1 FOCUS

Section Objective

23.4 **Describe** the distinguishing characteristics of each Jovian planet.

23.5 **Explain** why Pluto is not considered a planet.

Reading Focus

Build Vocabulary L2

Vocabulary Rating Chart Have students construct a chart with four columns labeled Word, Can Define or Use It, Heard or Seen It, and Don't Know. Have students copy words as they read the section into the first column and rate their word knowledge by putting a check in one of the other columns. Ask how many students actually know each word. Have them share their knowledge. Ask focused questions to help students predict text content based on the word, thus enabling them to have a purpose for reading. After students have read the section, have them rate their knowledge again.

Reading Strategy L2

Sample answers:
a. Saturn
b. largest ring system
c. Uranus
d. axis tilted more than 90°
e. Neptune
f. winds exceed 1000 km per hour

2 INSTRUCT

Jupiter: Giant Among Planets

Build Reading Literacy L1

Refer to **p. 392D** in **Chapter 14**, which provides guidelines for this reading strategy.

Preview Have students preview this section by skimming the headings and visuals. This will help students to activate their previous knowledge about the outer planets and will likely make them interested to read more about each planet.
Visual, Verbal

23.3 The Outer Planets (and Pluto)

Reading Focus

Key Concepts

- What characteristics distinguish each outer planet?
- Why is Pluto not considered a planet?

Vocabulary

- dwarf planet

Reading Strategy

Summarizing Make a table like the one shown that includes a row for each outer planet. Write a brief summary of the characteristics of each planet.

Outer Planets	Characteristics
Jupiter	largest; most mass, Great Red Spot
a. ___?___	b. ___?___
c. ___?___	d. ___?___

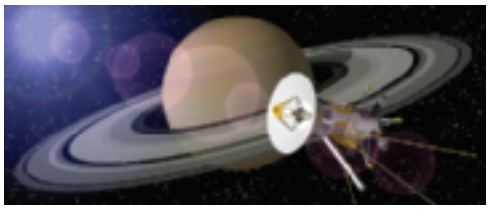

Figure 12 This artist's rendition shows *Cassini* approaching Saturn.

In 2004, the space probe *Cassini*, launched seven years earlier, finally reached the planet Saturn. The mission of *Cassini*, shown in Figure 12, was to explore Saturn's stunning ring system and its moons, including the unique moon Titan. In 2005, the *Huygens* probe, carried into space by the *Cassini* orbiter, descended to Titan's surface for further studies. In this section, we'll take a clue from *Cassini* and explore the outer planets—Jupiter, Saturn, Uranus, and Neptune.

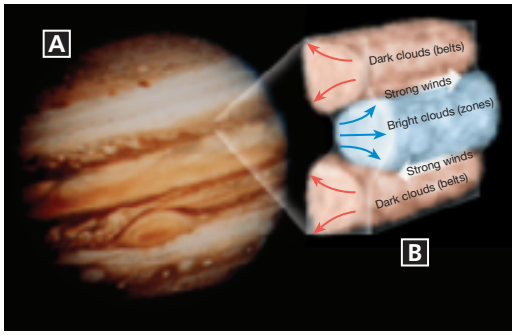

Figure 13 **A** When photographed by *Voyager 2*, the Great Red Spot was the size of two Earth-size circles placed side by side. **B** The dark clouds are regions where gases are sinking and cooling. The convection currents and the rapid rotation of the planet generate high-speed winds.

Jupiter: Giant Among Planets

Jupiter is only 1/800 as massive as the sun. Still, it is the largest planet by far. **Jupiter has a mass that is 2 1/2 times greater than the mass of all the other planets and moons combined.** In fact, had Jupiter been about 10 times larger, it would have evolved into a small star. Jupiter rotates more rapidly than any other planet, completing one rotation in slightly less than 10 Earth-hours.

When viewed through a telescope or binoculars, Jupiter appears to be covered with alternating bands of multicolored clouds that run parallel to its equator. The most striking feature is the Great Red Spot in the southern hemisphere, shown in Figure 13A. The Great Red Spot was first discovered more than three centuries ago by two astronomers, Giovanni Cassini (for whom the space probe was named) and Robert Hooke. When *Pioneer 11* moved within 42,000 kilometers of Jupiter's cloud tops, images from the orbiter indicated that the Great Red Spot is a cyclonic storm.

Structure of Jupiter Although Jupiter is called a gas giant, it is not simply a ball of gas. At 1000 kilometers below the clouds, the pressure is great enough to compress hydrogen gas into a liquid. Consequently, Jupiter is thought to be a gigantic ocean of liquid hydrogen. Less than halfway into Jupiter's interior, extreme pressures cause the liquid hydrogen to turn into liquid metallic hydrogen. Jupiter is also believed to have a rocky and metallic central core.

Jupiter's hydrogen-helium atmosphere is very active. It contains small amounts of methane, ammonia, water, and sulfur compounds. The wind systems, shown in Figure 13B, generate the light- and dark-colored bands that encircle this giant. Unlike the winds on Earth, which are driven by solar energy, Jupiter itself gives off nearly twice as much heat as it receives from the sun. Thus, the interior heat from Jupiter produces huge convection currents in the atmosphere.

Jupiter's Moons Jupiter's satellite system, consisting of 63 moons discovered so far, resembles a miniature solar system. The four largest moons, Io, Europa, Ganymede, and Callisto, were discovered by Galileo in 1610. Each of the four Galilean satellites is a unique geological world. The moons are shown in Figure 14. The innermost of the Galilean moons, Io, is one of four known volcanically active bodies in our solar system. The other volcanically active bodies are Earth, Saturn's moon Enceladus, and Neptune's moon Triton. The heat source for volcanic activity on Io is thought to be tidal energy generated by a relentless "tug of war" between Jupiter and the other Galilean moons. The gravitational power of Jupiter and nearby moons pulls and pushes on Io's tidal bulge as its orbit takes it alternately closer to and farther from Jupiter. This gravitational flexing of Io is transformed into frictional heat energy and results in Io's volcanic eruptions.

Go Online NSTA SCI LINKS

For: Links on the outer planets
Visit: www.SciLinks.org
Web Code: cjn-7233

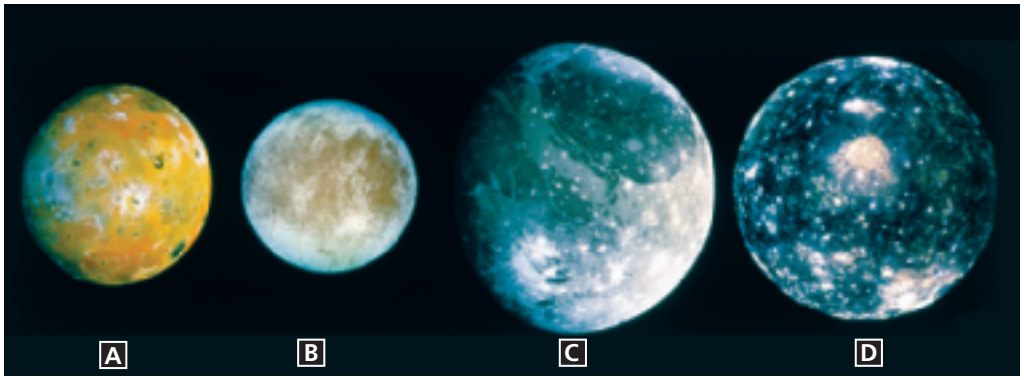

Figure 14 Jupiter's Moons
A Io is the innermost moon and is one of only four volcanically active bodies in the solar system. **B** Europa—the smallest of the Galilean moons—has an icy surface that is crossed by many linear features. **C** Ganymede is the largest Jovian moon, and it contains cratered areas, smooth regions, and areas covered by numerous parallel grooves. **D** Callisto—the outermost of the Galilean moons—is densely cratered, much like Earth's moon.

Use Visuals L1

Figure 14 This diagram shows Jupiter's four largest moons. Ask: **What do these moons have in common with each other?** *(They are all round, and they orbit around Jupiter.)* **Which of these moons have craters?** *(Europa, Callisto, and Io)* **Could Europa have craters?** *(Yes, but its surface is covered in ice.)* **Which of these moons has volcanoes?** *(Io)*
Visual

Integrate Language Arts L2

Mythological Characters All of the planets in our solar system, except for Earth, are named for characters or gods in Roman mythology. Have students work in groups. Each group should select the name of one planet to research. They should find out which mythological character or god the planet was named after, learn about the character, and determine why the name may have been given to the planet. For example, Mercury was named after the Roman messenger god because it is the planet with the fastest revolution rate around the sun. Each group should present its findings to the class.
Verbal, Interpersonal

Customize for English Language Learners

Have students create a concept map to organize what they will learn about the outer planets. Have them start with the main concept of the outer planets. Then have branches for Jupiter, Saturn, Uranus, and Neptune, which they will expand on by filling in characteristics of each planet as they read.

Go Online NSTA SCI LINKS

Download a worksheet on the outer planets for students to complete, and find additional teacher support from NSTA SciLinks.

Saturn: The Elegant Planet

Build Reading Literacy L1

Refer to **p. 124D** in **Chapter 5**, which provides the guidelines for this Reading Strategy.

Summarize Have students summarize the major characteristics of Saturn as they read. For example, Saturn has wind, storms, many moons, and rings. **Verbal**

Use Visuals L1

Figure 15 This diagram shows the rings of Saturn. Ask: **How are rings A and B different from ring C?** *(Ring C is a darker color.)* **What do you think is the cause of this difference?** *(They have different compositions.)* **How are the outer rings different from the inner rings?** *(The outer rings are much thinner than the inner rings.)* **How is ring E different from the other rings?** *(Ring E looks green, and is more diffuse.)* **Visual**

Jupiter's Rings Jupiter's ring system was one of the most unexpected discoveries made by *Voyager 1*. By analyzing how these rings scatter light, researchers concluded that the rings are composed of fine, dark particles, similar in size to smoke particles. The faint nature of the rings also indicates that these minute fragments are widely dispersed. The particles are thought to be fragments blasted by meteorite impacts from the surfaces of Metis and Adrastea, two small moons of Jupiter.

Reading Checkpoint *Which Galilean moon is volcanically active?*

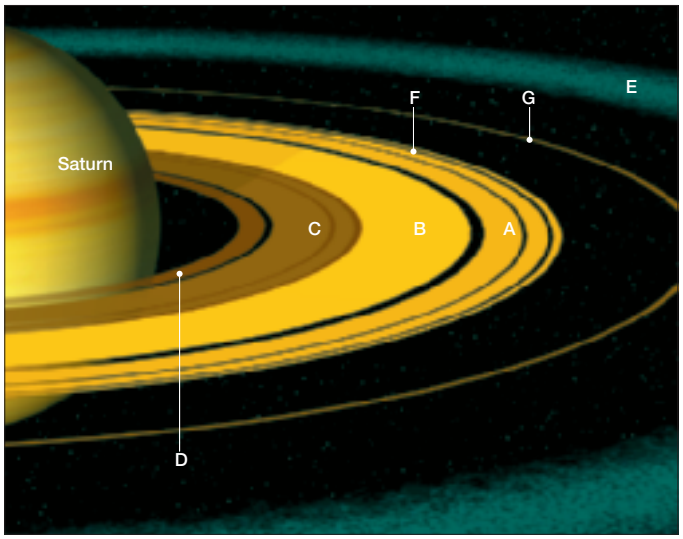

Figure 15 Saturn's Rings Saturn's rings fall into two categories based on particle density. The main rings (A and B) are densely packed. In contrast, the outer rings are composed of widely dispersed particles.

Saturn: The Elegant Planet

Requiring 29.46 Earth-years to make one revolution, Saturn is almost twice as far from the sun as Jupiter. However, its atmosphere, composition, and internal structure are thought to be remarkably similar to Jupiter's. **The most prominent feature of Saturn is its system of rings, shown in Figure 15.** In 1610, Galileo used a primitive telescope and first saw the structures that were later found to be the rings. They appeared as two small bodies adjacent to the planet. Their ring nature was explained 50 years later by the Dutch astronomer Christian Huygens.

Features of Saturn In 1980 and 1981, flyby missions of the *Voyagers 1* and *2* spacecraft came within 100,000 kilometers of Saturn. More information was gained in a few days than had been acquired since Galileo first viewed this elegant planet.

1. Saturn's atmosphere is very active, with winds roaring at up to 1500 kilometers per hour.
2. Large cyclonic "storms" similar to Jupiter's Great Red Spot, although smaller, occur in Saturn's atmosphere.
3. Eleven additional moons were discovered.
4. The rings of Saturn were found to be more complex than expected.

More recently, observations from ground-based telescopes, the Hubble Space Telescope, and *Cassini* have added to our knowledge of Saturn's ring and moon system. When the positions of Earth and Saturn allowed the rings to be viewed edge-on—thereby reducing the glare from the main rings—Saturn's faintest rings and satellites became visible.

Facts and Figures

Scientists believe that liquid water is the key to the development of life, so they carefully search other planets and moons for this key ingredient. Studies of Jupiter's moon, Europa, have revealed that it is covered with a thick layer of ice, and scientists have inferred that there may be liquid water beneath this layer. This makes Europa a prime target for future space probes to look for evidence of life on this moon.

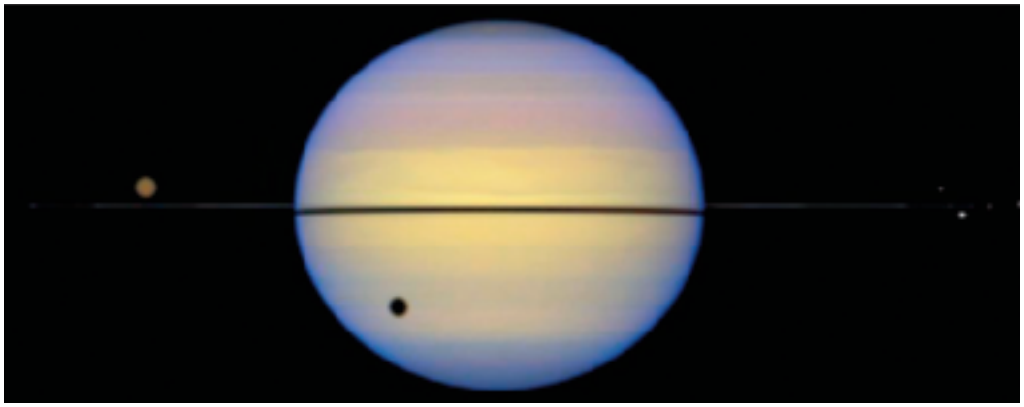

Figure 16 Saturn's Moons This image of Saturn shows several of its moons.

Saturn's Rings Until the discovery that Jupiter, Uranus, and Neptune also have ring systems, this phenomenon was thought to be unique to Saturn. Although the four known ring systems differ in detail, they share many attributes. They all consist of multiple concentric rings separated by gaps of various widths. In addition, each ring is composed of individual particles—"moonlets" of ice and rock—that circle the planet while regularly impacting one another.

Most rings fall into one of two categories based on particle density. Saturn's main rings, designated A and B in Figure 15, and the bright rings of Uranus are tightly packed and contain "moonlets" that range in size from a few centimeters to several meters. These particles are thought to collide frequently as they orbit the parent planet. Despite the fact that Saturn's dense rings stretch across several hundred kilometers, they are very thin, perhaps less than 100 meters from top to bottom.

At the other extreme, the faintest rings, such as Jupiter's ring system and Saturn's outermost rings, are composed of very fine particles that are widely dispersed. Saturn's outermost rings are designated E in Figure 15. In addition to having very low particle densities, these rings tend to be thicker than Saturn's bright rings.

Saturn's Moons Saturn's satellite system consists of 56 moons, some of which are shown in Figure 16. Titan is the largest moon and is bigger than Mercury. It is covered with rivers and oceans of liquid hydrocarbons. Titan and Neptune's Triton are the only moons in the solar system known to have substantial atmospheres. Because of its dense gaseous cover, the atmospheric pressure at Titan's surface is about 1.5 times that at Earth's surface. Another moon, Enceladus, is one of four known volcanically active bodies in our solar system. In 2006, the *Cassini* space probe discovered liquid water geysers in the moon's south polar region.

Reading Checkpoint *How many moons of Saturn have been discovered thus far?*

Build Science Skills L2

Inferring After reading the section on Saturn's rings, have students take another look at the image of Saturn's rings in Figure 15. Ask students to use what they read and observed, in addition to their prior knowledge of how the solar system formed, to infer how Saturn's rings might have formed. Have students share their ideas with the class. Then share the information in the Facts and Figures box below with the class.
Visual, Logical

Facts and Figures

There are several theories regarding the origin of ring particles. Some scientists believe the rings formed out of a cloud of gas and dust from which the planet formed. Others believe the rings formed later when a moon or asteroid was pulled apart by the planet's gravity. Still others believe a crash with a foreign body blasted apart one of the planet's moon. Scientists hope that future missions to Saturn will help them resolve this controversy.

Answer to . . .

Reading Checkpoint *Io is volcanically active.*

Reading Checkpoint *Fifty-six moons have been discovered around Saturn.*

Uranus: The Sideways Planet

Teacher Demo

Discovering the Rings of Uranus

L2

Purpose Students will experience a simulation of how the rings of Uranus were discovered.

Materials meter stick, flashlight

Procedure Darken the classroom, and have one student hold the flashlight at the front of the room. Hold the meter stick horizontally to represent the rings of Uranus. While the student holds the flashlight steadily, pass the meter stick slowly up and down in front of the flashlight so it appears to blink on and off to the class. Explain to students that the flashlight represents the distant star which was blocked by Uranus in 1977. Help students understand that the rings would have caused the light of the star to blink on and off a few times as Uranus and its rings passed in front of the distant star.

Expected Outcome Students will see that Uranus's rings would have caused the occluded star to blink on and off a few times before and after the passing of Uranus's body in front of the star.
Visual, Kinesthetic

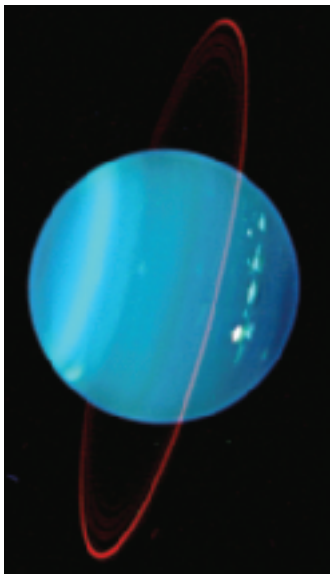

Figure 17 The axis of rotation of Uranus is nearly parallel with the plane of its orbit. This photo also shows the planet's ring system.

Uranus: The Sideways Planet

A unique feature of Uranus, shown in Figure 17, is that it rotates "on its side." **Instead of being generally perpendicular to the plane of its orbit like the other planets, Uranus's axis of rotation lies nearly parallel with the plane of its orbit.** Its rotational motion, therefore, has the appearance of rolling, rather than the top-like spinning of the other planets. Uranus's spin may have been altered by a giant impact.

A surprise discovery in 1977 revealed that Uranus has a ring system. This find occurred as Uranus passed in front of a distant star and blocked its view. Observers saw the star "wink" briefly both before and after Uranus passed by. Later studies indicate that Uranus has at least nine distinct ring belts.

The five largest moons of Uranus show varied terrain. Some of the moons have long, deep canyons and linear scars, whereas others possess large, smooth areas on otherwise crater-riddled surfaces. Miranda, the innermost of the five largest moons, has a greater variety of landforms than any body yet examined in the solar system.

Reading Checkpoint *What is unique about Uranus's axis of rotation?*

Neptune: The Windy Planet

As shown in Figure 18, Neptune has a dynamic atmosphere, much like those of Jupiter and Saturn. **Winds exceeding 1000 kilometers per hour encircle Neptune, making it one of the windiest places in the solar system.** It also had an Earth-size blemish called the Great Dark Spot that was reminiscent of Jupiter's Great Red Spot. The Great Dark Spot was assumed to be a large rotating storm. About five years after the Great Dark Spot was discovered, it vanished, only to be replaced by another dark spot in the planet's northern hemisphere, which also vanished within a few years.

Neptune has many surprising features. Perhaps most surprising are the cirrus-like clouds that occupy a layer about 50 kilometers above the main cloud deck. The clouds are most likely frozen methane. *Voyager* images revealed that the bluish planet also has a ring system.

Neptune has 13 known moons. Triton, Neptune's largest moon, is nearly the size of Earth's moon. Triton is the only large moon in the solar system that exhibits retrograde motion. This motion indicates that Triton formed independently of Neptune and was gravitationally captured.

Triton also has the lowest surface temperature yet measured on any body in the solar system at −200°C. Its atmosphere is mostly nitrogen with a little methane. Despite low surface temperatures, Triton displays volcanic-like activity.

Figure 18 The Great Dark Spot of Neptune (photographed by *Voyager 2* in 1989) is visible in the center of the left of the image. Bright cirrus-like clouds that travel at high speeds around the planet are also visible.
Identifying *What was the Great Dark Spot?*

Facts and Figures

The existence of Neptune was predicted before it was discovered. This prediction was based on irregularities in the orbit of Uranus and Newton's Universal Law of Gravitation. Scientists were ecstatic, in 1846, when Neptune was discovered exactly where it had been predicted. This discovery is an excellent example of a hypothesis being tested not in a lab, but in outer space itself.

Pluto: Dwarf Planet

Until 2006, Pluto was considered to be one of the nine planets. But in August of 2006, the International Astronomical Union (IAU) redefined the word "planet" in a way that excluded Pluto. **Pluto is not considered a planet, because it has not cleared the neighborhood around its orbit.**

Because Pluto was no longer a planet, the IAU also created a new term to describe it. A **dwarf planet** is a round object that orbits the sun but has not cleared the neighborhood around its orbit. A planet's gravity is strong enough for it to pull in smaller nearby bodies, thus clearing its orbital path. But a dwarf planet's gravity is too weak to attract all the debris nearby. Therefore, a dwarf planet orbits in a zone along with other small solar system bodies.

Pluto is the most well known of the dwarf planets. However, it is neither the largest nor the first to be discovered. The dwarf planet Ceres, which is in the asteroid belt, was discovered in 1801. And the dwarf planet Eris, just discovered in 2005, is slightly larger than Pluto. All dwarf planets likely contain a mixture of rock and ice, but can be found in very different parts of the solar system. Pluto is unusual in that it has a moon, Charon, which is more than half its size and may be considered a dwarf planet on its own. It is not yet known how many objects in the solar system will be considered dwarf planets. As new discoveries are made, this definition may be revisited.

Figure 19 This Hubble image shows Pluto and its moon Charon.

Section 23.3 Assessment

Reviewing Concepts

1. What is the largest planet? What is the smallest?
2. What is Jupiter's Great Red Spot?
3. Identify one distinguishing characteristic of each outer planet and Pluto.
4. How are Saturn's moon Titan and Neptune's Triton similar?
5. In what way is Io similar to Earth? What other body shows this similarity?

Critical Thinking

6. **Relating Cause and Effect** What may have caused Uranus's unique axis of rotation?
7. **Making Judgments** Should Pluto have been reclassified as a dwarf planet? Explain your answer.

Connecting Concepts

Convection Currents Write a brief paragraph comparing and contrasting atmospheric convection currents on Jupiter and Earth.

Pluto: Dwarf Planet

Build Science Skills L2

Comparing and Contrasting Challenge students to find similarities and differences between Pluto and the planets (both terrestrial and Jovian). They may also want to compare Pluto to some of the moons in our solar system. **Verbal**

3 ASSESS

Evaluate Understanding L2

Put students in cooperative groups, and have them compare the summaries of this section that they made in response to this section's first Reading Strategy.

Reteach L1

Have students make concept maps for each outer planet that list its major characteristics.

Connecting Concepts

Before students begin writing, review with them how convection currents in Earth's atmosphere work. Describe their cause *(solar energy)*, what they look like *(hot, less dense air rises while cooler, denser air sinks)*, and some results of convection currents *(wind)*.

Sample answer: On Earth, atmospheric convection currents are driven by solar energy. Jupiter, however, gives off nearly twice as much heat as it receives from the sun. The interior heat from Jupiter produces huge convection currents in the atmosphere.

Section 23.3 Assessment

1. Jupiter is the largest planet. Mercury is the smallest.
2. a cyclonic storm
3. Sample answer: Jupiter is the largest planet. Saturn has an amazing ring system. Uranus's axis of rotation is nearly parallel with the plane of its orbit. Neptune is one of the windiest places in the solar system. Pluto is small and cold with a very eccentric orbit.
4. Titan and Triton are the only moons in the solar system with significant atmospheres.
5. Io is volcanically active, just like Earth. Neptune's moon Triton is also volcanically active.
6. A giant impact may have changed Uranus's spin.
7. Sample answer: Further study is likely required to determine if our definition of a dwarf planet should apply to Pluto.

Answer to . . .

Figure 18 *The Great Dark Spot is assumed to be a large rotating storm, much like Jupiter's Great Red Spot.*

Reading Checkpoint *Uranus's axis lies nearly parallel with the plane of its orbit.*