Topic 3.3

What has space exploration taught us about our solar system?

Key Concepts

- The four inner Earth-like planets are small and rocky.
- The four outer "gas giant" planets are large and ringed.
- Rocky chunks of various sizes make up the rest of the solar system.

Key Skills

Inquiry
Literacy
Numeracy

Key Terms

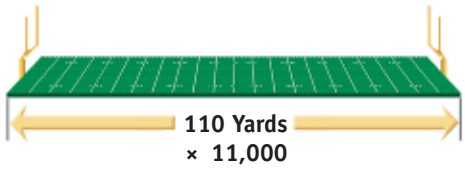
inner planets
outer planets
asteroid
meteoroid
comet

Space probes launched from Earth have visited every planet in our solar system. By venturing out into space, these robotic "eyes" have taught us much about the system of objects, our Earth included, that are linked to the star we call the Sun. Sometimes, however, we learn about our solar system when objects from *it* come to visit *us*. This is what happened, for example, 1.85 billion years ago in a part of Earth that is now called Sudbury, Ontario. A rock measuring 10 km in diameter hurtled through the atmosphere at speeds as great as 200 000 km/h. When it landed, it exploded with the force of several billion nuclear bombs and left a crater 250 km wide—the second-largest crater on Earth. (The largest is in South Africa.) Much of the wealth of material that is mined in the Sudbury area today is linked to the intense rock-changing heat from that ancient, cataclysmic explosion.

Starting Point Activity

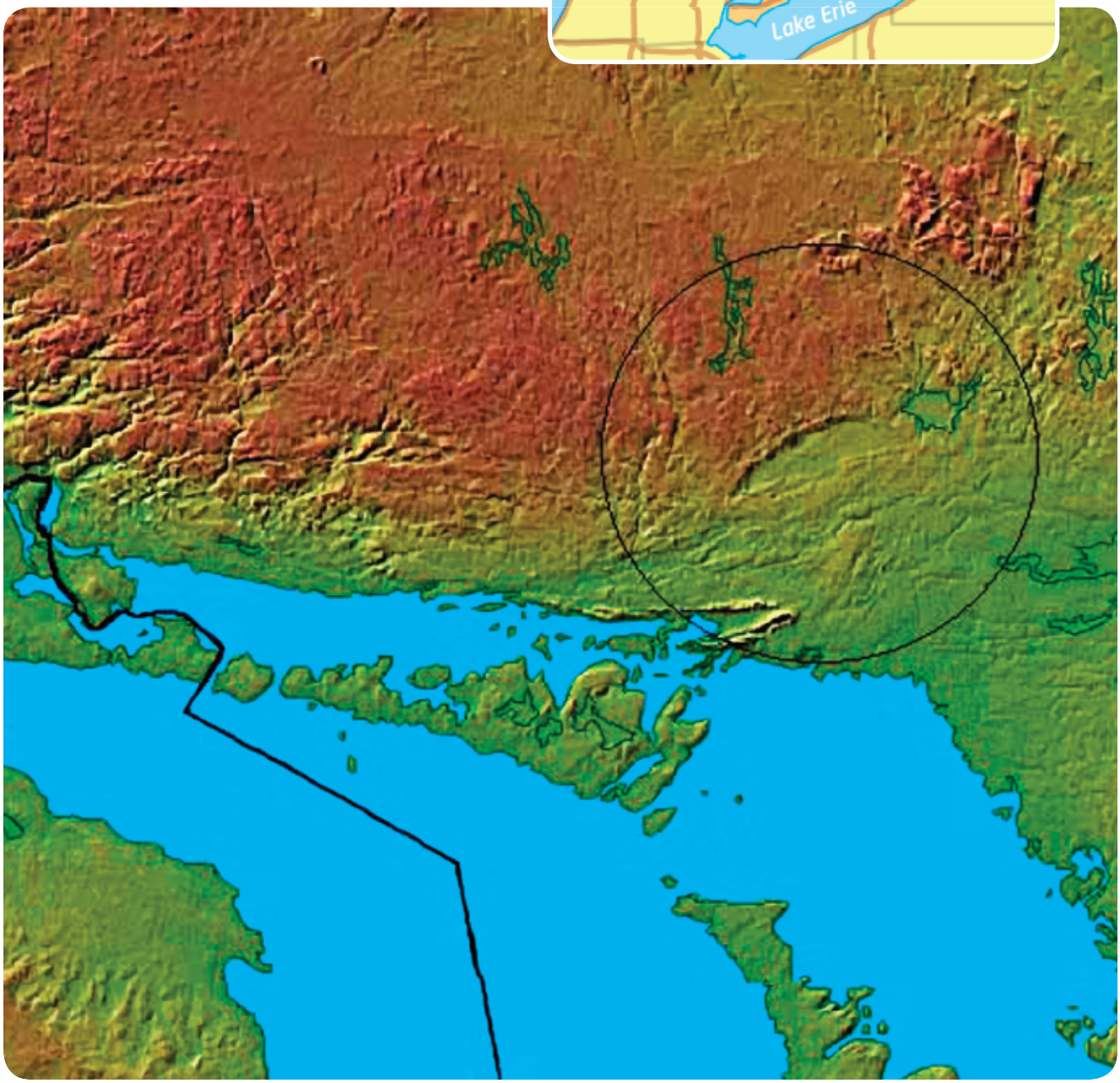
The object that caused the Sudbury Crater was a meteorite. What do you know about meteorites? How are they related to meteors and meteoroids? Share what you know or remember about these and other solar-system words such as those below. Add any other solar-system names or words that you know or remember.

- inner planets
- outer planets
- comet
- dwarf planet
- asteroid
- asteroid belt
- moon
- solar system



110 Yards
× 11,000
= 10 km

(size of the object that struck Sudbury)



The four inner Earth-like planets are small and rocky.

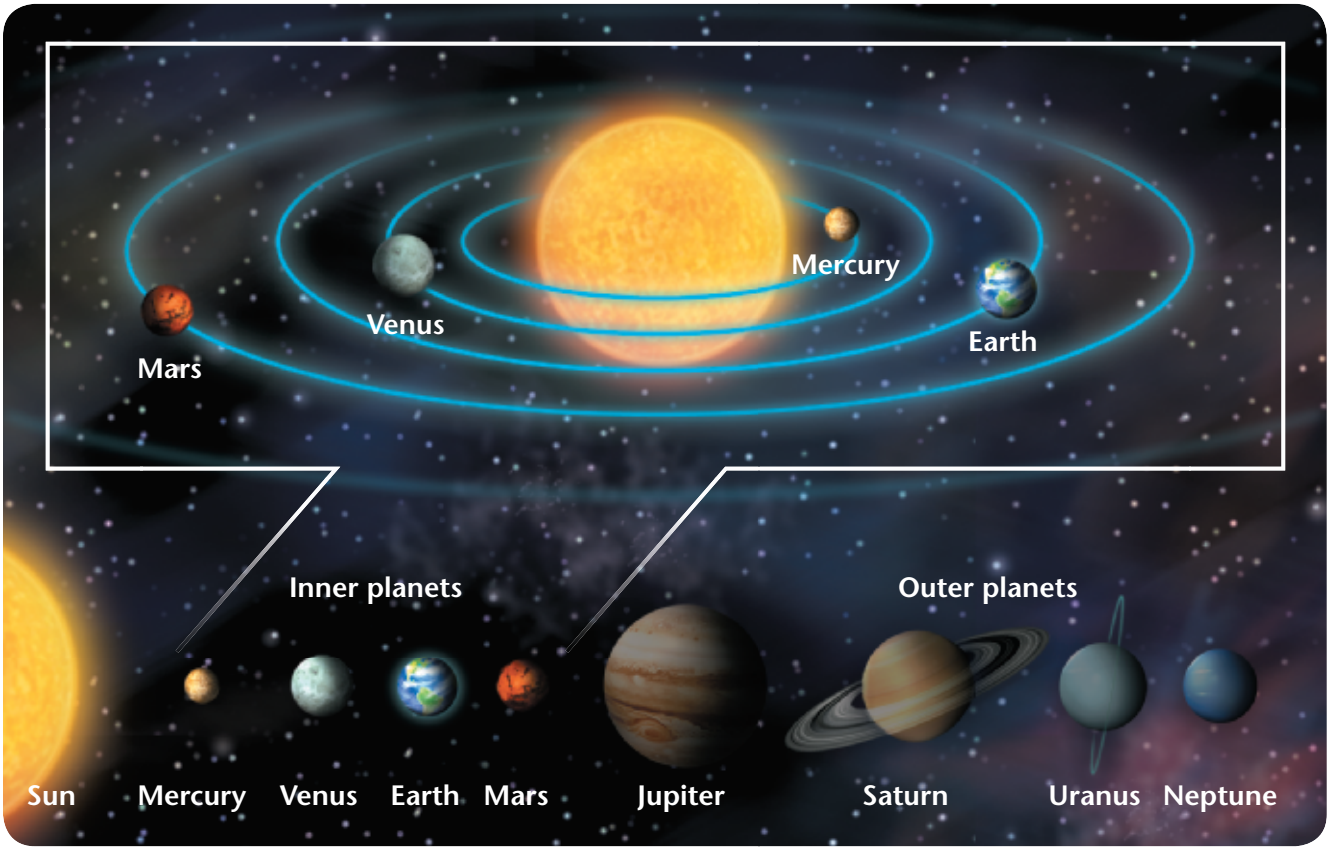
inner planets: the four planets of the solar system that are closest to the Sun: Mercury, Venus, Earth, and Mars

The four planets closest to the Sun are called the **inner planets**. Figure 3.14 shows the planets in this group: Mercury, Venus, Earth, and Mars. The inner planets are also known as the terrestrial (Earth-like) planets, because they have many features in common with Earth. For example, the inner planets:

- have a rocky, cratered surface
- are much smaller than the other planets in the solar system
- have orbits that bring them much closer to the Sun than the other planets
- have no moons or very few moons compared with the other planets

LEARNING CHECK

1. Identify the inner planets in our solar system.
2. State another name for the inner planets.
3. Use a table to compare four similarities and four differences between Earth and the other inner planets.



▼ **Figure 3.14** The four inner planets of the solar system are highlighted in the expanded-view area at the top of this diagram.

Mercury—The Smallest Planet

Distance from Sun: 0.39 AU

Size (Diameter): 4878 km (about one-third of Earth's)

Temperature Range: –184°C to 427°C

Time for One Rotation: 59 days

Time for One Orbit: 88 days (0.24 years)

Number of Moons: 0

Atmosphere: so weak and unstable as to be almost non-existent (but—as discovered in 2008 by NASA's MESSENGER probe—it includes water vapour)

Notable features: numerous craters, many named for famous Earth musicians, artists, and authors

Symbol: ☿

Name Origin: Named for the speedy Roman messenger god. (Mercury travels in its orbit faster than any other planet.)

Venus—The Hottest Planet

Distance from Sun: 0.72 AU

Size (Diameter): 12 104 km (nearly the same as Earth's, so Venus is sometimes called our sister planet)

Average Temperature: 457°C

Time for One Rotation: 243 days

Time for One Orbit: 226 days (0.62 years)

Number of Moons: 0

Atmosphere: mostly (about 97 percent) carbon dioxide, a gas that traps heat from the Sun, and that's why the temperature stays the same

Notable features: mountains, valleys, and volcanoes etched by rains of sulfuric acid

Symbol: ♀

Name Origin: Named for the Roman goddess of love and beauty. (Venus is bright, beautiful, and very noticeable in the sky at dawn and dusk.)

Earth—The Living Planet

Distance from Sun: 1.0 AU

Size (Diameter): 12 756 km

Temperature Range: –89°C to 58°C

Time for One Rotation: 23 hours, 56 minutes

Time for One Orbit: 365 days, 5 hours

Number of Moons: 1

Atmosphere: 78 percent nitrogen, 20 percent oxygen, 2 percent other gases (including carbon dioxide)

Notable features: Most of our craters are either underwater or have been eroded by weather and time. Oh, yes, and we have life!

Symbol: ♁

Name Origin: Earth is the only planet not named after a god or goddess from mythology. Earth simply refers to the material world—earth (as in soil, land, ground).

Mars—The Red Planet

Distance from Sun: 1.5 AU

Size (Diameter): 6785 km

Temperature Range: –140°C to 20°C

Time for One Rotation: 24.6 hours

Time for One Orbit: 1.88 years

Number of Moons: 2 (Phobos and Deimos, named after two children of Mars and Venus)

Atmosphere: mostly carbon dioxide (95 percent), plus other gases, including a small amount of oxygen

Notable features: rust in the soil (hence the red colour), the tallest volcano in the solar system, and methane in the atmosphere—a possible sign of life.

Symbol: ♂

Name Origin: Named for the Roman god of war and weaponry. (Mars, along with Venus and Mercury, are children of Jupiter in Roman myth.)

The four outer "gas giant" planets are large and ringed.

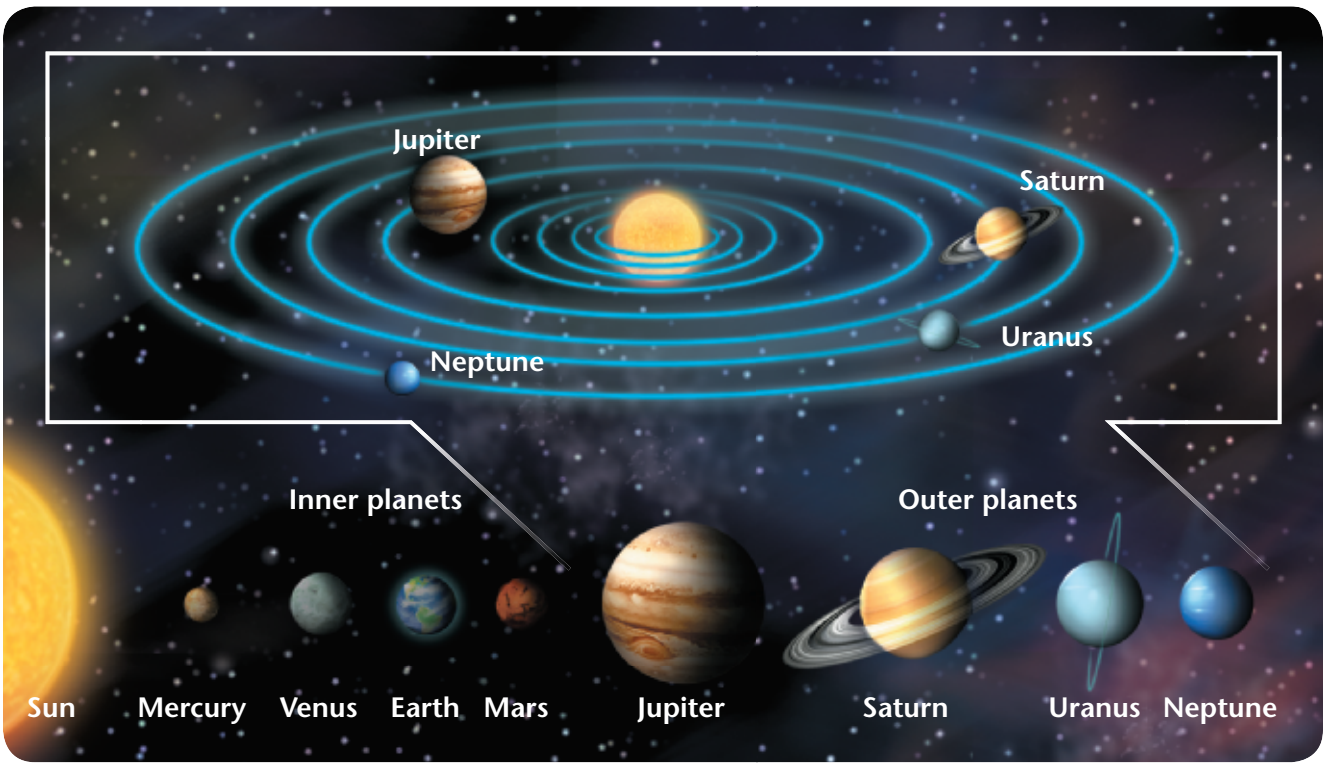
outer planets: the four planets of the solar system that are farthest from the Sun: Jupiter, Saturn, Uranus, and Neptune

The four planets farthest from the Sun are called the **outer planets**. Figure 3.15 shows the planets in this group: Jupiter, Saturn, Uranus, and Neptune. The outer planets are also known as the gas giants, because they have substantial gaseous atmospheres and their "surfaces" are gaseous, rather than solid. The outer planets have other features in common as well. For example, the outer planets:

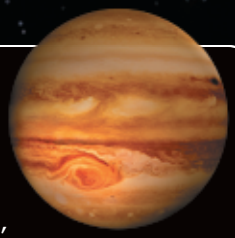
- have a gassy atmosphere and no solid surface
- are very large compared with the inner planets
- have orbits that keep them far from the Sun
- have rings surrounding them
- have numerous moons

LEARNING CHECK

1. Identify the outer planets in our solar system.
2. State another name for the outer planets.
3. Use a table to compare four similarities and four differences between Earth and the outer planets.



▼ **Figure 3.15** The four outer planets of the solar system are highlighted in the expanded-view area at the top of this diagram.



Jupiter—The Giant Planet

Distance from Sun: 5.2 AU

Size (Diameter): 142 800 km (if Earth were the size of a pea, Jupiter would be the size of an orange)

Average Temperature: –150°C

Time for One Rotation: 9.8 hours

Time for One Orbit: 12 years

Number of Moons: 63 (as of the year 2009), including the solar system's largest and the only one with a magnetosphere (Ganymede). Moons are named for mythological lovers and relatives of Jupiter.

Atmosphere: mostly hydrogen and helium

Notable features: the Great Red Spot's bone-crushing atmospheric pressure 30 000 times greater than Earth's, and a slender ring system

Symbol: ♃

Name Origin: Named for the ruler of all the Roman gods and goddesses. (Jupiter is the father of Mercury, Venus, and Mars.)

Saturn—The Ringed Planet

Distance from Sun: 9.5 AU

Size (Diameter): 120 536 km

Average Temperature: –170°C

Time for One Rotation: 10.7 hours

Time for One Orbit: 29.5 years

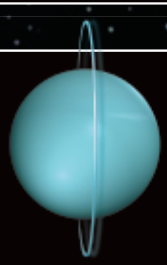
Number of Moons: 61 (as of the year 2009), including Titan, the only moon in the solar system with its own atmosphere. Moons are named after giants from Greek and Roman myths, as well as Inuit, French, and Scandinavian myths.

Atmosphere: mostly hydrogen and helium

Notable features: a Great White Spot (a storm that appears and disappears every 30 years), a density so small that Saturn would float on Earth's ocean, and—of course—its rings

Symbol: ♄

Name Origin: Named for the Roman god of agriculture, who was also father of Jupiter.



Uranus—The Tilted Planet

Distance from Sun: 19 AU

Size (Diameter): 51 120 km

Average Temperature: –215°C

Time for One Rotation: 12.2 hours

Time for One Orbit: 84 years

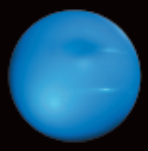
Number of Moons: 27 (as of the year 2009). Moons are named after characters from the plays of William Shakespeare and the poetry of Alexander Pope.

Atmosphere: mostly hydrogen and helium, with a small amount of methane

Notable features: a faint ring system, and the tilt of its axis is almost 90°, so it rotates "sideways"

Symbol: ♅

Name Origin: Named for the Greek god of the sky, who was also father of Saturn. (Oh, and by the way, it's pronounced YOU-ran-us.)



Neptune—The Deep-Blue Planet

Distance from Sun: 30 AU

Size (Diameter): 49 530 km

Average Temperature: –235°C

Time for One Rotation: 16.1 hours

Time for One Orbit: 165 years

Number of Moons: 13 (as of the year 2009). Moons are named after the lesser gods and goddesses from Greek and Roman myth associated with Neptune.

Atmosphere: mostly hydrogen and helium, with a small amount of methane

Notable features: a Great Dark Spot surrounded by whitish clouds of frozen methane, and a faint ring system

Symbol: ♆

Name Origin: Named for the Roman god of the sea, who was also a son of Saturn.

Rocky chunks of various sizes make up the rest of the solar system.

The Sun contains about 99.85 percent of all the mass of the solar system. The planets and their moons contain most of the rest. What's left over, a mere 0.02 percent of the mass of the solar system, is made up of chunks of rocky material. These chunks range in size from dust-sized specks to moon-sized orbs. They include asteroids, dwarf planets, comets, and meteoroids.

Asteroids

asteroid: a rocky object, located in the region between the orbits of Mars and Jupiter, that orbits the Sun

Figure 3.16 shows that between the orbits of Mars and Jupiter lies a ring of rocky objects that orbit the Sun. Some are round, and others are irregular in shape. Some are dozens or hundreds of kilometres across, but most are much smaller. All these rocks are called **asteroids**, and their location in the solar system is known as the Asteroid Belt. Scientists know the positions of a few hundred thousand asteroids, but there are millions more.

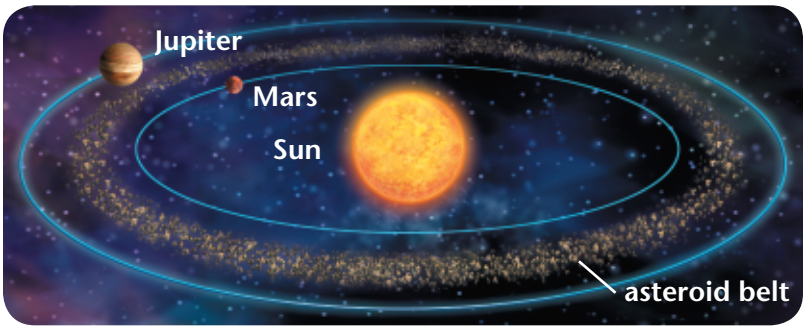


Figure 3.16 The Asteroid Belt is a ring of rocky chunks of various sizes that orbit the Sun between the orbits of Mars and Jupiter.

Dwarf Planets

The largest object in the Asteroid Belt is called Ceres. With a diameter of about 950 km, Ceres is referred to as a dwarf planet rather than an asteroid. Ceres is one of five known dwarf planets in the solar system. The others are Pluto, Eris, Haumea, and Makemake. They are located far beyond Neptune. A dwarf planet is larger than an asteroid but smaller than a planet. Unlike a planet, a dwarf planet does not have enough gravity to pull all the rocky debris around it out of the path of its orbit.

What about Comets and Meteoroids?

Comets are chunks of loosely held rock and ice that come from the outer parts of the solar system. They start their journeys toward and around the Sun when they are pulled from the outer regions of the solar system by the gravity of other objects. The orbits of comets bring them near the Sun with predictable regularity (**Figure 3.17**). For example, the orbit of Halley's Comet makes it visible to us on Earth every 76 years. Other comets have such huge orbits that they take thousands or millions of years to make one trip around the Sun.

comet: chunks of loosely held rock and ice that are thought to come from the outer regions of the solar system

Meteoroids are chunks of rock, metal, or both that are shed from the asteroids or comets. When a meteoroid enters Earth's atmosphere and starts to burn up, it makes a streak of light across the sky lasting a few seconds or shorter. This streak of light made by a meteoroid is called a meteor (**Figure 3.18**). Any part of the original object that survives the atmosphere and lands on Earth's surface is called a meteorite.

meteoroid: chunk of rock, metal, or both that is shed from an asteroid or comet

LEARNING CHECK

1. Refer to **Figures 3.17** and **3.18**. Compare a comet to a meteoroid.
2. Describe what a dwarf planet is, and state how many known dwarf planets there are.
3. In the past, many people viewed comets with suspicion and fear. Predict why people might have been fearful of comets.

Go to **scienceontario** to find out more

▲ **Figure 3.17** As a comet nears the Sun, the solar wind causes parts of the comet to vaporize and pushes them off the comet's surface. This forms what we call the tail of a comet.

▲ **Figure 3.18** The streak of light is the result of heat generated by friction between the meteoroid and Earth's atmosphere.

Research Focus

Activity 3.10

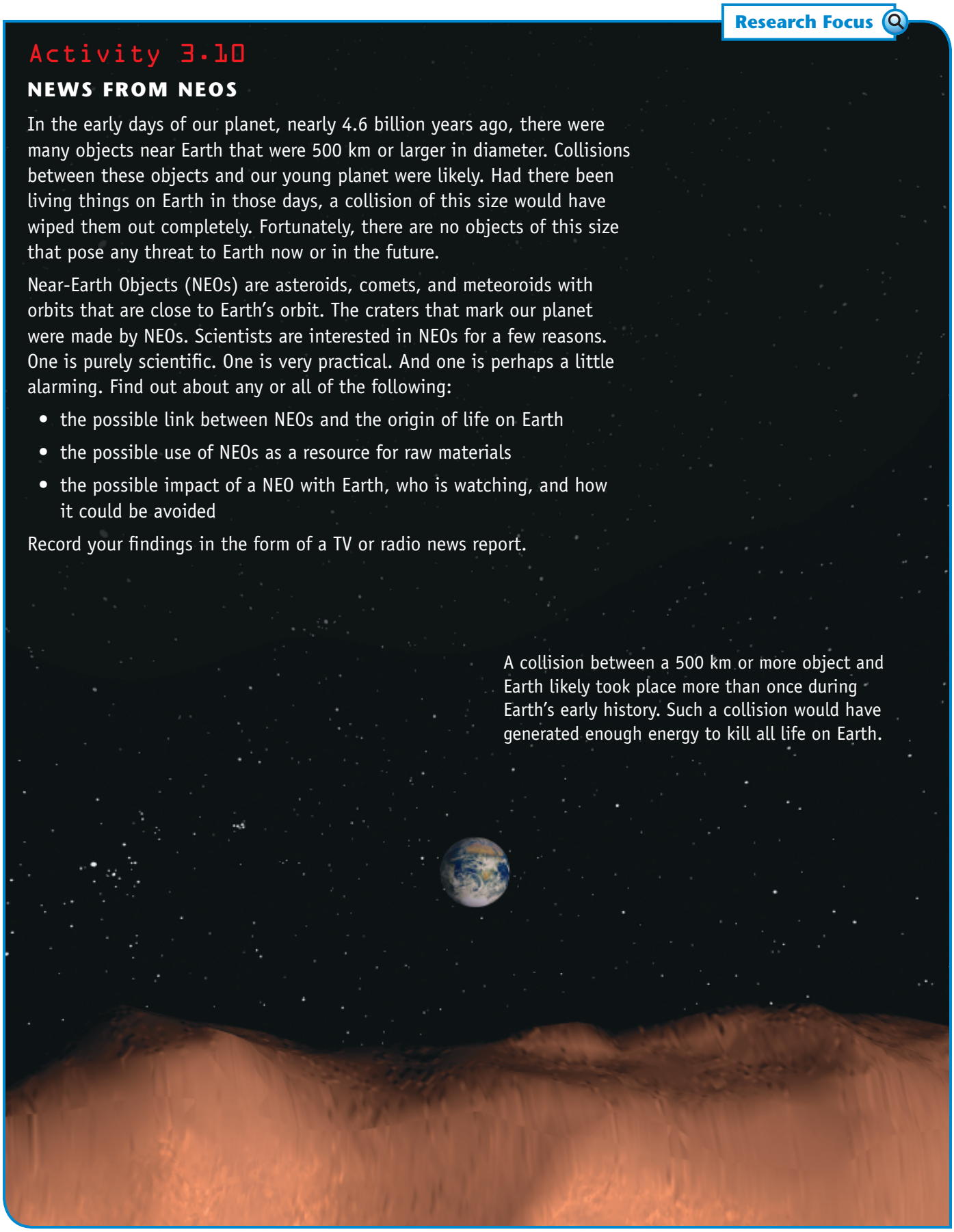
NEWS FROM NEOS

In the early days of our planet, nearly 4.6 billion years ago, there were many objects near Earth that were 500 km or larger in diameter. Collisions between these objects and our young planet were likely. Had there been living things on Earth in those days, a collision of this size would have wiped them out completely. Fortunately, there are no objects of this size that pose any threat to Earth now or in the future.

Near-Earth Objects (NEOs) are asteroids, comets, and meteoroids with orbits that are close to Earth's orbit. The craters that mark our planet were made by NEOs. Scientists are interested in NEOs for a few reasons. One is purely scientific. One is very practical. And one is perhaps a little alarming. Find out about any or all of the following:

- the possible link between NEOs and the origin of life on Earth
- the possible use of NEOs as a resource for raw materials
- the possible impact of a NEO with Earth, who is watching, and how it could be avoided

Record your findings in the form of a TV or radio news report.



A collision between a 500 km or more object and Earth likely took place more than once during Earth's early history. Such a collision would have generated enough energy to kill all life on Earth.

Numeracy Focus

Activity 3.11

BIKE ME TO THE MOON, AND BEYOND

Imagine that you can ride a bike at a constant rate of 20 km/h without ever stopping. How long would it take you to bike across the country, around the world, and to places beyond Earth? Find out in this activity.

What To Do

1. The table to the right lists the distances for several trips. For each trip, you will predict the time it would take. Then you will calculate the time. Make a table with three headings—Trip, Predicted Time, and Calculated Time—and one row for each trip.
2. Estimate and record the time you think it will take to make the trip at a speed of 20 km/h.
3. Calculate how long it would take to travel each distance. The first calculation is done as an example below.

Description of Trip	Approximate Distance
Canada, from west coast to east coast	5.20×10^3 km
Around Earth's equator	4.00×10^4 km
From Earth to the Moon	3.85×10^5 km
From Earth to Mars	5.80×10^7 km
From Earth to the Sun	1.50×10^8 km
From Earth to Jupiter	9.30×10^8 km
From Earth to Neptune	4.30×10^9 km
From Earth to the outer regions of the solar system	9.46×10^{12} km (at least)

What Did You Find Out?

1. How close were your predictions to your calculated values?
2. Which trips do you think would be practical if you could travel in a space ship at a speed of 1.0×10^5 km/h?

Description of Trip	Approximate Distance
To find the number of hours the trip will take, divide the distance by the speed. $\text{time} = \frac{\text{distance}}{\text{speed}}$ or $t = \frac{d}{s}$	$t = \frac{d}{s}$ $t = \frac{5.2 \times 10^3 \cancel{\text{km}}}{20 \frac{\cancel{\text{km}}}{\text{h}}}$ $t = 2.6 \times 10^2$ h or 260 h
To find the time in days, divide the number of hours by the number of hours in a day. $\text{time in days} = \frac{\text{time in hours}}{\text{24 hours in a day}}$	$\text{time in days} = \frac{\text{time in hours}}{\text{24 hours in a day}}$ $\text{time in days} = \frac{260 \cancel{\text{h}}}{24 \frac{\cancel{\text{h}}}{\text{day}}}$ time in days = 10.83 days
To find the time in years, divide the number of days by the number of days in a year. $\text{time in years} = \frac{\text{time in days}}{\text{365 days in a year}}$	$\text{time in years} = \frac{\text{time in days}}{\text{365 days in a year}}$ $\text{time in years} = \frac{10.83 \cancel{\text{days}}}{365 \frac{\cancel{\text{days}}}{\text{year}}}$ time in years = 0.0297 years

Inquiry Focus

Activity 3.12

MAP THE SOLAR SYSTEM

You can get a better grasp of large distances in space by bringing them down to Earth. In this activity, you will use a scale to reduce the distances between planets and the Sun so they fit within the boundaries of your community.

What You Need

- map of your community
- sticky notes
- coloured pencils or markers
- ruler

What To Do

1. Copy the following table into your notebook.

Planet Distances from Sun

Planet	Distance from Sun (AU)
Mercury	
Venus	
Earth	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	

2. The planet profiles on pages 199 and 201 give the distance of each planet from the Sun. Use this data to complete the table.
3. Spread out the map of your community on a desk or tape it to the chalkboard.
4. Find the location of your school on the map. Using a sticky note and a coloured marker, label your school as the Sun.
5. Copy the following scale onto a sticky note and place it on your map: 1 AU:1 km.
6. The map of your community will have a scale on it. Find this scale and use a ruler to determine what distance represents 1 km on your map.
7. Refer to the table that you copied into your notebook. Use sticky notes and coloured markers to mark the locations of the planets on your map. Start measuring from your school.
8. Compare your map with another student and see how the locations of the different planets compare on the two maps.

What Did You Find Out?

1. What is the distance between Earth and the Sun on your map? Where is Earth located in your community?
2. Which planet is about five times farther from the Sun than Earth is? Where is this planet located in your community?
3. Did you find it more difficult to mark the inner planets or the outer planets on your map? Explain why this was the case.
4. In step 8 you compared your map with another student's map. How were your maps similar? How did they differ?

Inquire Further

Figure out how to add these other solar system objects to your map: the Asteroid Belt, the Kuiper Belt, the Oort Cloud.

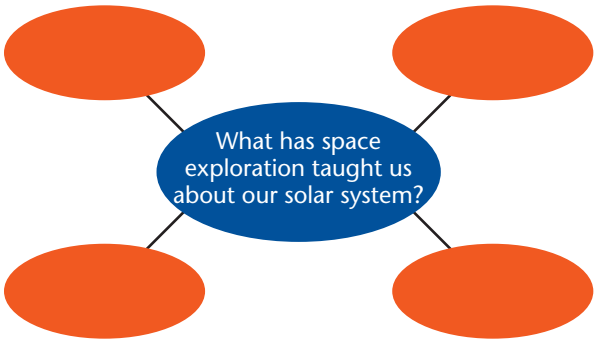
Topic 3.3 Review

Key Concepts Summary

- The four inner Earth-like planets are small and rocky.
- The four outer planets are large and ringed.
- Rocky chunks of various sizes make up the rest of the solar system.

Review the Key Concepts

1. K/U Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. K/U Copy and complete the table below in your notebook.

Comparing Asteroids, Comets, and Meteoroids

	Asteroid	Comet	Meteoroid
Description			
Origin			

3. C Draw a Venn diagram to compare the similarities and differences between the inner planets and the outer planets in our solar system.

4. C Although Venus is sometimes referred to as Earth's sister planet, Mars has more in common with Earth than Venus does. Provide at least three facts to support this idea.

5. T/I In your notebook, construct a bar graph to show the data in the table below. Based on this data, list the planets in order from the smallest planet to the largest planet.

Planet	Diameter (km)
Earth	12 756
Uranus	51 120
Mercury	4878
Jupiter	142 800
Mars	6785
Neptune	49 530
Venus	12 104
Saturn	120 536

6. A *Voyager 2* is an unpiloted, interplanetary spacecraft designed originally to study Neptune and Uranus. To save fuel, *Voyager 2* used a planet's gravity during a flyby to slingshot it farther into space. This technique is called a "gravity assist trajectory." Predict which planet the *Voyager 2* spacecraft used as a slingshot and justify your answer.

7. A Refer to **Figure 3.14**. Venus is farther from the Sun than Mercury, yet it is hotter than Mercury. Explain why Venus is hotter than Mercury.

8. K/U Identify four features of Venus that would lead some people to refer to Venus as Earth's sister planet.