18.2 Earth Cycles

Do you ever wonder where our calendar comes from? Or why the Moon gradually changes its shape? Or why we have seasons? The answers have to do with the relative positions of Earth, the Sun, and the Moon. Earth rotates on its axis as it revolves around the Sun. The Moon rotates on its axis as it revolves around Earth. These movements cause the *astronomical cycles* you experience like days, years, seasons, and the lunar cycle (the Moon's changing shape).

Days and years

Calendars A *calendar* is a means of keeping track of all the days in a year. Ancient civilizations developed calendars based on their observations of the Sun, Moon, and stars. Many such civilizations independently invented almost identical calendars. Figure 18.9 shows a timeline of various calendars from around the world.

Years and days As Earth rotates on its axis, it also travels around the Sun. You have learned that one year is the amount of time it takes Earth to complete one revolution around the Sun. This is equal to 365.25 days. Each day is one rotation of Earth on its axis. Since Earth spins from west to east, the Sun appears to travel across the sky from east to west. Ancient observers thought that the Sun really did move across the sky. Can you see why?

Leap years The ancient Egyptian calendar described in Figure 18.9 added up to 365 days and eventually evolved into the calendar we use today. However, because we know that one year is approximately 365.25 days long, our calendar adjusts for this. It has eleven months with 30 or 31 days each, and one month—February—with 28 days. In a *leap year*, February has 29 days. The extra day every four years makes up for the extra 0.25 days that occur each year.

Calendars throughout human history

20,000 years ago. Ice-age hunters in Europe scratched lines in bones to mark the passage of days.
7,000 BC. Babylonians kept a calendar with 29- and 30-day months. They needed to add an extra month every eight years.
4,000 BC. The Egyptians adopted a solar calendar with 365 days in a year. This was divided into 12 months, each with 30 days, and an extra five days at the end.
2,000 BC. Mayans of Central America calculated that there were 365.25 days in a year.
700 BC. The Roman calendar consisted of 10 months in a year of 304 days. It ignored the remaining 61 days, which fell in the middle of winter.
46 BC. Romans adopted the Julian calendar, named after Julius Caesar. It is very close to the modern calendar we use today.

Keeping track of time

The time of day A *clock* tells you the exact time of day and is used to mark the division of the day into equal parts. It may be hard to imagine, but there once was a time when humans did not need to keep track of the exact time of day. The rise and fall of the Sun was the only "clock" that prehistoric humans needed to regulate their daily activities. Then, around 5,000 years ago, some civilizations found the need to keep track of time.

Obelisks and sundials

The ancient Egyptians divided the day into parts that were similar to hours. As early as 3500 BC, monuments called *obelisks* were built to separate the day into parts. These monuments cast a shadow that moved during the day as the Sun appeared to move across the sky. Markers were placed around the base of the monument to mark the subdivisions of time during the day (Figure 18.10). Obelisks evolved into *sundials* and these became more and more accurate (Figure 18.11).

Water clocks *Water clocks* were an early way to keep track of time at night (Figure 18.11). Early water clocks were stone containers with sloping sides that allowed water to drip at a constant rate through a small hole in the bottom. Markings on the inside surface of the container measured the passage of "hours."

Modern clocks Today we divide each rotation of Earth into 24 equal parts called *hours*. Each hour is divided up into 60 parts called *minutes* and each minute into 60 parts called *seconds*. Like the water clock, modern clocks use a constant, repetitive action or process to keep track of equal increments of time. Where the water clock used the constant dripping of water, modern clocks use a pendulum, vibrating crystal, balance wheel, electromagnetic waves, or even atoms to mark time.

The lunar cycle

What is the lunar cycle?

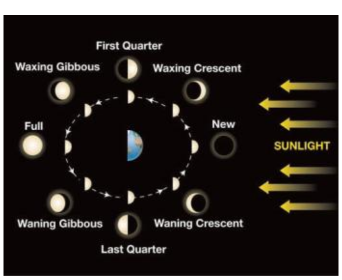
The revolution of the Moon around Earth makes the Moon appear as if it is gradually changing shape each night. The gradual change in the appearance of the Moon is called the **lunar cycle**. The lunar cycle occurs because of the relative positions of Earth, the Moon, and the Sun.

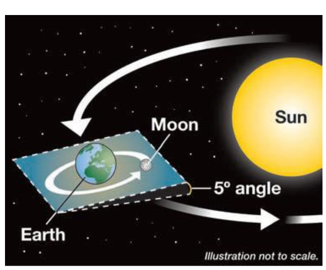
What causes the lunar cycle?

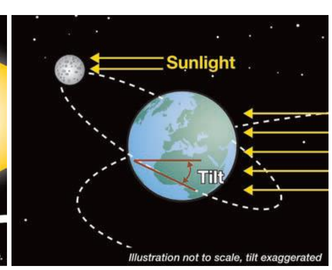
The orbit of the Moon is tilted about 5 degrees from Earth's orbit (Figure 18.12). This means the Moon is not in Earth's shadow except during rare *eclipses*. The Sun-facing side of the Moon is lit by sunlight almost all the time. The lunar cycle is caused by the *angle* the Moon makes with Earth and the Sun as it orbits Earth, not by Earth's shadow falling on the Moon.

Moon phases

What you see when you look at the Moon depends on its location in relationship to the Sun and Earth. As the Moon revolves, we see a different fraction of sunlight being reflected from the Moon to Earth. Remember, the Moon doesn't give off light; it reflects the light of the Sun. Although the lunar cycle is a continuous process, there are eight recognized *phases* (see the diagram below)







New moon The Moon is not visible (except during a solar eclipse). The lighted side of the Moon faces away from Earth. This means that the Sun, Earth, and the Moon are almost in a straight line, with the Moon in between the Sun and Earth.

Waxing crescent The lighted fraction of the Moon is increasing. The crescent grows larger and larger each day.

First quarter The right half of the Moon appears lighted and the left side of the Moon appears dark. The part of the Moon that appears lighted gets larger and larger every day.

Waxing gibbous *Waxing* means increasing, or growing larger. The Moon appears to be more than half, but not fully, lit by sunlight.

Full moon The Moon appears to be completely lit by sunlight. The lighted side of the Moon faces Earth. Earth, the Sun, and the Moon are nearly in a straight line, with Earth in the middle.

Waning gibbous *Waning* means decreasing, or growing smaller. The lighted fraction of the Moon is decreasing. The amount of the Moon that we can see will grow smaller and smaller every day.

Last quarter The left half of the Moon appears lighted, and the right side of the Moon appears dark. The part of the Moon that appears lighted gets smaller and smaller every day.

Waning crescent The Moon appears to be less than half lit by sunlight. The fraction of the Moon that is lit is decreasing. The crescent will grow smaller and smaller each day, until the Moon becomes the New Moon.

The length of the lunar cycle

The lunar cycle—from New Moon to New Moon—takes 29.5 days to complete (Figure 18.13). This roughly corresponds to one month. However, if we based our calendar on the lunar cycle, we would soon get ahead of an Earth year. Why? Because a year of lunar cycles adds up to only 354 days, not 365.25, leaving a balance of 11.25 days each year!

Lunar eclipses

The Moon's orbit is tilted

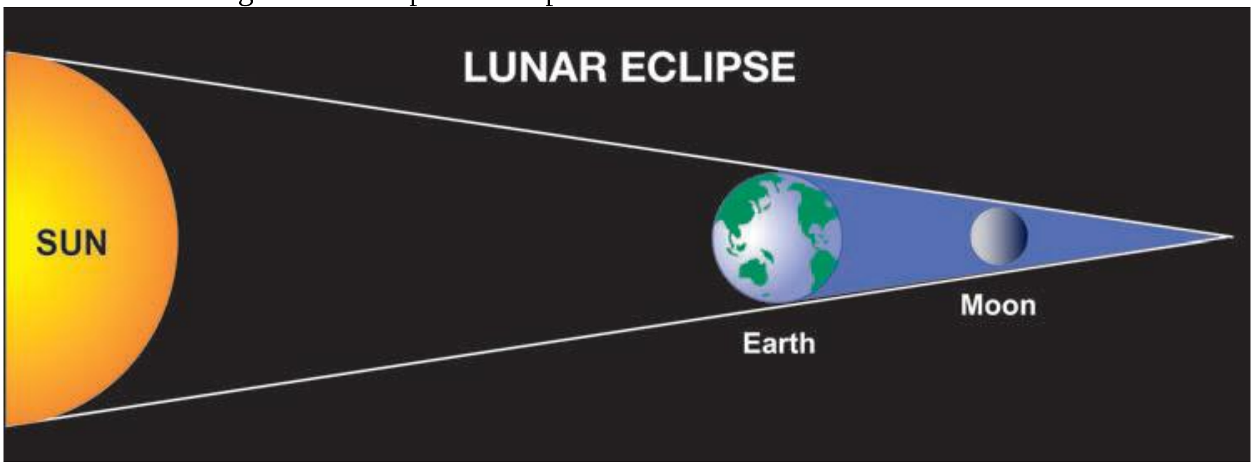
A **lunar eclipse** occurs when Earth's shadow falls on the Moon. If you look at the lunar cycle diagram on page 432, you may wonder why Earth's shadow doesn't cover the Moon when it is between the Moon and the Sun. Instead, you get a Full Moon (Figure 18.14)! The reason a lunar eclipse doesn't occur very often is because of the 5 degree tilt of the Moon's orbit.

Lunar eclipses

Because of its tilted orbit, in most months, Earth's shadow does not block the sunlight from hitting the Moon. However, sometimes the Moon's orbit is perfectly aligned with Earth's orbit during a Full Moon. Because of this alignment, Earth's shadow temporarily blocks the sunlight from hitting the Moon, causing a *lunar eclipse*. As the Moon continues to move in its orbit, it gradually moves into a position where the sunlight hits it again. During a lunar eclipse, the Moon is still visible and appears reddish.

Total and partial lunar eclipses

A lunar eclipse can be total or partial and all observers on the dark side of Earth can see it at the same time. A partial eclipse occurs when only part of the Moon falls in Earth's shadow. Figure 18.15 shows an alignment for a partial eclipse.



Solar eclipses

Solar eclipses

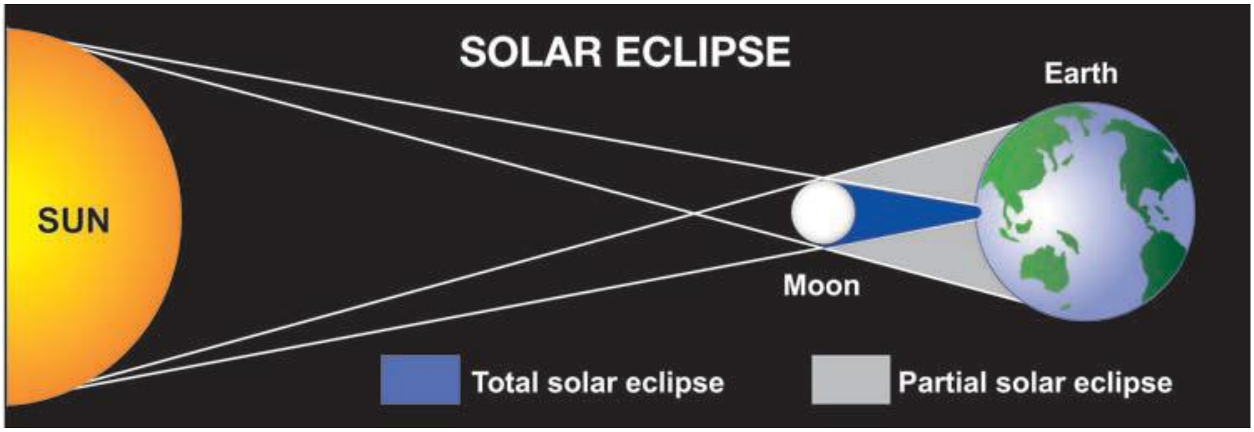
A **solar eclipse** occurs when the Moon's shadow falls on Earth. During a New Moon, the Moon is almost exactly between Earth and the Sun. Most of the time, however, the Moon travels just above or below the Sun in the sky because of the 5 degree tilt of its orbit. During a *solar eclipse*, the New Moon is directly between Earth and the Sun and the Moon's shadow hits part of Earth as shown below.

Total solar eclipse

The darkest part of the Moon's shadow is cone-shaped and falls on only a small part of Earth's surface. Viewers in this region experience a total eclipse of the Sun because the light is completely blocked by the Moon. During a total eclipse, the Sun gradually disappears behind the Moon and then gradually reappears (Figure 18.16). This is because the Moon revolves around Earth, so it gradually moves into the path of the sunlight, and then gradually moves out again. The Sun is completely blocked by the Moon's shadow for about two or three minutes.

Partial solar eclipse

In the diagram above, you can see that the Moon casts a larger, lighter shadow on Earth's surface. Viewers in this region of the Moon's shadow experience a partial eclipse. During this time, only part of the Sun is blocked. You should NEVER look directly at the Sun—even during a total or partial eclipse!



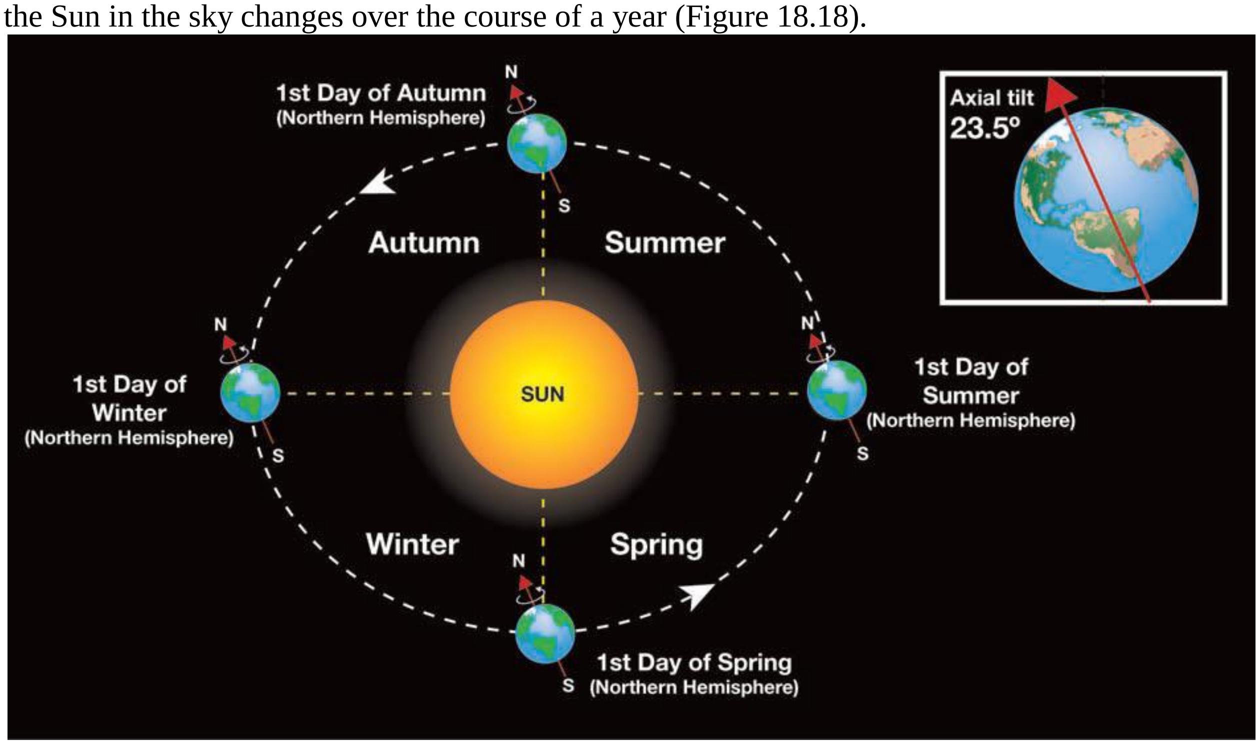
The seasons

Seasons

As Earth revolves around the Sun, we experience different seasons. The seasons are caused by the 23.5° tilt of Earth's axis with respect to the plane of its orbit around the Sun. As Earth rotates around the Sun, its axial tilt remains fixed.

The axial tilt causes the seasons

During summer in the Northern Hemisphere, the north end of the axial tilt is facing *toward* the Sun. This results in more direct sunlight and higher temperatures. Six months later, the north end of the axial tilt is facing *away* from the Sun. The sunlight is more spread out and is less intense. This brings winter to the Northern Hemisphere (Figure 18.17). The opposite happens in the Southern Hemisphere. The fact that Earth's axial tilt is fixed also explains why the position of the Sun in the sky changes over the course of a year (Figure 18.18).



18.2 Section Review

1. Name two examples of astronomical cycles. For each, describe an event that is directly related to it. Example: Moon revolves around Earth, resulting in the phases of the Moon.

2. What is a leap year? Why does a leap year occur every four years?

3. Since the Moon does not produce its own light, how can you see it?

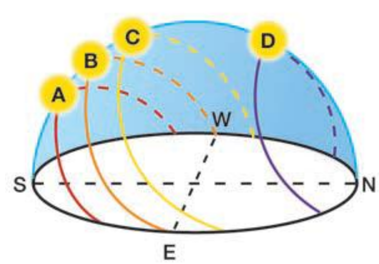
4. The lunar cycle is closely related to which part of our calendar—a year, a month, or a day?

5. Answer True or False. The phases of the Moon are caused by Earth's shadow falling on the Moon.

6. Explain how you could use the shadow of a streetlight pole to track the time of day on a sunny day.

7. Explain the difference between solar and lunar eclipses.

8. Match the letters on the diagram with the correct terms. You may use a letter more than once.



_____First day of summer
_____First day of winter
_____First day of spring
_____First day of autumn