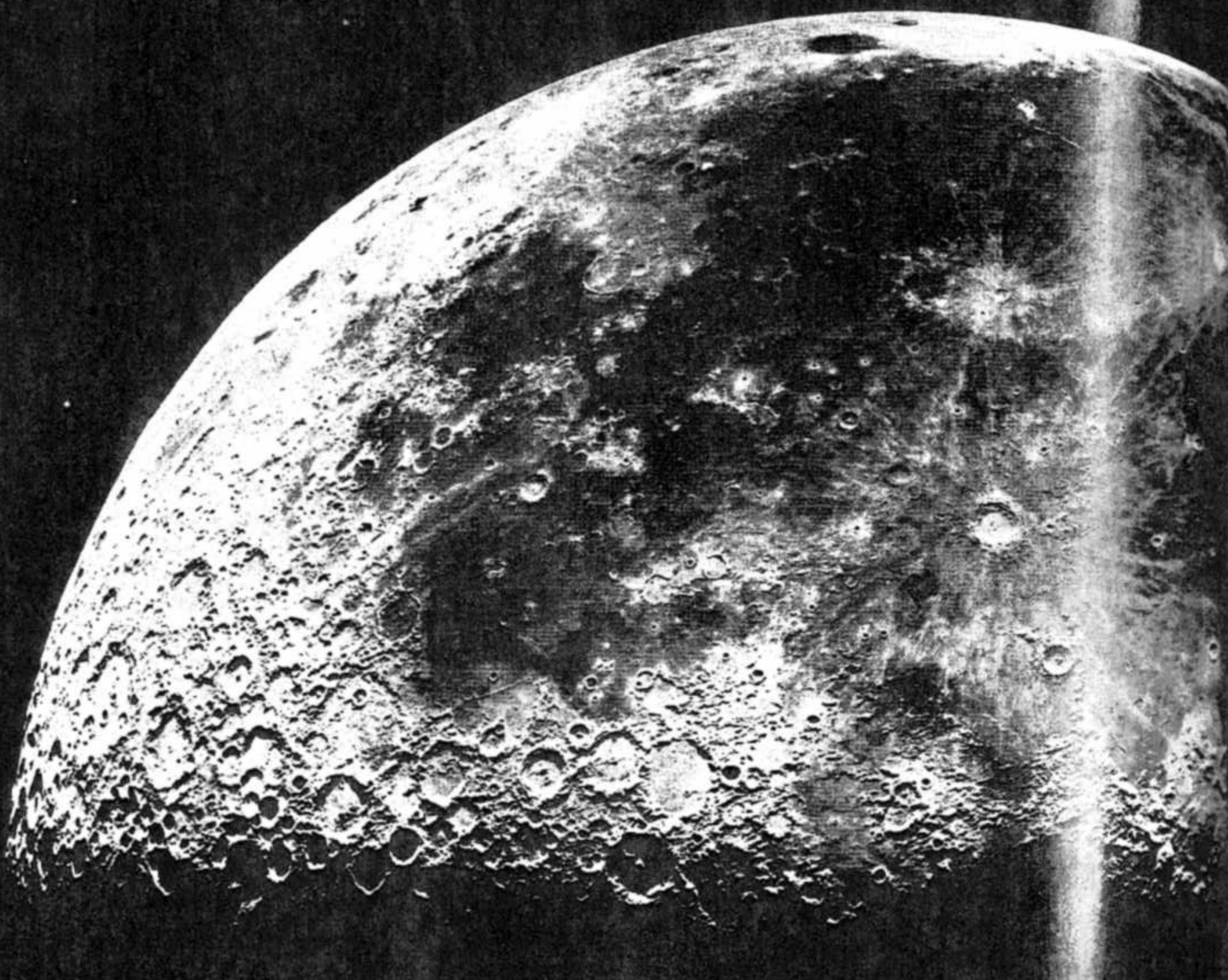
CHAPTER 25

Earth's Moon

Cold and airless, the moon has long been the subject of scientific study.

What can our exploration of the moon tell us about Earth and the universe?



CHAPTER 25

PREVIEW

▶ FOCUS QUESTIONS **In this chapter you will study the moon and learn more about the key questions listed below.**

Section 1 How did the moon form? What are its properties?

Section 2 How does the moon move in relation to Earth?

▶ REVIEW TOPICS **As you investigate the moon, you will need to use information from earlier chapters.**

- density (p. 20)

▶ READING STRATEGY

PREVIEW

Before you read, look through the chapter and examine the headings, photographs, and other visuals. Does any visual surprise you? Write any questions you might have in your Science Notebook.

INTERNET RESOURCES
CLASSZONE.COM

At our Web site, you will find the following Internet support for this chapter.

DATA CENTER

EARTH NEWS

VISUALIZATIONS

- Moon Formation
- Moon Phases
- Lunar Eclipse
- Solar Eclipses

LOCAL RESOURCES

INVESTIGATIONS

- What If Earth and the Moon Were Hit by Twin Asteroids?

25.1

KEY IDEAS

The moon was probably formed by a large impact between Earth and a planet-sized object.

The moon has a heavily cratered surface that consists of older highlands and younger maria.

KEY VOCABULARY

- astronomy
- meteoroid
- crater
- micrometeoroid
- maria
- mascons
- rille
- ray
- regolith

VISUALIZATIONS
CLASSZONE.COM

Observe images illustrating the impact theory of the moon's formation.
Keycode: ES2501

Origin and Properties of the Moon

Astronomy, the study of the universe, has a long history. Even so, when probes from the Soviet *Luna* spacecraft first encountered the moon in 1959, the human perspectives on Earth and space changed dramatically. In 1969—a mere ten years later—*Apollo* astronauts from the United States landed on the moon. By the end of the final *Apollo* mission in 1972, about 400 kilograms of lunar rock had been brought back to Earth, most of it by *Apollo* spacecraft missions. Scientists are still using these rocks, along with thousands of lunar photographs and other data, to study the moon.

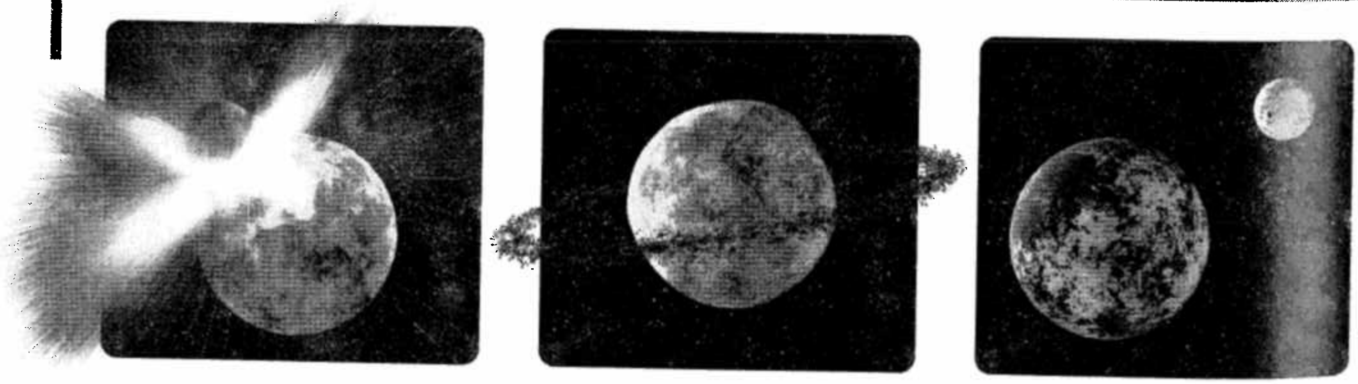
Origin of the Moon

There are several theories about the moon's origin. One suggests that Earth and the moon formed simultaneously, with the moon in orbit around Earth. Another suggests the early Earth was spinning so fast that a chunk of it spun off into orbit. Still another theory suggests that the moon formed elsewhere in the solar system and was later captured by Earth's gravitational field. These three theories are plausible; however, a fourth theory has become widely accepted by most planetary scientists. This theory proposes that the moon formed about 4.5 billion years ago as a result of a collision between Earth and a planet-sized object.

Development of the Moon

Over a period that may have been less than one year, debris from the impact went into orbit around Earth, and its gravity started to pull it together to form the moon. Additional impacts occurred, mostly involving meteoroids. A **meteoroid** is a celestial body that can range in size from a speck to an object weighing thousands of kilograms. Frequent impacts melted the moon's surface layers, forming a huge "magma ocean." Lighter materials, such as aluminum compounds, floated to the top of the ocean. The crust cooled and hardened, still additional impacts continue to blow out **craters,**

Formation of the Moon—Impact Theory



1 Earth is hit off-center by a planet-sized object.

2 The impact heats and deforms both bodies. Some rocky debris remains in orbit around Earth.

3 The debris ring—comprised of rock from the lighter outer layers of Earth and the impactor—gradually coalesces, forming the moon.

or depressions in the moon's surface, and to raise up mountains. The largest impacts blasted out great basins, and formed cracks through which lava flowed from the interior. Tiny particles ground and pitted the surface. Rock fragments and dust spread over the landscape.

Approximately 4.0–3.0 billion years ago, impacts from meteoroids decreased in frequency. Over millions of years, magma—richer in iron than the original surface layers—rose to the surface, filling the largest impact basins. When the lava cooled, it formed large, flat plains that are darker than the older, lighter highlands. The interior of the moon gradually cooled and became geologically inactive.

The Moon Today

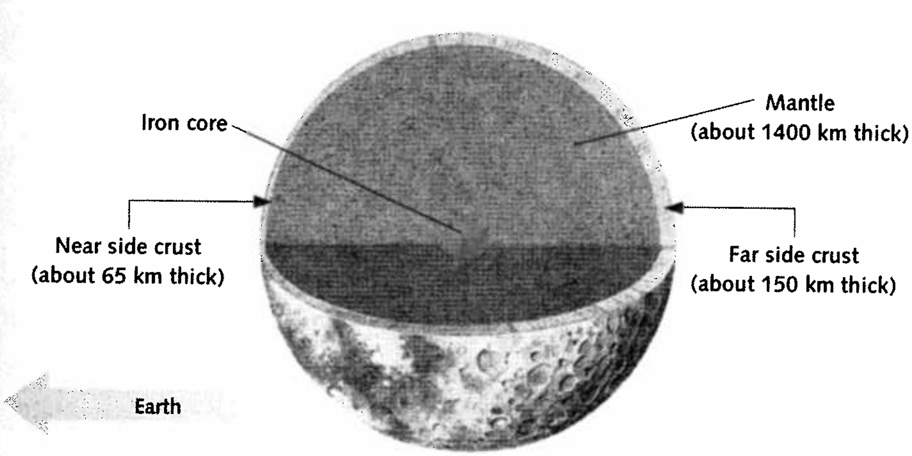
For approximately 3 billion years, the interior of the moon has been relatively quiet. However, impacts have continued to change the lunar surface. None of these impacts has been large enough to blow out new basins, but smaller ones have dug many new craters. The bombardment going on now is mainly by **micrometeoroids,** tiny objects no larger than sand grains. Micrometeoroids are the major cause of erosion on the moon today. The moon's lack of an atmosphere allows micrometeoroids, which would burn up in Earth's atmosphere, to reach the surface.

Properties and Features of the Moon

The moon turns once on its axis in the same time period in which it completes one orbit around Earth. Thus, the same side of the moon always faces Earth. We see only the "front side" of the moon.

The moon's diameter is 3476 kilometers, or more than one-fourth Earth's diameter. The moon's mass is only about one-eightieth Earth's mass, and the density of the moon, about 3.3 grams per cubic centimeter, is lower than Earth's (5.5 g/cm^3). The moon's lower density supports the impact theory whereby the moon would have formed from the less dense materials from the outer layers of early Earth and the object that had impacted it.

Layers of the Moon



25-Minute **Mini LAB**

Weights on the Moon and Earth

Materials

- calculator

Procedure

1. This table lists the approximate weight of objects on the moon.

Object	Weight (lb)
Blue whale	40,000
Mid-size car	500
Refrigerator	29
VCR	1.5
Loaf of bread	0.2

2. Estimate how much these objects weigh on Earth.
3. Using your estimates, determine the ratio between what objects weigh on Earth and what they weigh on the moon.

Analysis

Based on your calculated ratio, how much would you weigh on the moon? How can you check to see if your answer is correct?

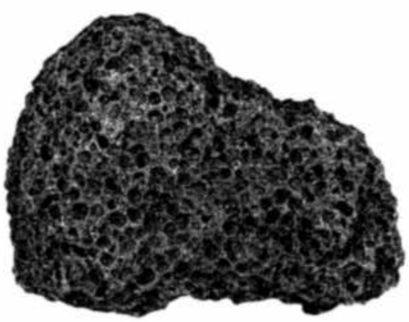
Lunar Maria

To the unaided eye, the moon appears as a pattern of light and dark areas. The light areas are lunar highlands, which are rugged mountains pockmarked with craters. The dark areas are great basins and level plains, formed when lava spewed up to the surface through the fractures made by earlier giant impacts. The first observers to look at the moon with telescopes thought the basins were filled with water and so named them **maria** (MAH-ree-uh), the Latin word for seas (singular *mare*, MAH-ray).

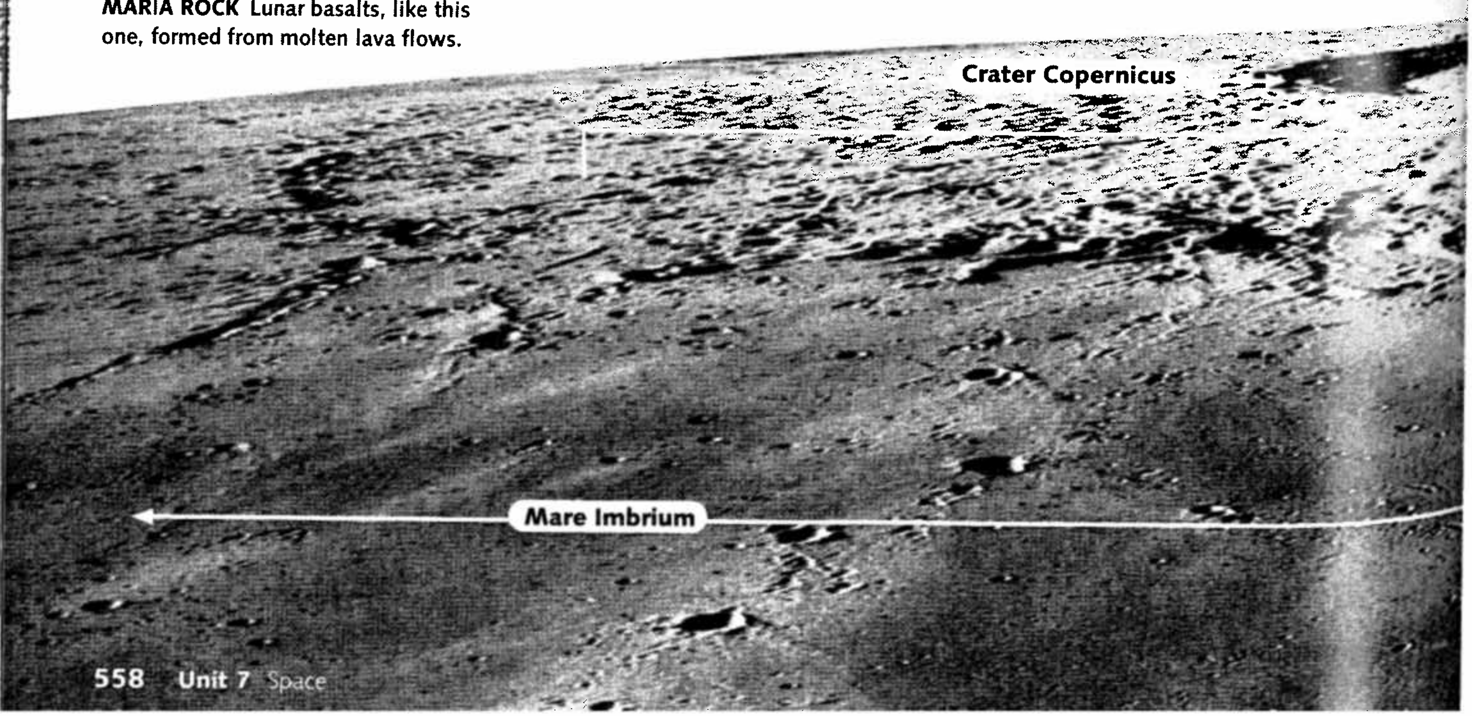
The first two *Apollo* missions to land on the moon explored the maria. Rock samples returned by these missions strongly resemble the basalts in lava flows from Hawaiian and Icelandic volcanoes. Like those basalts, the mare basalts are fine-grained crystalline rocks. They are dark gray or black and contain mostly plagioclase feldspar and pyroxene. Some mare basalts contain olivine and ilmenite (a mixture of oxygen, iron, and titanium). Scientists who have studied the moon's rock have determined that the mare basalts are the youngest lunar rocks. They range in age from 3.1 to 3.8 billion years.

In the 1960s, lunar orbiters found that the moon's gravity was greater over some of the more circular maria. Higher gravity readings indicate that the material beneath the surface has a different density from that of the surrounding rock. Some lunar geologists suspect that denser material from deep inside the moon—the same type of material that spewed up to create a mare basin—solidified within the fractures at a fairly shallow depth beneath the surface. These areas of higher gravity are called **mascons,** short for "mass concentrations."

A distinctive feature in maria bedrock is a **rille.** Rilles are trenchlike valleys running through maria bedrock. The best known is Hadley Rille on the floor of Mare Imbrium. This rille may have formed when a river of molten lava flowed along the surface. After a hard crust formed over the river, the molten lava drained away, leaving a hollow tunnel, the roof of which later caved in.



MARIA ROCK Lunar basalts, like this one, formed from molten lava flows.



Lunar Highlands

The lunar highlands appear brighter than the maria because their rocks are lighter in color and thus reflect more sunlight. Within the lunar highlands are a few mountain ranges and many craters.

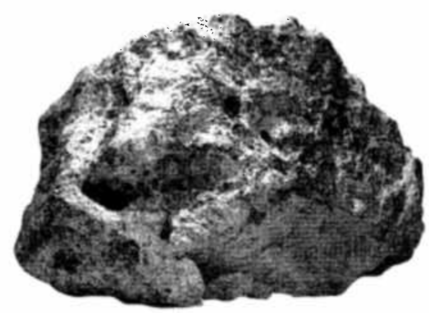
Most lunar mountain ranges lie at the edges of maria. One great range forms the western border of Mare Imbrium. This range includes the lunar Alps, Apennines, and Caucasus Mountains. These mountains tower as high as 5 kilometers—over 13 times the height of the Empire State Building—above the mare floor.

Lunar scientists think that the Apennines were thrust up by the impact that created Mare Imbrium. Perhaps all lunar mountains that border maria were formed in this way. There are two explanations for how such great masses of rock could be thrown so high. First, the moon has no atmosphere to slow down flying particles. Second, the moon's weak gravity does not exert the same downward force that Earth's gravity exerts.

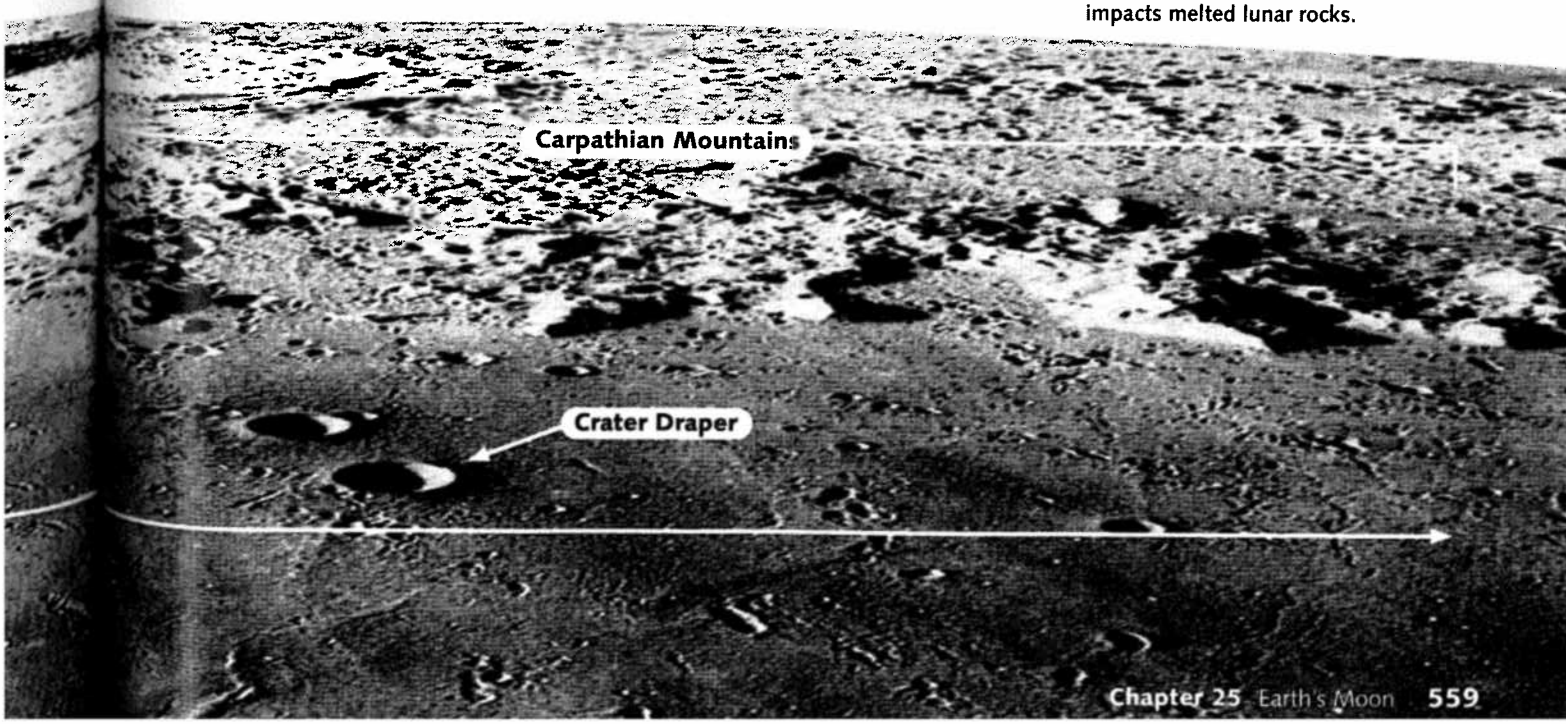
Two types of rock have been retrieved from the lunar highlands. One is a light-colored, coarsely crystalline igneous rock. The composition of this rock is similar to gabbro and anorthosite. Scientists think that this anorthositic gabbro makes up all the moon's solid crust except in areas where mare basalts cover it.

The other specimens brought back from the lunar highlands are lunar breccias. Breccias are rocks made of angular fragments cemented together with fine material. Breccias on Earth are often caused by volcanic eruptions. On the moon, breccias were formed by meteoroid impacts that melted the rocks together.

Most highland rock specimens are between 4.0 and 4.3 billion years old. A few specimens collected by the *Apollo 17* mission, however, have been dated at between 4.2 and 4.5 billion years, nearly the age the moon itself is thought to be. This correspondence in age supports the hypothesis that the lunar highlands are the original lunar crust.



HIGHLAND ROCK Lunar breccias, such as this one from the highlands, formed after meteoroid impacts melted lunar rocks.



RAYS extending out from the crater Copernicus

Lunar Craters and Rays

Lunar craters are circular hollows on the moon's surface. Craters are formed by the impact of meteoroid strikes. The smallest craters are microscopic pits, but the largest, the Aitken Basin, is nearly 2100 kilometers across. Scientists think the Aitken Basin formed when a large object, such as an asteroid or meteoroid, collided with the moon.

Crater rims are rugged cliffs. In large craters, the rims may tower thousands of meters above the surrounding plains, and their floors may lie a thousand meters below the plains. Most crater floors are dotted with many small craters and include peaks that reflect light just as the lunar highlands do. Many of the moon's craters are named after people from around the world, including scientists (Einstein), inventors (Edison), explorers (Shackleton), mathematicians (Fermat), and astronauts (Scobee).

The 93-kilometer-wide crater named Copernicus is fringed with bright streaks called rays. **Rays** radiate from a number of craters; some rays appear to be hundreds of kilometers long. For a long time, their origin was a mystery. Recent evidence suggests that rays consist of shattered rock and dust that were splashed out by the meteoroids that formed the craters.

Lunar Soil

Lunar soil is not really soil. Scientists prefer to call it **regolith,** which means loose rock materials. Regolith is a grayish brown mixture of small rock pieces and fine particles that range in size from sand grains to fine dust. Unlike Earth soil, regolith contains no water or organic material. Regolith is formed by the smashing impact of meteoroids of all sizes. When large meteoroids explode, they mix rock fragments over broad areas. This stirring of the regolith is called gardening.

The regolith ranges in depth from approximately 2 to 20 meters. It is likely to consist of chips from many different kinds of rocks and minerals. Regolith also contains tiny beads of glassy material which form from rock melted by high-speed meteoroid impacts. Droplets of the melted rock solidify to form glassy beads. Some of the melted rock forms a glaze on other rocks.

VOCABULARY STRATEGY

In the word *regolith*, *rego-* is from a Greek word for "blanket," and *-lith* is from a Greek word for "stone."

25.1 *Section Review*

1. According to the most widely accepted theory, what event led to the formation of the moon?
2. What factors might affect the length of the rays formed after an impact?
3. **CRITICAL THINKING** How does the size of the moon's core support the impact theory of the moon's formation?
4. **CHEMISTRY** Materials, such as water, that become gaseous easily at room temperature are called volatiles. How does the complete lack of volatiles in lunar rocks support the impact theory of the moon's formation?

SCIENCE & Technology

One Small Step into the Cosmos

The Apollo *missions not only led to important discoveries about the moon but also opened the way for further explorations, including those of the space shuttle and the International Space Station.*

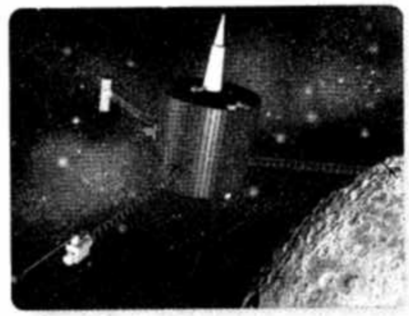
Where will *Apollo's* legacy lead us next?

Today, space missions take place so regularly that they may not attract much attention. But this wasn't always the case, especially in the late 1960s and early 1970s, when the name *Apollo* captured everyone's imagination.

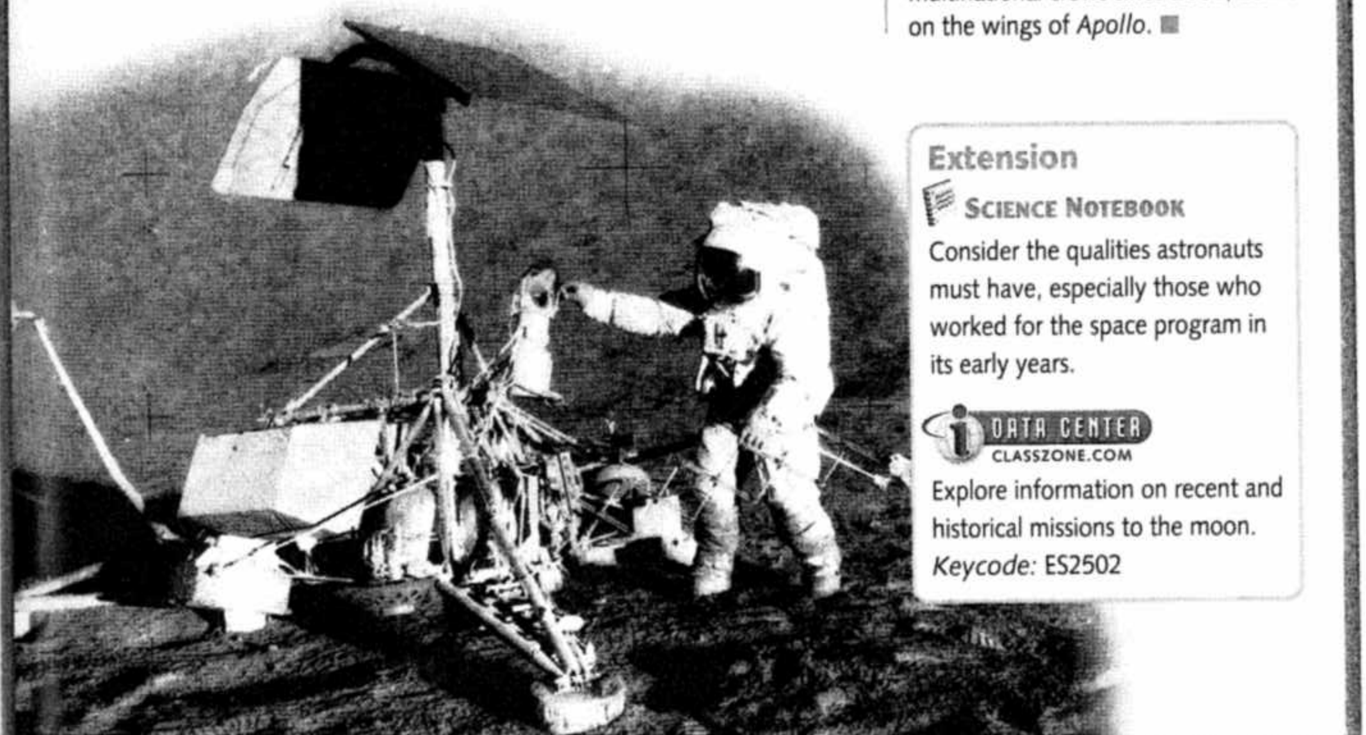
The *Apollo* missions followed years of intense effort to find out whether humans could survive in space and whether there was anywhere safe to land on the moon. The *Ranger* probes of the early 1960s sent back photographs of the moon's surface, and *Surveyor 3* landed softly on the moon in 1967 to study the crust. Manned missions *Mercury* and *Gemini* allowed scientists to determine that humans could indeed survive in outer space.

Using a multistage rocket, *Apollo* astronauts made several attempts to reach the moon. Tragedy struck the *Apollo* program when three astronauts died in a fire on the launch pad. But on July 20, 1969, Neil Armstrong broadcast to the world the immortal words "Houston, Tranquility Base here. The Eagle has landed." *Apollo 11* had reached the moon safely, and the course of human history had been changed forever.

Apollo's success made possible other space-exploration projects. The *Voyager* probes have given us an up-close look at parts of the solar system. *Mars Sojourner* and the twin rovers *Spirit* and *Opportunity* crawled about the surface of another planet. Probes, including *Lunar Prospector* and *Galileo*, have further expanded human understanding. The International Space Station has housed multinational crews since 2000, borne on the wings of *Apollo*. ■



***LUNAR PROSPECTOR*, launched in 1998 and shown here in an artist's rendering, was NASA's first lunar mission in 25 years.**



ON THE MOON *Apollo 12* commander Charles Conrad, Jr., examines *Surveyor 3*, an unmanned probe that paved the way for *Apollo* missions.

Extension

SCIENCE NOTEBOOK

Consider the qualities astronauts must have, especially those who worked for the space program in its early years.

DATA CENTER
CLASSZONE.COM

Explore information on recent and historical missions to the moon.
Keycode: ES2502

25.2

KEY IDEA

Moon phases, lunar eclipses, and solar eclipses are all caused by the moon's changing position relative to Earth.

KEY VOCABULARY

- phases
- waxing
- waning
- gibbous
- umbra
- penumbra
- lunar eclipse
- solar eclipse

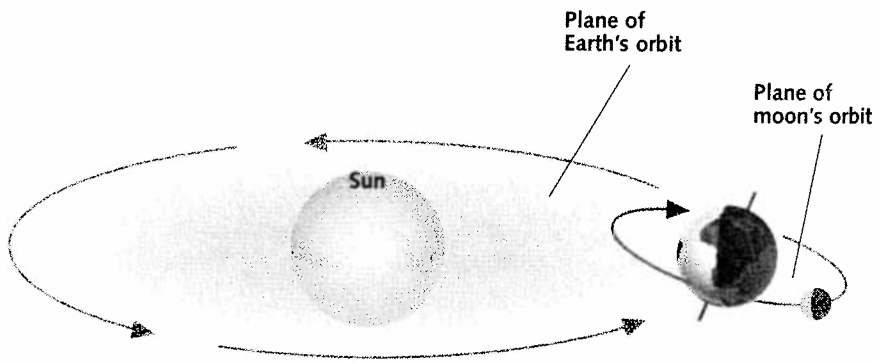
The Moon's Motions

The moon travels in a regular and predictable motion. This motion explains why the moon sometimes appears as a thin crescent in the sky, and sometimes appears as a fully illuminated disk. By keeping track of the moon's motion, astronomers can predict exactly when the moon will pass between Earth and the sun, and exactly where the shadow of the moon will fall upon Earth.

The Moon's Orbit

The moon rises in the east and sets in the west. Like the sun's rising and setting, this motion is apparent—it's really a result of Earth's turning on its axis. But unlike the sun, the moon is in orbit around Earth, taking about $27\frac{1}{3}$ days to complete each orbit. When the moon is on the side of Earth opposite the sun, it is seen mostly in the night sky. When it is between Earth and the sun, it is seen mostly in the daytime sky.

The moon orbits in a different plane than Earth does. This difference is important in determining how often eclipses occur; you will read more about eclipses later in this section.



THE MOON'S ORBIT is not in exactly the same plane as Earth's orbit. The angle between the two orbits is about 5 degrees (exaggerated in the illustration for clarity).

The moon rises above the horizon at a different time each day (or night). This happens because every time Earth spins around once, the moon moves about 13° eastward along its orbit. Thus, Earth must rotate an extra 13° more each day for a point on its surface to be roughly under the moon again. Since Earth takes about 50 minutes to spin 13°, the moon rises about 50 minutes later each day and sets about 50 minutes later as well. So if you were to see the moon rise above the horizon at 9:00 tonight, you could expect to see the moon rise at about 9:50 tomorrow night.

The moon's orbit around Earth is elliptical. The moon's average distance from Earth is about 384,000 kilometers, about a hundred times the distance between New York and Los Angeles. When the moon is nearest Earth, it is said to be at perigee. When farthest from Earth, it is at apogee.

The Moon's Phases

The **phases** of the moon are the daily changes in the moon's appearance as viewed from Earth. Moon phases occur for two reasons. One is that we see the moon only because it reflects sunlight. The other is that the moon is in orbit around Earth.

The sun lights the half of the moon that is facing it. However, we see changing amounts of the sunlit half. From Earth, the face of the moon changes from all dark to all light, or from new moon to full moon, in about two weeks. During this time, the moon is said to be **waxing.** During the next two weeks, the face of the moon gradually changes from all light back to all dark, or from full moon back to new moon. During this time, the moon is said to be **waning.**

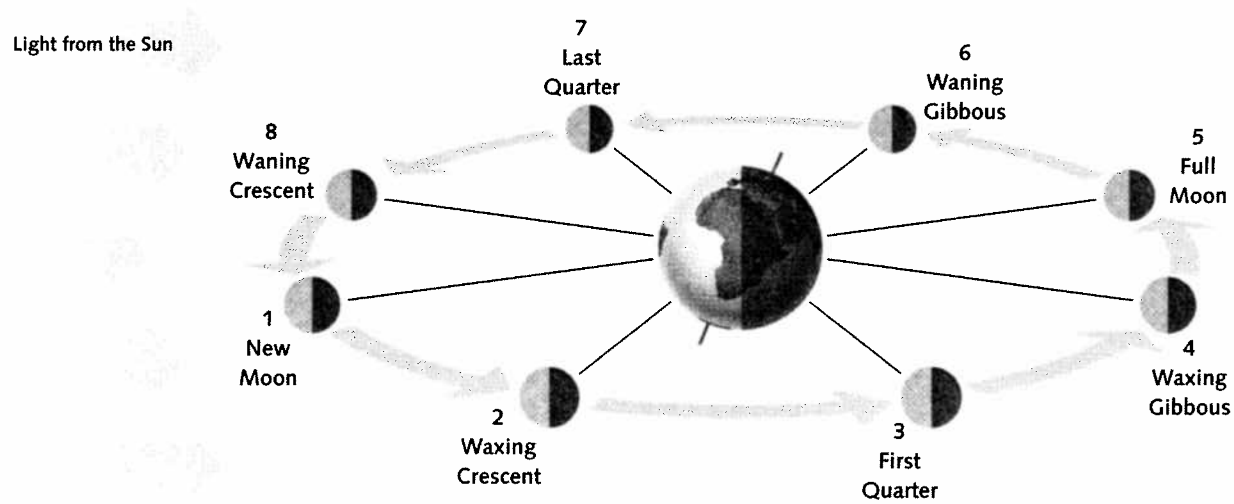
The diagram below shows the moon at eight points in its orbit. Although the half of the moon facing the sun is always fully lit, a different portion of the bright half is visible from Earth during each phase.

When the moon is new, the bright half faces away from Earth and the moon cannot be seen. At the two crescent phases, only one edge of the bright half faces Earth. At the two quarter phases, the half of the moon facing Earth is half bright and half dark. At the two **gibbous** phases, almost all of the bright half of the moon faces Earth. When the moon is full, the entire bright half faces Earth. Each of these phases occurs each month.

VISUALIZATIONS
CLASSZONE.COM
Examine the phases of the moon from Earth and space.
Keycode: ES2503

Phases of the Moon

Numbers by the photographs of the moon correspond to the eight phases shown on the diagram.



PHASES OF THE MOON AS SEEN FROM EARTH

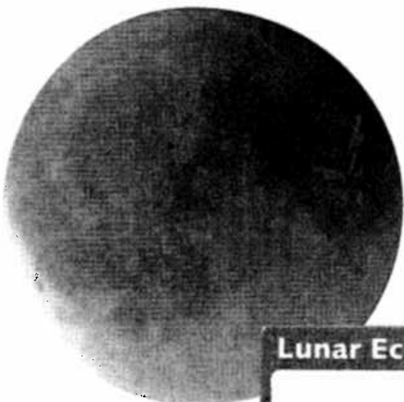
1 2 3 4 5 6 7 8

Lunar Eclipses

The shadow cast by any opaque object has two parts: the **umbra** is the area of total shadow, and the **penumbra** is the area of partial shadow surrounding the umbra. Both Earth and the moon cast shadows into space. Earth's umbra is shaped like a long, narrow cone, with its tip stretching nearly 1,400,000 kilometers beyond Earth, well past where the moon orbits. The penumbra is also cone-shaped, but as it stretches out into space, it becomes wider and more faint. Because the moon is smaller than Earth, the moon's shadows are smaller and shorter.

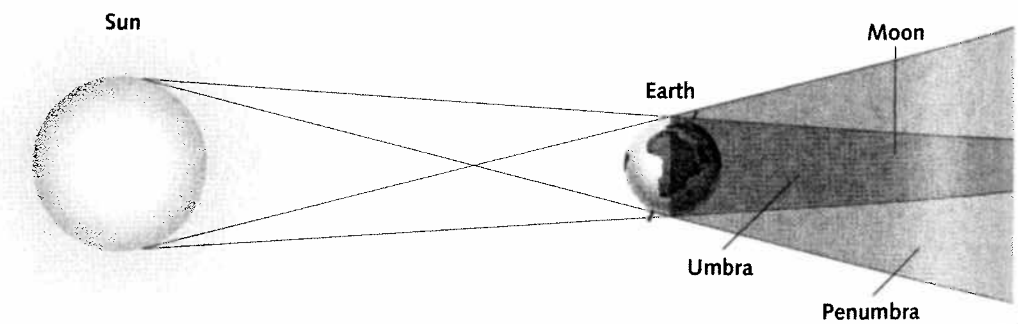
A **lunar eclipse** is an event during which Earth's shadow prevents the sunlight from reaching the moon. A lunar eclipse can occur only at the full moon phase. Even though a full moon occurs every month, a lunar eclipse occurs less often, because of the 5° angle between the plane of Earth's orbit and the plane of the moon's orbit. The full moon is usually above or below Earth's umbra, and no eclipse occurs. When an eclipse does occur, the moon usually remains visible, but has a dusky red or coppery color. This color results when Earth's atmosphere bends some sunlight—mostly longer red wavelengths—into the umbra.

LUNAR ECLIPSE Light from the sun can refract through Earth's atmosphere and onto the moon, giving the moon a coppery color.



Lunar Eclipse

A lunar eclipse occurs when the moon passes into Earth's umbra.



VISUALIZATIONS CLASSZONE.COM
Observe a lunar eclipse.
Keycode: ES2504

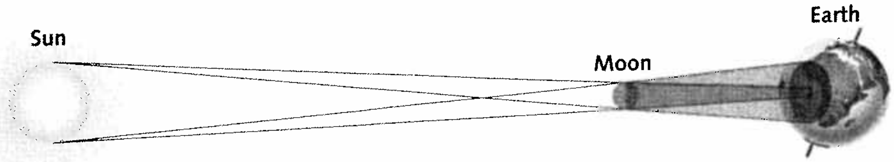
A total lunar eclipse occurs when the moon is fully within Earth's umbra. A partial lunar eclipse occurs when only a portion of the moon is in Earth's umbra. On average, at least one total lunar eclipse occurs every year. In good weather it is visible from the entire nighttime half of Earth. If the moon travels through the center of the umbra, a total lunar eclipse may last as long as two hours.

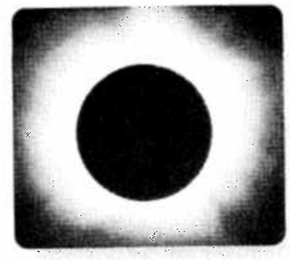
Solar Eclipses

A **solar eclipse** occurs when the moon comes between the sun and Earth, and the moon's shadow hits Earth's surface. The entire shadow—the umbra and the penumbra—is about 7000 kilometers wide, wider than the continental United States. However, the diameter of the umbra, where the effects of the eclipse are most dramatic, never exceeds 270 kilometers, which is only about as wide as Indiana.

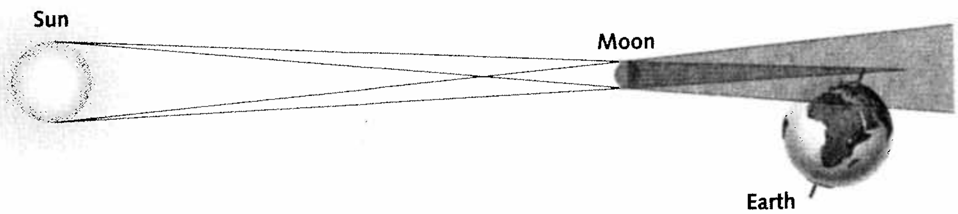
Solar Eclipse

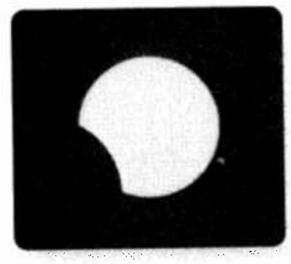
TOTAL SOLAR ECLIPSE At perigee, when the moon is closest in its orbit to Earth, areas of Earth within the moon's umbra experience a total solar eclipse.



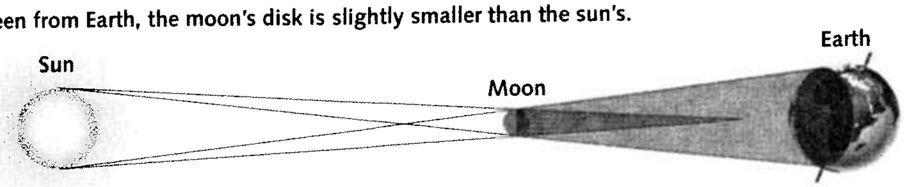


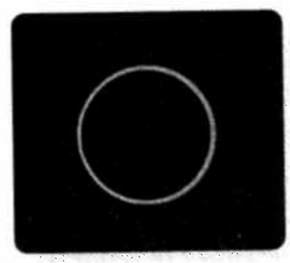
PARTIAL SOLAR ECLIPSE When the moon is at perigee, a partial solar eclipse is visible at areas of Earth within the moon's penumbra.





ANNULAR ECLIPSE When the moon is at apogee, its umbra fails to reach Earth. As seen from Earth, the moon's disk is slightly smaller than the sun's.





A solar eclipse occurs only at the new-moon phase. Because of the plane of moon's orbit, the moon's shadow usually falls above or below Earth. Therefore, like a lunar eclipse, a solar eclipse does not occur every month.

Although at least one solar eclipse occurs every year, a given area experiences a total solar eclipse only once every three or four centuries. This rarity is due to the small size of the moon's umbra. The moon's revolution makes the narrow shadow, called the eclipse path, race across Earth at over 1500 kilometers per hour. The eclipse path may be thousands of kilometers long, but at any one place a total solar eclipse can last at most only $7\frac{1}{2}$ minutes.

VISUALIZATIONS
CLASSZONE.COM
Observe solar eclipses.
Keycode: ES2505

25.2 *Section Review*

1. Why does the moon rise at a different time each day or night?
2. What is the difference between a partial and a total lunar eclipse?
3. What is the difference between an annular and a total solar eclipse?
4. **CRITICAL THINKING** How many days would you expect to fall between the new moon and the first quarter? The last quarter?
5. **PAIRED ACTIVITY** Use a light source to show how shadows from a small object and a large object change with distance.

CHAPTER 25 LAB Activity

Making Impact Craters

Skills and Objectives

- ***Model*** the creation of impact craters.
- ***Compare*** and ***evaluate*** factors involved in the making of impact craters.

Materials

- pan
- surface material
- sieve or sifter
- dry tempera paint
- balance
- safety goggles
- 3 spheres of varying size and weight (impactors)
- meter stick
- metric ruler
- graph paper
- colored pencils

The surface of the moon is covered with impact craters—circular features caused by projectiles striking the moon with enough force to mark the surface. When a projectile, or impactor, hits, material flies in all directions, causing a circular dent, or crater. The impact may leave streaks of material, called rays, running outwards from the circle. Impact craters vary greatly in size, and can be found on all the terrestrial planets and on many moons. In this experiment, you will model the formation of impact craters. By altering variables, you will better understand some of the factors that affect the size and shape of impact craters.

Procedure

1. Fill a pan with surface material to a depth of about 7.5 cm. Smooth the surface, then tap the pan to make the material settle evenly.
2. Sift a fine layer of dry tempera paint evenly over the entire surface.
3. Using the balance, measure the mass of the first impactor in grams. Copy the data table below and record the mass.
4. **CAUTION: Put on a pair of safety goggles.**
5. Drop the first impactor into the pan from a height of 30 cm, using the meter stick to determine height. Record the height on the data table.

Impactor Mass (g) ____	Drop Height (m)____			
	Trial 1	Trial 2	Trial 3	Average
Crater diameter (cm)				
Crater depth (cm)				
Average ray length (cm)				

6. Using the metric ruler, measure and record the diameter and depth of the resulting crater. Count and measure the length of any rays. Determine the average ray length and record it on the data table for that impactor. Smooth the surface of the material in the pan, and evenly sift a new layer of dry tempera paint over it.
7. Repeat Steps 5 and 6 twice more for a total of three trials. Compute the average value for each measurement taken during the trials.
8. Complete more trial drops for the first impactor, increasing the drop heights to 60 cm, 90 cm, and 2 meters. Use a separate copy of the data table for each height.
9. Repeat Steps 3 through 7 for the other two impactors.

10. Draw a graph with "Impactor Velocity (cm/s)" on the x-axis and "Average Crater Diameter (cm)" on the y-axis. Use the chart on the right to determine the velocity based on height. Use different colors for each impactor. Connect each impactor's data points with a smooth curve.

11. Draw a second graph, this time with "Average ray length (cm)" on the y-axis. Again place "Impactor Velocity (cm/s)" on the x-axis, use different colors for each impactor, and connect with a smooth curve.

Drop height	Velocity
30 cm	242 cm/s
60 cm	343 cm/s
90 cm	420 cm/s
2 meters	626 cm/s

Analysis and Conclusions

1. Based on your observations, describe the appearance of an impact crater. Draw a picture of an impact crater. Label the rays and include an arrow to represent the path of the impactor.

2. According to your observations, what is the relationship between the velocity of the impactor and crater size? What about the relationship between the velocity of the impactor and ray length? Why is this?

3. If an impactor were dropped from 6 meters, would the crater be larger or smaller than the crater made by the same impactor dropped from 2 meters? How much larger or smaller? Note that the velocity of the impactor would be 1,084 cm/s. Explain your reasoning.

4. The size of a crater made during an impact depends on the amount of kinetic energy possessed by the impacting object. Kinetic energy, the energy of motion, is described using the equation $KE = 0.5\ mv^2$, in which KE stands for kinetic energy, m stands for mass, and v stands for velocity. During impact, the kinetic energy of the projectile is transferred to the target surface, breaking up material and moving rock particles. How would you expect kinetic energy to relate to crater diameter?

5. Use the equation in Question 4 to compute the kinetic energy for each object at each height. Write your answer underneath the table and record as "Kinetic Energy of Impactor (g-cm^2/s^2)".

6. Draw another graph, this time with "Average Crater Diameter (cm)" on the x-axis and "Kinetic Energy of Impactor (g-cm^2/s^2)" on the y-axis.

7. Which of the following was the most important factor controlling the kinetic energy of your impactors: the object's diameter, mass, or velocity? Explain. Compare your results to the kinetic energy equation.

DATA CENTER
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Learn more about impact craters on planets and moons.
Keycode: ES2507

CHAPTER 25
REVIEW

Summary of Key Ideas

25.1 Scientists think the moon formed after a large object, about the size of a planet, hit Earth. The same side of the moon always faces Earth. Dark areas called maria are great basins and level plains on the moon. They are younger than the lunar highlands. Lunar rocks have textures similar to Earth rocks but differ in composition. Lunar highland rocks are older than mare rocks. Most lunar craters were caused by the impact of meteoroids; rays were splashed out by the impacts. Regolith is the loose rock material covering the moon's surface.

25.2 The moon's orbit is tilted 5 degrees relative to the plane of Earth's orbit. The moon's movement around Earth causes it to rise later each day and to go through phases. A lunar eclipse occurs when Earth passes between the sun and the moon, and the moon is within Earth's shadow. A solar eclipse occurs when the moon passes between the sun and Earth, and the moon's shadow falls on Earth.

KEY VOCABULARY

astronomy (p. 556)
crater (p. 556)
gibbous (p. 563)
lunar eclipse (p. 564)
maria (p. 558)
mascon (p. 558)
meteoroids (p. 556)
micrometeoroids (p. 557)
penumbra (p. 564)
phases (p. 563)
ray (p. 560)
regolith (p. 560)
rilles (p. 558)
solar eclipse (p. 564)
umbra (p. 564)
waning (p. 563)
waxing (p. 563)

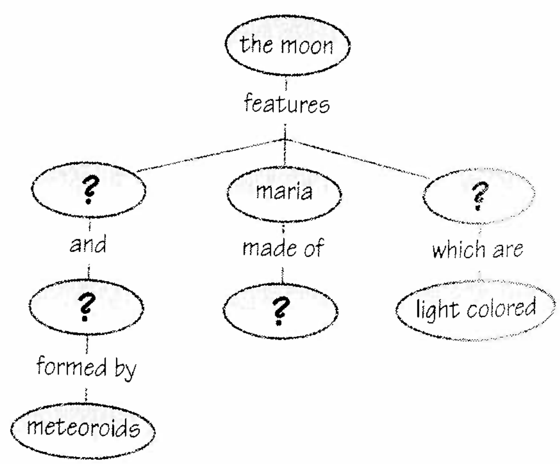
Vocabulary Review

Write the term from the key vocabulary list that best completes the sentence.

1. The daily changes in the moon's appearance are called the __?__ of the moon.
2. Long trenchlike valleys running through the bedrock of lunar maria are called __?__ .
3. The Aitken Basin on the moon is the largest known __?__ in the solar system.
4. Craters form after __?__ strike the surface of the moon.
5. A total solar eclipse occurs when the tip of the moon's __?__ reaches Earth at perigee.

Concept Review

6. What theory do most scientists think best explains the formation of the moon?
7. How do lunar maria differ from lunar highlands?
8. What evidence do scientists have of past volcanic activity on the moon?
9. How does lunar soil, or regolith, differ from the soil found on Earth?
10. Describe how the moon's appearance to an observer on Earth changes during the course of a month.
11. Explain how a lunar eclipse differs from a solar eclipse.
12. **Graphic Organizer** Copy and complete the concept map below.



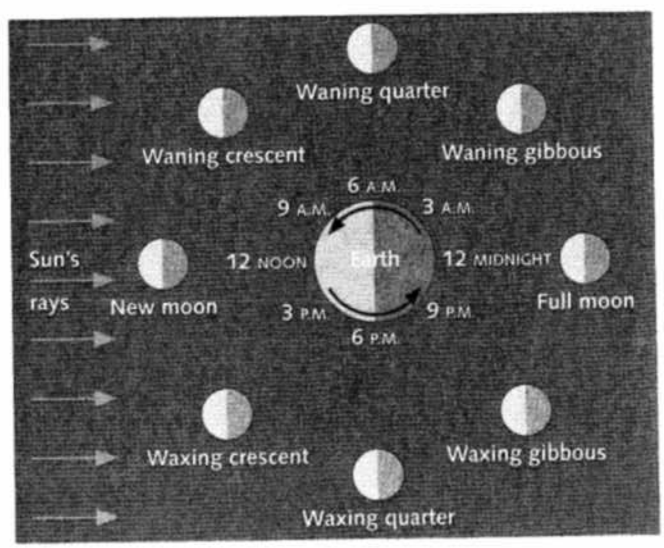
Critical Thinking

13. **Hypothesize** Write a statement suggesting how solar and lunar eclipses would be affected if the moon and Earth kept their present sizes and separation, but were five times farther from the sun (at about the orbit of Jupiter).
14. **Communicate** Write an explanation of the importance of the five-degree difference in the orbital planes of the moon and Earth.
15. **Infer** Could an astronomer stationed in a moon base observe a meteor shower? Explain your reasoning.
16. **Analyze** Evidence indicates that the moon and Earth formed at about the same time; however, rocks found on the moon are older than rocks found on Earth. How could you account for this apparently conflicting evidence?

Interpreting Diagrams

Each phase of the moon is visible only at a particular time of day or night. For example, a full moon cannot be seen at 12 noon because it is on the side of Earth opposite the sun. The approximate times that each phase is visible can be determined. The figure at right is similar to the one on page 563 except that times are shown—12 noon toward the sun, 12 midnight away from the sun, 6 A.M. at sunrise, and so on. Use a piece of paper to cover the daytime side of Earth and the moon phases on that side. The full moon is at its highest point in the sky at about midnight. It rises 6 hours earlier, at 6 P.M., and sets 6 hours later, at 6 A.M.

17. Cover the times when the waxing quarter phase CANNOT be seen. At what time is the waxing quarter at its highest point? What time does it rise? What time does it set?
18. Determine the time of moonrise and moonset for the waning gibbous phase.
19. When the waning crescent phase is at its highest point, what time is it?
20. Which phases could never be seen at 3 P.M.?
21. When the waning quarter phase is midway between moonrise and its highest point, what time is it?



Internet Extension

INVESTIGATIONS CLASSZONE.COM

What If Earth and the Moon Were Hit by Twin Asteroids? Examine images of impact craters to predict the results of each impact.

Keycode: ES2506

Writing About the Earth System

SCIENCE NOTEBOOK The moon is distant from Earth's atmosphere, hydrosphere, geosphere, and biosphere. However, the moon impacts the Earth system. Choose one way in which the moon affects Earth, such as its impact on tides. Write a description on how changing tides affect the life and the geology of an area.