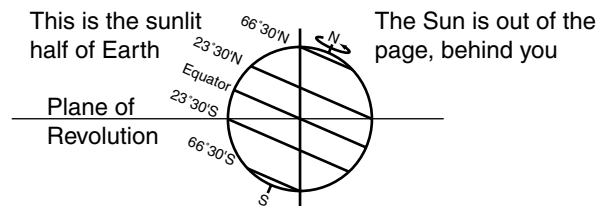
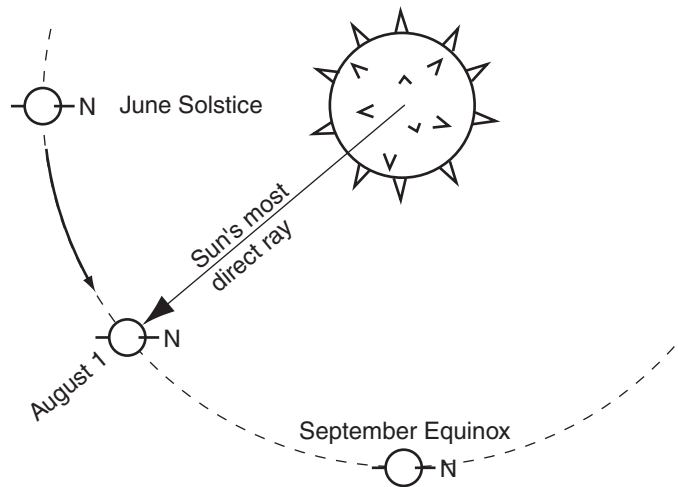
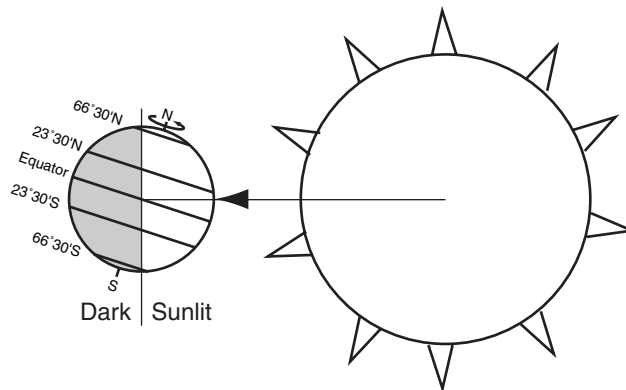


Figure 1.13. The March equinox.

### "In-Between" Days

Because of the way Earth is tilted with respect to its plane of revolution, the Sun can never be directly overhead north of  $23\frac{1}{2}^{\circ}\text{N}$  (tropic of Cancer) or south of  $23\frac{1}{2}^{\circ}\text{S}$  (tropic of Capricorn). The Sun can only be overhead in the tropics (between Cancer and Capricorn). The Sun will be directly overhead at the equator on the two equinox days of the year (in March and September). Days that are not an equinox or a



**Figure 1.14.** On August 1, the Earth–Sun relationship will be “in between” the conditions from the June solstice and the September equinox. *Top:* The Sun will be most directly overhead in the Northern Hemisphere, somewhere between the tropic of Cancer and the equator (it will actually be at about 18°N). On this day, all places in the Northern Hemisphere spend more than half a day on the sunlit side of Earth. *Bottom:* Don’t be misled by two-dimensional depictions of the situation. The Sun is directly overhead at 18°N latitude. Earth is still tilted 23½° away from perpendicular with respect to its plane of revolution around the Sun. The North Pole is still aimed at the North Star.

solstice (i.e., the other 361) are simply “in the middle.” If you interpolate between the solstice and equinox extremes, you should be able to figure out Earth–Sun relations for any day. Here are the basic principles:

- The Sun must be overhead somewhere between the tropics of Cancer and Capricorn.

If it is March–September, the Sun will be directly overhead a place in the Northern Hemisphere.

If it is September–March, the Sun will be directly overhead a place in the Southern Hemisphere.

The closer a date is to a solstice, the closer to a tropic the Sun will be overhead.

The closer a date is to an equinox, the closer to the equator the Sun will be overhead.

- Hours of daylight will be controlled by which hemisphere the Sun is “in” (i.e., in which hemisphere it is overhead) and then by latitude.

In a hemisphere in which the Sun is overhead, the closer to a pole a place is in that hemisphere, the more hours of daylight there will be at that place.

There are 12 hours of daylight every day of the year at the equator.

In a hemisphere in which the Sun is not overhead, the closer to a pole a place is in that hemisphere, the fewer hours of daylight there will be at that place.

Why would a place like New York City (lat.  $41^{\circ}\text{N}$ ) have about 15 hours of daylight in June but only about 9 hours in December? \_\_\_\_\_

*Answer:* The Northern Hemisphere is tilted most directly toward the Sun in June, and a place at  $41^{\circ}\text{N}$  spends most of a day on the illuminated part of Earth. In December, the Northern Hemisphere is tilted away from the Sun, and a place at  $41^{\circ}\text{N}$  spends most of a day on the dark side of Earth.

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### Seasonal Changes

Seasons are produced because Earth revolves around the Sun with a tilted axis, which directs different parts of the planet toward or away from the Sun at different stages of the journey.

Seasons have nothing to do with how close Earth and the Sun are to each other. If proximity was the cause of seasons, then it would be the same season in the Northern and Southern Hemispheres on the same day.

#### Yearly Sunlight Variations because of Earth's Revolution and Tilt

	Month	Sun Overhead	Daylight at North Pole	Daylight in the 48 states	Daylight at Equator	Daylight in Australia	Daylight at South Pole
Solstice	June	23½°N	24 hrs	>12 hrs	12 hrs	<12 hrs	0 hrs
Equinox	September	0°	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs
Solstice	December	23½°S	0 hrs	<12 hrs	12 hrs	>12 hrs	24 hrs
Equinox	March	0°	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs
Solstice	June	23½°N	24 hrs	>12 hrs	12 hrs	<12 hrs	0 hrs
	August 1	18°N	24 hrs	>12 hrs	12 hrs	<12 hrs	0 hrs
Equinox	September	0°	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs
Solstice	December	23½°S	0 hrs	<12 hrs	12 hrs	>12 hrs	24 hrs
Equinox	March	0°	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs
Solstice	June	23½°N	24 hrs	>12 hrs	12 hrs	<12 hrs	0 hrs

What causes seasons? \_\_\_\_\_

*Answer:* The tilt of Earth's axis changes the alignments of the two hemispheres and the Sun over the course of a year.

#### SELF-TEST

- How much is Earth's rotation axis tilted away from perpendicular to the planet's plane of revolution around the Sun?
  - 0°
  - 23½°
  - 78½°
  - 90°
- The moment when the Sun is directly over either of the two tropics is called a(n) \_\_\_\_\_.
  - solstice
  - equinox
  - season
  - ellipse

3. The Sun is directly above the tropic of Cancer ( $23\frac{1}{2}^{\circ}\text{N}$ ) in which of these months?
  - a. February
  - b. April
  - c. June
  - d. August
4. Earth's North Pole is always pointed toward the \_\_\_\_\_.
5. The Sun is directly above the equator in the months of \_\_\_\_\_ and \_\_\_\_\_.
6. The reason that it is hot in the summer is because that is when Earth is closest to the Sun. (True or False)
7. There are 12 hours of daylight at the equator every day of the year. (True or False)
8. How does Earth's rotation on its axis cause night and day?
9. With respect to Earth-Sun relationships, how are tropical latitudes different from middle and high latitudes?
10. For February 1, describe in general terms the latitude zone where the Sun will be directly overhead.

## ANSWERS

1. b
2. a
3. c
4. North Star
5. March; September
6. False
7. True
8. Rotation spins a place into the sunlit half of Earth, then around out of the sunlight to the dark side of the planet.
9. The Sun can be directly overhead in tropical areas (between  $23\frac{1}{2}^{\circ}\text{N}$  and  $23\frac{1}{2}^{\circ}\text{S}$ ), but it can never be  $90^{\circ}$  overhead in the middle or high latitudes.
10. The Sun will be directly overhead in the Southern Hemisphere, between the equator and the tropic of Capricorn.

### Links to Other Chapters

- Latitude affects the length of day and the duration of daily insolation (chapter 2), which affects heating and temperature (chapter 2).
- Earth's rotation on its axis will produce night and a day with changing sunlight intensity, which will affect daily temperature patterns (chapter 2).
- Variations in heating help establish the general circulation of the atmosphere (chapter 5).
- Earth's spin on its axis contributes a Coriolis force, which affects how the wind moves across the surface of Earth (chapters 4, 5).
- Seasonal variations in heating are a major factor in climate (chapter 7).
- Temperature and seasons affect geomorphic forces such as weathering (chapter 11), soil formation (chapter 11), and glacial processes (chapter 14).