LEARN ABOUT

Why Planets Have Seasons

FIND OUT

- why there are seasons on Earth
- what seasons are like on other planets

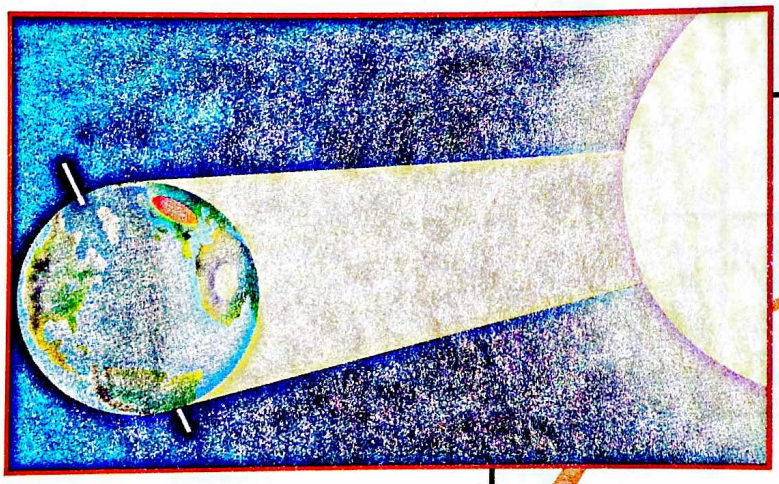
VOCABULARY

season
axial tilt

Seasons on Earth

In most places on Earth, the weather changes with the season. A **season** is a period of the year with a certain level of temperature and type of weather. Winter can bring lower temperatures and sometimes ice and snow. Summer can bring hot, sunny days and thunderstorms. Why does the temperature change from one season to another?

In the investigation you saw the reason for seasonal temperature differences. When the sun's rays hit Earth's surface directly, the surface absorbs more energy and the temperatures are high. When rays hit at



▲ WINTER
Rays from the sun hit the Northern Hemisphere indirectly in winter. The slanting rays spread the solar energy over a larger area than in summer, causing lower temperatures.

September 23—Autumnal Equinox
This is one date of almost equal daylight and darkness in both hemispheres. Neither hemisphere receives more direct sunlight. Fall begins in the Northern Hemisphere, and spring begins in the Southern Hemisphere.

December 22—Winter Solstice
The date with the least daylight in the Northern Hemisphere marks the beginning of winter. The Southern Hemisphere receives more direct sunlight. In the Southern Hemisphere, summer begins on this date.

an angle of less than 90°, the surface absorbs less energy and the temperatures are lower.

If Earth rotated on a vertical axis, the angle of the sun's rays at each location on Earth would be the same all year. There would be no seasons. But Earth's axial tilt causes the angle of the sun's rays to change during the year. **Axial tilt** is the angle that a planet's axis is tilted from vertical. Earth's axis is tilted 23.5°, enough to cause seasons.

Earth's axis remains tilted in the same direction all year. As Earth revolves around the sun, the axial tilt causes the Northern Hemisphere to be pointed toward the sun for part of the year and away from the sun for another part.

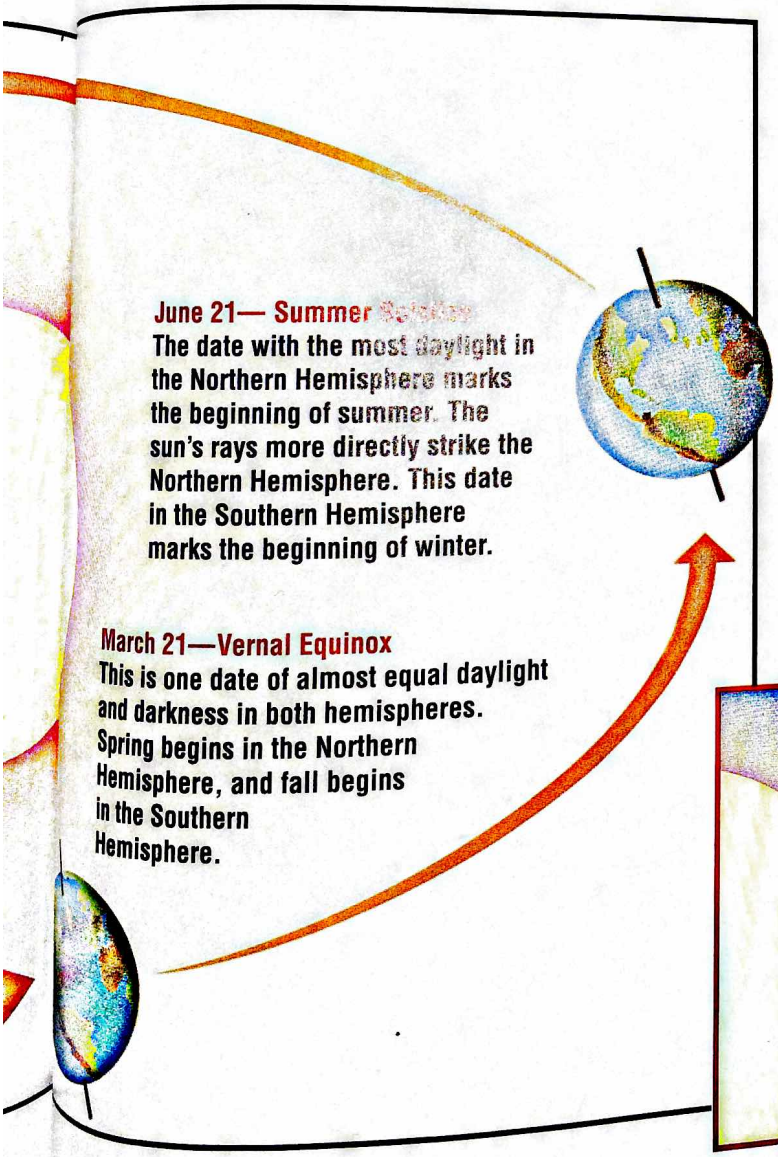
When the Northern Hemisphere is pointed toward the sun, the sun's rays hit it more directly and there are more hours of daylight. More solar energy is absorbed. The hemisphere's climate grows warmer, and summer occurs.

As Earth continues to revolve, it reaches a point in its orbit where the axial tilt is neither toward nor away from the sun. The angle of sunlight is less direct than in summer. Hours of daylight and darkness are almost equal. The hemisphere's temperatures are cooler, and fall begins.

When the Northern Hemisphere is pointed away from the sun, the sun's rays are the most slanted and indirect. There are fewer hours of daylight. The hemisphere's climate grows cooler, and winter occurs.

When Earth reaches the second point in its orbit where the axial tilt is neither toward nor away from the sun, spring begins.

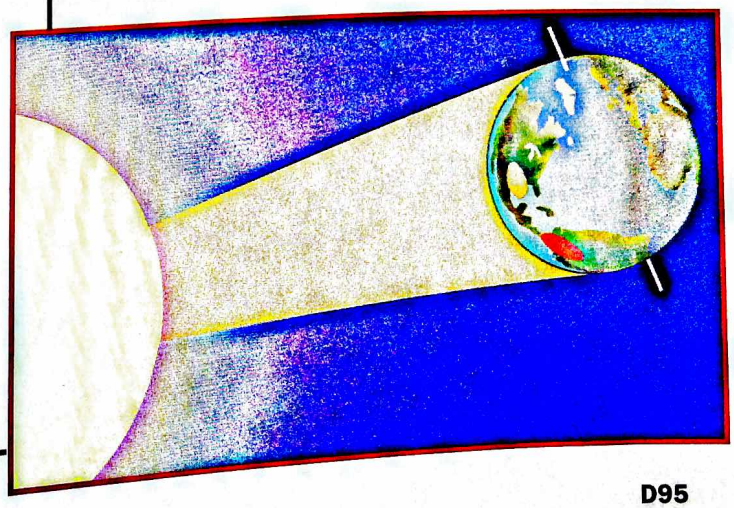
✔ **Why is it warmest in the summer?**



June 21— Summer Solstice
The date with the most daylight in the Northern Hemisphere marks the beginning of summer. The sun's rays more directly strike the Northern Hemisphere. This date in the Southern Hemisphere marks the beginning of winter.

March 21—Vernal Equinox
This is one date of almost equal daylight and darkness in both hemispheres. Spring begins in the Northern Hemisphere, and fall begins in the Southern Hemisphere.

SUMMER
Solar energy hits the Northern Hemisphere more directly in summer than in winter. Direct rays concentrate the solar energy on a smaller area, causing higher temperatures. ▼



The Seasons on Mars

No one has ever experienced summer on Mars or winter on Pluto. But astronomers know that these planets and several others have axial tilts that can cause seasons.

The axial tilts of the planets differ. For example, Mercury, Venus, and Jupiter have almost no axial tilt. The three planets have axes almost vertical to their orbits, so they have no seasons. Uranus and Pluto have extreme axial tilts. Uranus is tilted 97.9° from vertical. Pluto has an even greater axial tilt of 122.5°.

The amount of axial tilt affects seasons. In some cases so does a planet's orbit. Earth's orbit is nearly circular, so it does not have much effect on the seasons. However, Mars has a much more elliptical orbit that affects the amount of solar energy it receives at different times of the year.

For years people observed seasonal changes on Mars. Polar icecaps grew each winter, and large greenish regions appeared to grow every summer. Some people also thought they saw canals. They imagined vast areas of Martian plants being watered every summer by Martians.

Today we know that Mars has no canals, no plants, and no Martians. But it does have seasons. Mars is farther from the sun than Earth

THE INSIDE STORY

Seasons on Mars

Northern Polar Summer
The perman[illegible] mostly water ice. In [illegible] frost of mostly carbon [illegible] evaporates away. The polar [illegible] shrinks.

NORTHERN SUMMER
Mars reaches its farthest point from the sun, causing a long, cool summer in the northern hemisphere and a long, very cold winter in the southern hemisphere. Winds may uncover dark stone, causing seasonal patches of "green."

177 Martian days

Fall Equinox
As Mars approaches perihelion, the shortest season occurs. It is fall in the north and spring in the south.

142 Martian days

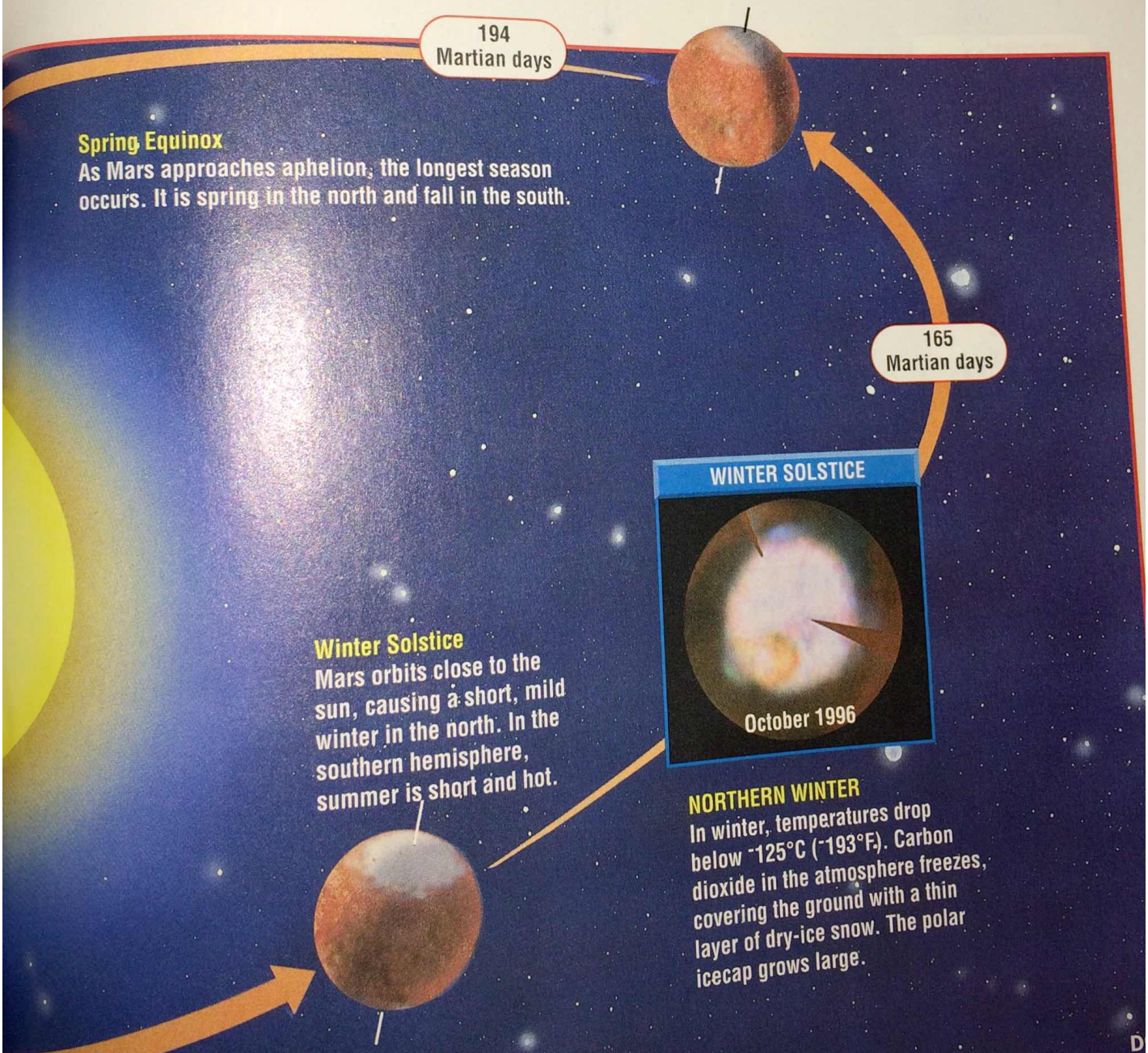
and takes a longer time to orbit the sun. So Martian seasons are colder and twice as long as Earth's. The hottest Martian summer day reaches only 20°C (68°F). A winter day might reach ⁻140°C (⁻220°F).

Because of the 25.2° tilt and elliptical orbit, Martian seasons are more extreme than Earth's. The difference between Earth's greatest distance from the sun and its least distance is relatively small—just 5 million kilometers (about 3 million mi). That is because Earth's orbit is almost circular. For Mars the difference between the greatest distance from the sun and the least distance is 43 million km (about 27 million mi).

So, unlike Earth's seasons, the seasons on Mars are affected by both the axial tilt and the shape of the orbit. You can see this in the diagram.

Mars has higher summer temperatures in the southern hemisphere than in the northern hemisphere because the southern summer comes at perihelion. The southern hemisphere winter occurs when Mars is at its greatest distance from the sun. This causes southern hemisphere winters to be much colder than those in the northern hemisphere.

✔ **Why do astronomers think that, besides Earth, other planets in the solar system also have seasons?**

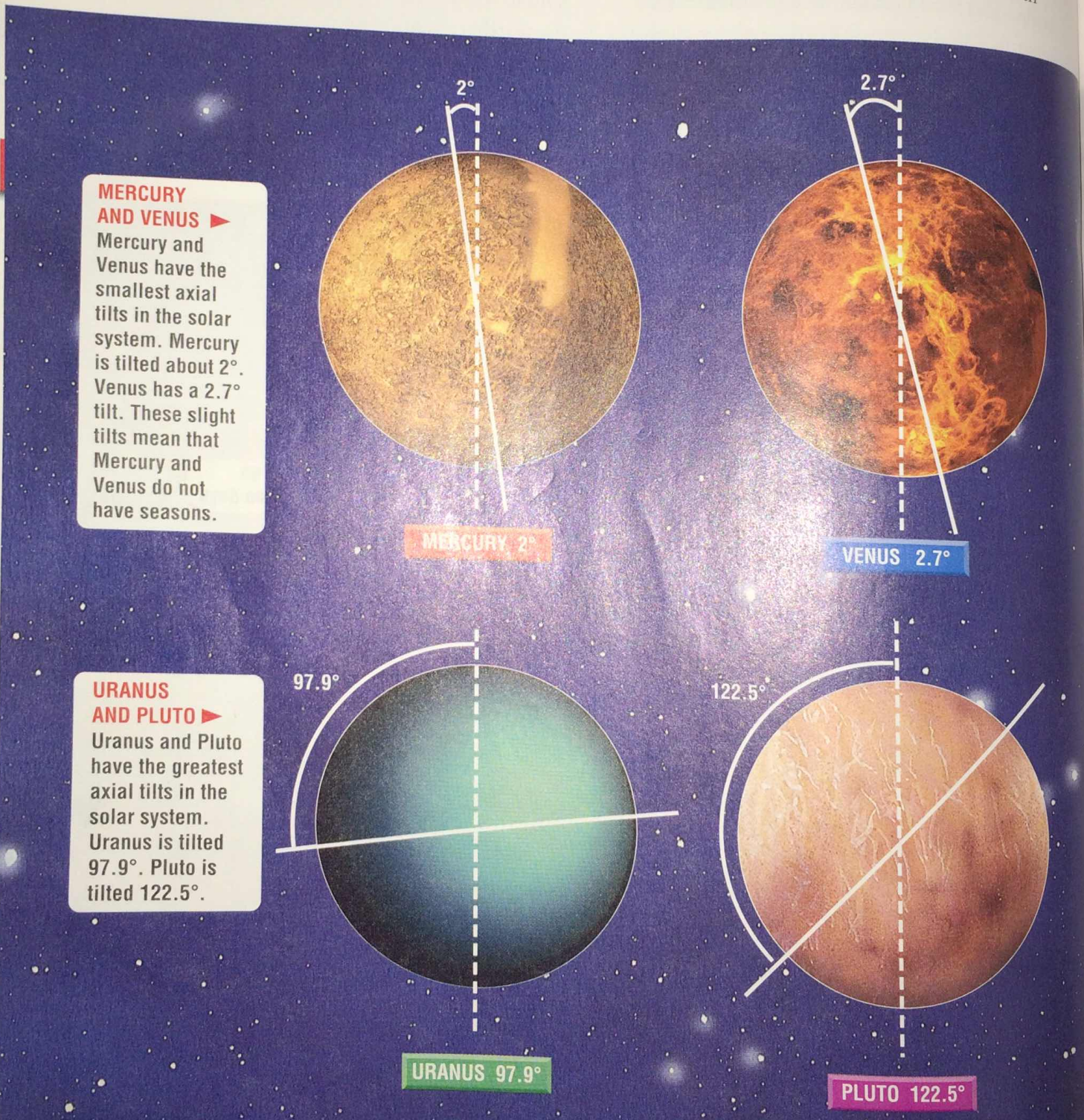


Seasons and Other Planets

The amount of axial tilt affects seasons. How far a planet is from the sun can determine temperature patterns. The planets with the least axial tilt, Mercury and Venus, are near to the sun. They have no seasons. All of Venus and the sunlit side of Mercury are always hot.

The planets with the greatest axial tilt are Uranus and Pluto. Astronomers hypothesize that a collision with an Earth-sized object changed Uranus's axial tilt. As a result, Uranus now lies on its side. This position gives Uranus a pattern of sunlight and darkness rather than seasonal change.

Because of its tilt, Uranus seems to roll on its orbit, with one pole facing the sun for about one-fourth of its year—about 21 Earth years. At the same time, the other pole has 21 Earth



years of continuous night. As the planet revolves, the pole that was in daylight moves into darkness, while the pole that was in darkness moves into light.

Pluto does have seasonal temperature changes. But Pluto is so far from the sun—5.9 billion km (about 3.7 billion mi)—that temperatures range from cold for the part facing the sun to even colder for the part facing away. The average temperature on Pluto is about ⁻210°C (⁻346°F). From Pluto the sun looks like a very bright star, and it casts a dim light. Pluto's sky is always dark. Its surface is always icy, and its temperatures are always bitterly cold—regardless of which pole is tilted toward the sun.

✓ **Why don't Mercury and Venus have seasons?**

Summary

Earth's axial tilt causes seasons. Its distance from the sun has little effect on the seasons. Some other planets are also tilted on their axes, so some of these planets also have seasons. For other planets, both the axial tilt and the distance from the sun affect their seasons.

Review

1. What is axial tilt?
2. How do seasons of the Northern Hemisphere relate to seasons of the Southern Hemisphere on Earth?
3. Name two factors that affect Mars's seasons.
4. **Critical Thinking** How would Earth's seasons be different if it had no tilt?
5. **Test Prep** One visual sign of seasons on Mars is the change in the planet's —
   - **A** icecaps
   - **B** axes
   - **C** moons
   - **D** plant life

LEARN ABOUT

The Phases of Moons

FIND OUT

- why we see phases of the moon
- what planetary phases are

VOCABULARY

phase
first quarter
third quarter

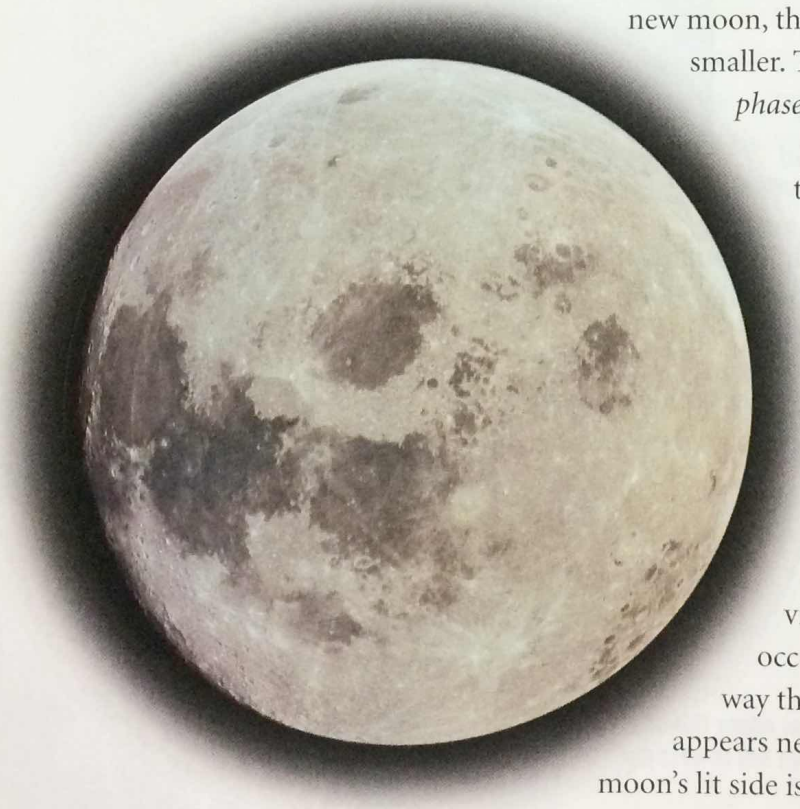
Phases of Earth's Moon

If you observe the moon, you will find that on some nights it rises in the evening sky as a big, round disk. On other nights, after hours of darkness, just a thin crescent appears. You are seeing the moon's phases. **Phases** are the different shapes the moon seems to have when it is viewed from Earth. In the investigation, you saw how the phases change as the moon revolves around Earth. The diagram on the next page shows the eight main phases of the moon.

If the moon produced light, it would always appear as a bright round disk. But the moon does not produce light. It reflects light from the sun. As the moon revolves around Earth, one-half of the moon is always lit by the sun. Depending on where the moon is in its orbit, you see different amounts of its lit side. The shape you see depends on how much of the moon's lit side is visible from Earth.

The moon takes $29\frac{1}{2}$ days to go through its cycle of phases—from new moon to full moon and back to new moon again. Between the new moon and the full moon, the visible part of the lit side gets larger. The shapes you see are called the *waxing phases*. From full moon to new moon, the visible part of the moon's sunlit side gets smaller. The shapes you see are called the *waning phases*.

During a full moon, you see all of the moon's sunlit side. ▼

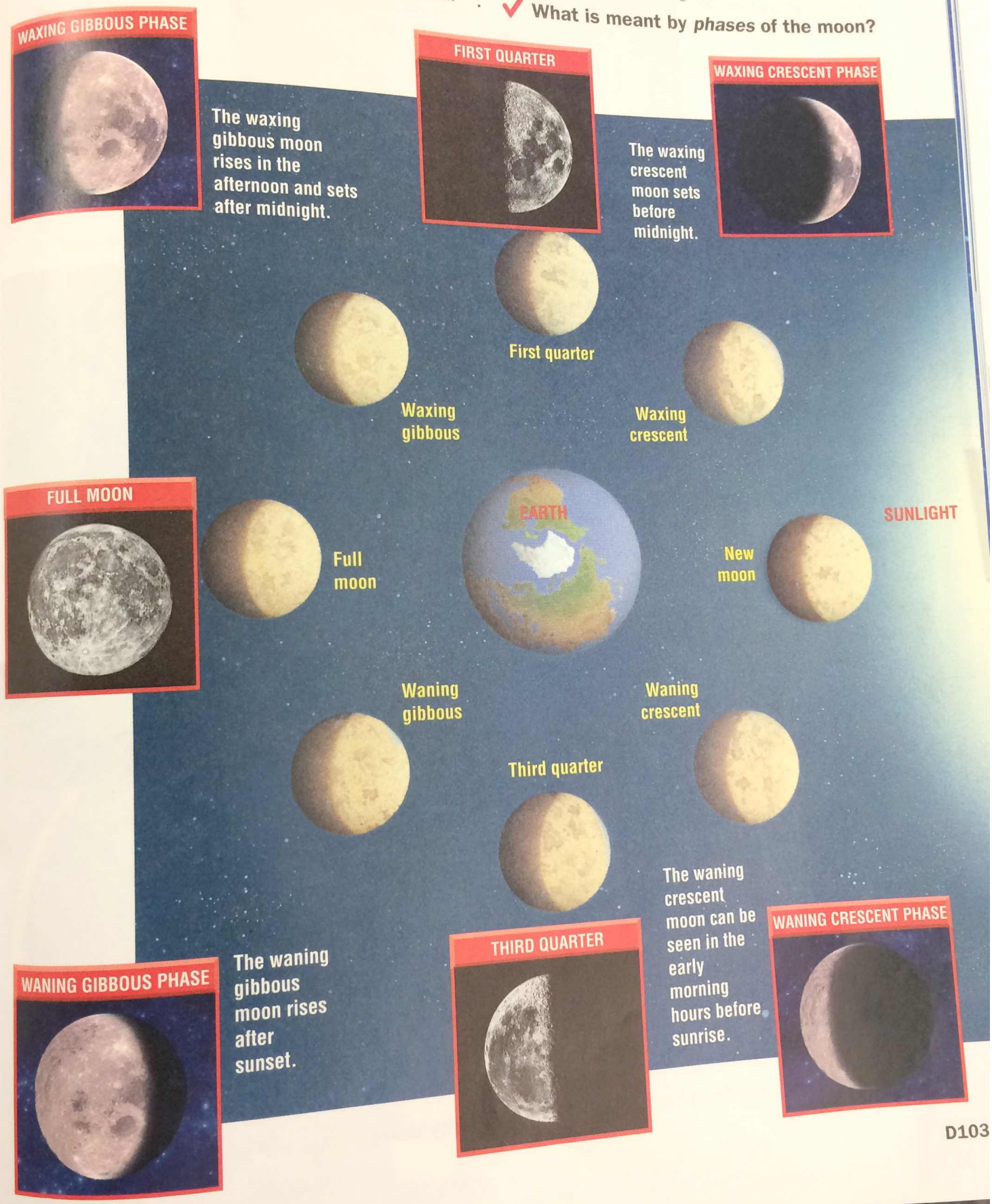


The new moon can barely be seen because the unlit half of the moon is facing Earth. The moon's lit half faces away from Earth. There is, however, enough sunlight reflected from Earth to light the dark side of the moon very dimly.

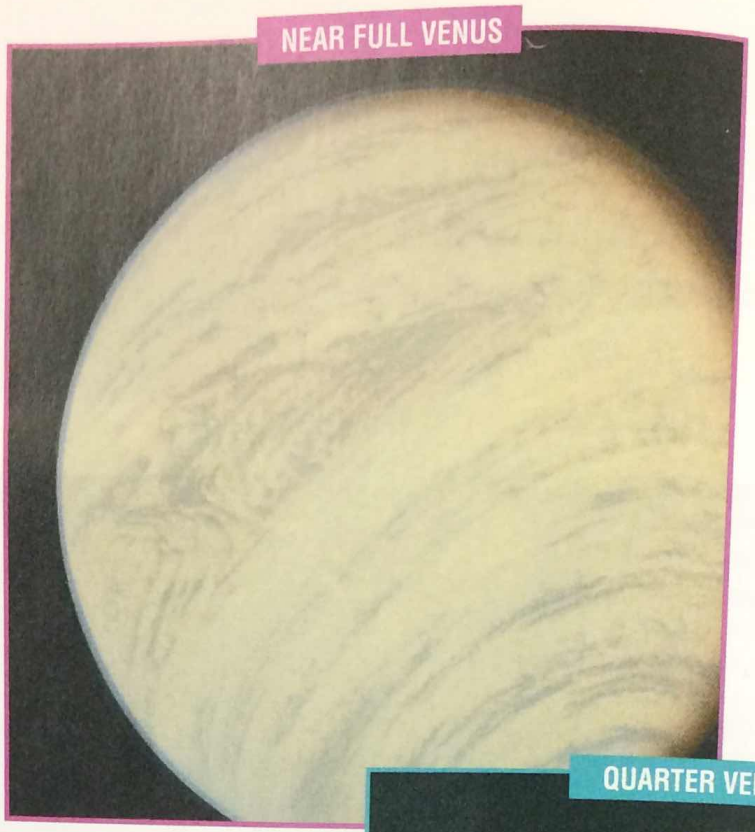
In later phases, the moon's sunlit side comes into view. First, you see just an edge. This is the waxing (growing) crescent. The next phase is the first quarter. In the **first quarter**, half the moon's lit side is visible. It is called the first quarter because it occurs when the moon is one-quarter of the way through its orbit. The waxing gibbous moon appears next. In this phase about three-fourths of the moon's lit side is visible. When the moon is halfway around its orbit, its whole lit side is visible. This phase is the full moon.

After the full moon, less and less of the moon's sunlit side is visible and the moon wanes (grows smaller) through its phases. The waning gibbous moon is followed by the third quarter moon. In the **third quarter**, half of the moon's lit side is visible—the half that was dark in the first quarter. This phase is called the third quarter because it happens when the moon is three-quarters of the way through its orbit. The last phase is the waning crescent. Then a new moon starts the cycle again.

✔ **What is meant by *phases* of the moon?**



From Earth the new phase and the full phase of Venus cannot be seen. However, the crescent phases and "quarter" phases can be seen clearly.



Although you can see more of its lit side, Venus looks smallest near its full phase because then it is farthest from Earth. The planet disappears from our skies because it moves behind the sun in full phase. ►

Phases of Other Moons and Planets

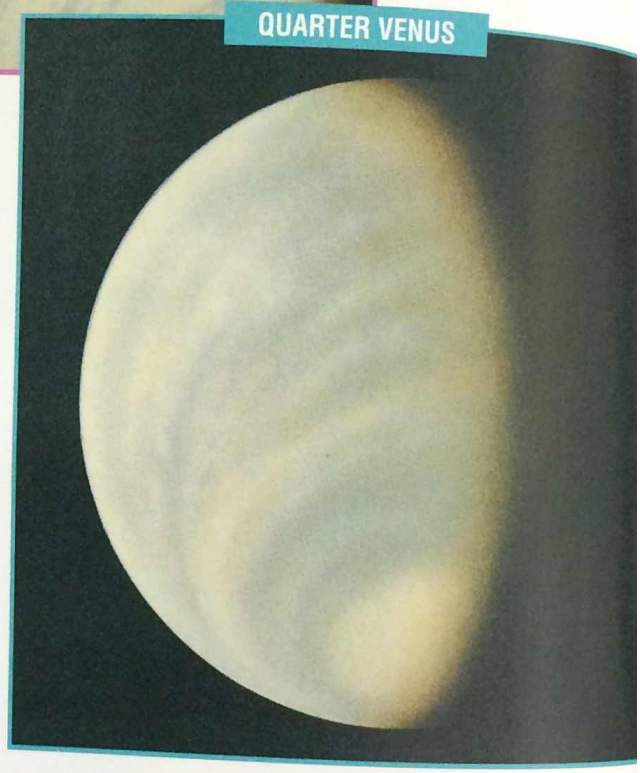
You see the moon's phases because, as the moon revolves, different amounts of its lit side are visible from Earth. What about other bodies in the solar system? Do they have phases?

There are more than 60 known moons in our solar system. If you could stand on the surface of one of the other planets with moons, you would see phases like those of Earth's moon.

In 1609 Galileo showed that planets also have phases. He was the first astronomer to see the phases of Venus. Galileo's observations helped him show that Venus and the other planets orbit the sun.

During much of the year, Venus appears as a bright star in either the morning or evening sky. Depending on its position in orbit, you can see different phases of Venus from Earth with a small telescope or binoculars.

Viewed from Earth, Mercury also has phases. However, Mercury's phases are difficult to see because the planet is close to the sun. Mercury's phases are best seen when Mercury and the sun are farthest apart as viewed from Earth.



▲ This view of Venus occurs one-quarter through its cycle of phases. The phases of Venus as seen from Earth follow a 584-day cycle.

If we send a probe out beyond other planets such as Mars and Jupiter, we see that they also have phases. But because the planets beyond Earth are so far from the sun, their phases are much harder to see.

✓ **Why does Venus have phases?**

Summary

Phases are the different amounts that you see of the moon's sunlit side as the moon orbits Earth. Some other moons and planets of the solar system also have phases.

Review

1. What is a new moon?
2. What are waxing phases?
3. What are waning phases?
4. **Critical Thinking** Would it be possible to see phases of Earth from Mars? Explain your answer.
5. **Test Prep** It is easiest to see the phases of the moon and —
   - **A** Pluto
   - **B** Neptune
   - **C** Venus
   - **D** the sun

Although you cannot see much of it, Venus looks largest in the crescent phase because then it is closest to Earth. When Venus moves in front of the sun (during the "new Venus" phase), it disappears in the glare of sunlight for a second time. ▼