Inquiry Launch Lab

20 minutes

How does rotation affect shape?

When the solar system formed, it was an enormous ball of gas and dust spinning slowly in space. As gravity pulled it closer together, the solar system spun faster. What happened to the shape of the solar system as it spun faster?

1. Read and complete a lab safety form.
2. Make a round ball about the size of your fist from a piece of **salt dough.**
3. Place the dough in a **small bucket.** Attach 1 m of sturdy **string** to the bucket's handle.
   ⚠ Be sure the string is securely attached.
4. ⚠ Stand away from all furniture and people. Whirl the bucket around your head for 1 min.
5. Lower the bucket. Observe the salt dough and record your observations in your Science Journal.

Think About This

1. What happened to the salt dough? What other objects change shape as they spin?
2. **Key Concept** How do you think gravity influenced the shape of the early solar system?

The Solar System

The Sun and everything that orbits it make up the solar system. The solar system formed 4.6 billion years ago from a cloud of gas and dust. As gravity pulled the cloud together, it became smaller and hotter and began to spin. In the center of the cloud, where the gas was hottest and densest, a star formed—the Sun.

At first, the solar system was shaped like a ball. As it rotated, gravity caused it to flatten, and it became a disk. Gravity also caused leftover gas and dust from the solar system's formation to clump together and form small, rocky or icy bodies. These bodies merged and formed planets and other objects.

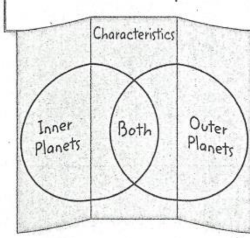
Key Concept Check What role did gravity play in the formation of the solar system?

Other than the Sun, planets are the largest objects in the solar system. *A* **planet** *orbits the Sun, is massive enough to be nearly spherical in shape, and has no other large object in its orbital path.* All eight planets revolve in the same direction. The closer a planet is to the Sun, the faster it revolves. Mercury orbits the Sun once every 88 Earth days. The planet farthest from the Sun, Neptune, orbits once every 165 Earth years.

Recall that Earth orbits the Sun at a distance of 1 AU. Neptune is 30 times farther from the Sun. But the Sun's gravitational pull extends far beyond Neptune. Billions of small, icy objects orbit the Sun at a distance of 50,000 AU.

FOLDABLES®

Make a horizontal trifold Venn book. Label it as shown. Use it to compare and contrast characteristics of the inner and outer planets.



Objects in the Solar System

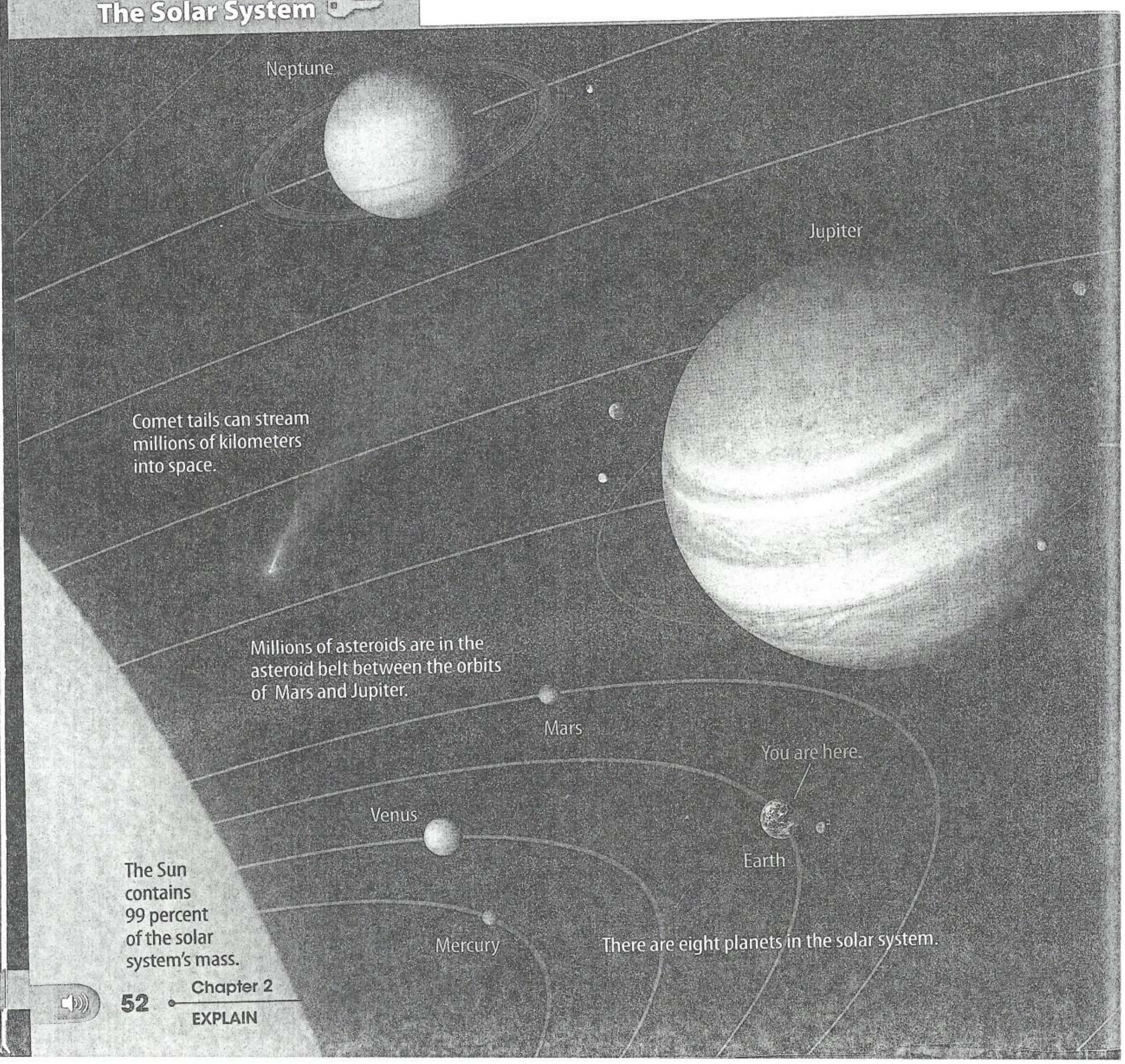
As shown in **Figure 11**, the solar system contains many different objects. These objects include planets as well as objects too small to be classified as planets.

Planets and Dwarf Planets Recall that planets are massive objects that do not have other objects of similar size in their orbital paths around the Sun. Some spherical objects that orbit the Sun are similar to planets but are not massive enough to be planets. Some of these are dwarf planets. **Dwarf planets** *orbit the Sun and are nearly spherical in shape, but they share their orbital paths with other objects of similar size.* Pluto was once considered a planet but is now classified as a dwarf planet.

Figure 11 The solar system includes the Sun, planets, and many other objects.

Visual Check What percentage of the mass in the solar system exists outside the Sun?

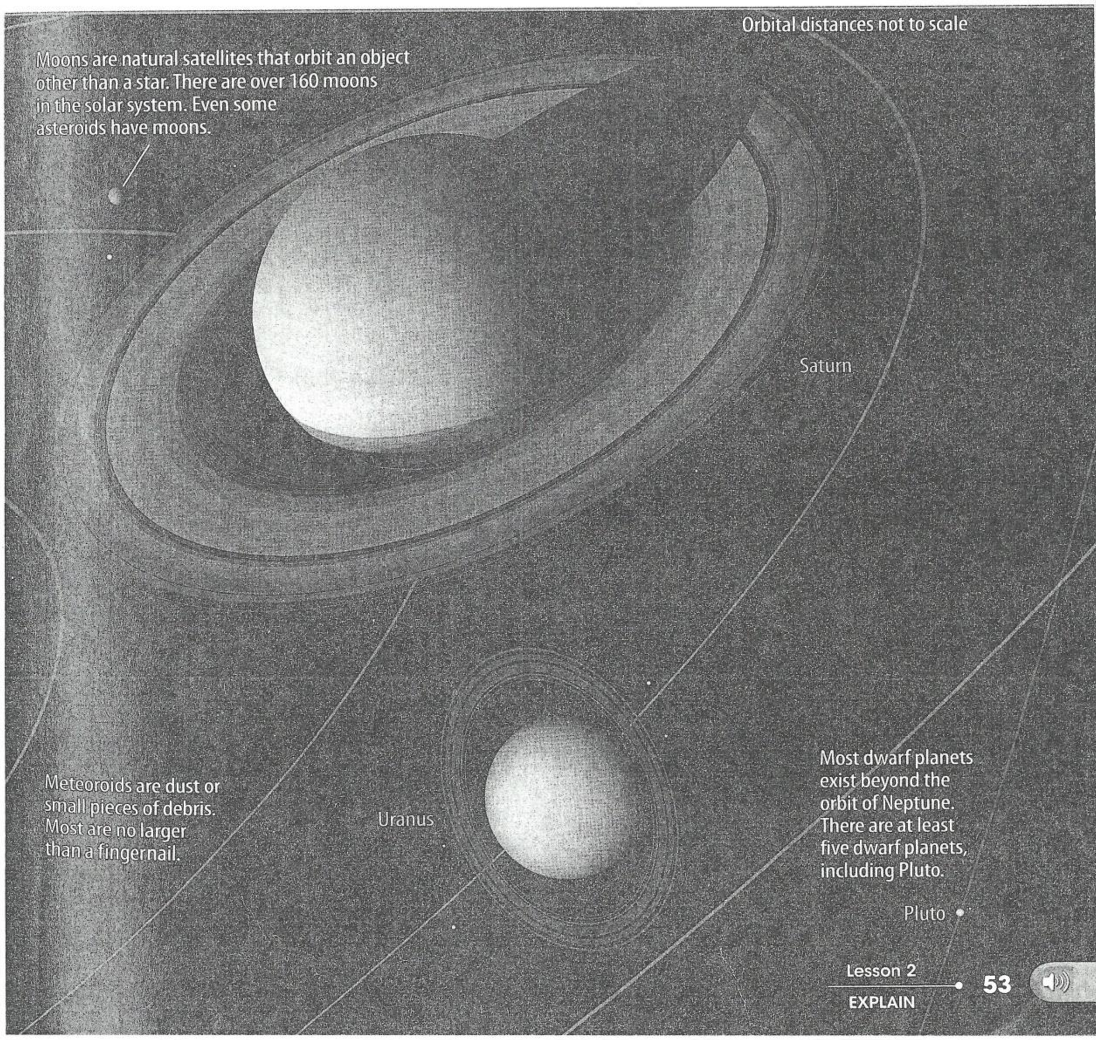
The Solar System



Other Solar System Bodies Not all spherical bodies in the solar system are planets. Many moons are massive enough to be spherical. *A* **moon** *is a natural satellite that orbits an object other than a star.* Some asteroids also are spherical. **Asteroids** *are small, rocky objects that orbit the Sun.* Most known asteroids are in the asteroid belt located between the orbits of Mars and Jupiter. **Comets** *are small, rocky, icy objects that orbit the Sun.* As comets near the Sun, the ice melts and the water forms a "tail" behind the comet. The orbital paths of comets extend to the outer solar system, beyond Neptune. **Meteoroids** *are small, rocky particles that move through space. When a meteoroid enters Earth's atmosphere, it produces a streak of light called a* **meteor.** A meteoroid becomes a meteorite only if it impacts Earth.

Key Concept Check What objects are in the solar system?

WORD ORIGIN
comet
from Greek *komētēs*, means "long-haired"

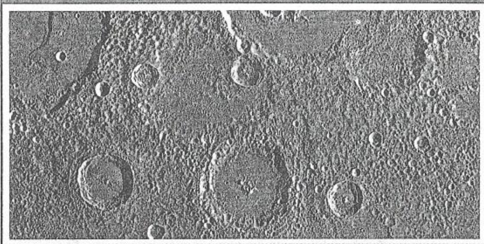
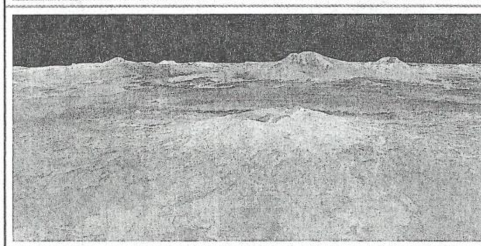
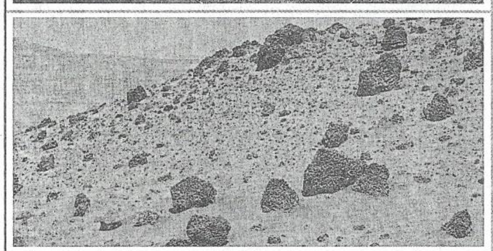


Inner Planets

The center of the solar system was extremely hot when it formed. Gases and materials with low boiling points escaped from the region closest to the Sun. The four inner planets, also called the rocky planets, formed from the rocks and the heavy elements, including metals, left behind. The cores of the inner planets are mostly iron. The inner planets are the smallest planets. They have few or no moons, no rings, and they rotate more slowly than the outer planets. The inner planets are shown and described in **Table 1**.

Table 1 The inner planets are mostly rock and metal.

Table 1 The Inner Planets

	**Mercury** At 0.39 AU from the Sun, Mercury is the planet closest to the Sun. It is also the smallest planet, only about one-third the diameter of Earth. Mercury rotates slowly. As its surface heats and cools during its long day, temperatures can vary by as much as 500°C. Mercury has almost no atmosphere. Its gray surface has many impact craters and resembles the Moon.
	**Venus** Venus is 0.72 AU from the Sun. It is almost the same size and has nearly the same makeup as Earth. It has the slowest rotation of any planet. One day on Venus is equal to 244 Earth days. Its heavy layer of clouds and thick carbon-dioxide atmosphere traps energy from the Sun. This makes Venus the hottest planet. Scientists think some volcanoes on its surface might be active.
	**Earth** Earth is 1 AU from the Sun. The largest and densest of the inner planets, Earth is the only planet where life is known to exist. It is also the only planet with large amounts of liquid water on its surface. Earth's water and water vapor appear blue and white when viewed from space. Earth's atmosphere is 78 percent nitrogen and 21 percent oxygen.
	**Mars** Mars is half the size of Earth and orbits at 1.5 AU from the Sun. Mars is too cold for liquid water to exist on the surface, although ice has been detected at the poles and might exist below its surface. Liquid water likely flowed on the planet in the past. Rocks on Mars's surface contain iron oxides, which give Mars a reddish color. Mars has some of the largest volcanoes in the solar system, including Olympus Mons.

Key Concept Check How does Earth differ from other inner planets?

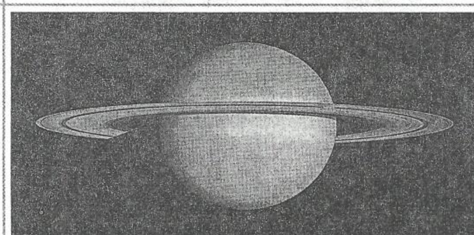
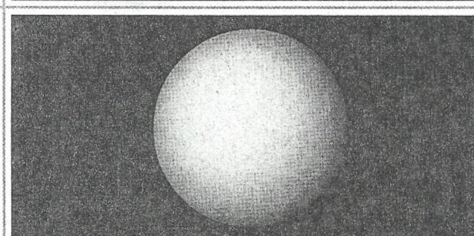
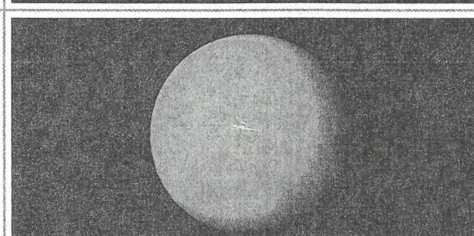
Outer Planets

The four outermost planets, shown in **Table 2**, formed from gases and other materials that escaped from the region closest to the Sun. They are often called the gas giants. They are larger than the inner planets, they rotate more quickly, and they each have rings. Except for Saturn's rings, the rings are barely visible. Each outer planet also has many moons. Scientists suspect each has a small, rocky core. These planets do not have solid surfaces. They have thick atmospheres of hydrogen and helium.

Table 2 The outer planets are made almost entirely of gas and ice.

Visual Check What makes Uranus and Neptune appear blue?

Table 2 The Outer Planets

Jupiter Though it is made mostly of hydrogen and helium, Jupiter contains more mass than the rest of the planets combined. Jupiter revolves around the Sun at a distance of 5 AU. It has the fastest rotation of any planet—a day lasts just 10 Earth hours. Jupiter's clouds swirl with various colors because they contain small amounts of sulfur and phosphorus. Jupiter has strong weather systems.	
Saturn Saturn is the second-largest planet. At 9.5 AU from the Sun, it is nearly twice as far from the Sun as Jupiter, but its makeup is similar. Saturn has thousands of thin rings made of billions of pieces of ice ranging in size from pebbles to boulders. Saturn's clouds form bands and spots, but it is hard to see them. Saturn's hazy upper atmosphere hides its colorful lower layers.	
Uranus Uranus orbits the Sun at a distance of nearly 20 AU. Uranus is tilted so much that its axis sometimes points directly toward the Sun. The planet is a bluish-green color because of a small amount of methane in its atmosphere. Scientists suspect that a layer of icy liquid water, ammonia, and other compounds lies deep below Uranus's thick atmosphere.	
Neptune At 30 AU, Neptune is so far away that it cannot be seen from Earth without a telescope. Neptune's makeup is similar to that of Uranus, although it has more methane in its atmosphere and is deeper blue in color. Neptune has the fastest winds of any planet, recorded at over 1,100 km/h. The spots on its surface are hurricane-like storms, which do not last long.	

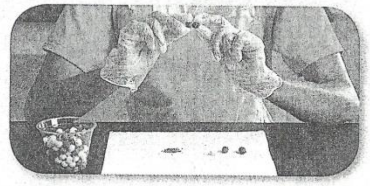
Key Concept Check How do the inner and outer planets differ?

Launch Lab

20 minutes

Where does a star's energy come from?

The inside of a star is so hot that light elements combine, or fuse, and make heavier elements. This reaction is called nuclear fusion. It occurs in a sequence of steps.



1. Read and complete a lab safety form.
2. Obtain a **cup of chocolate puffs and corn puffs.** A chocolate puff represents the one proton of hydrogen. A corn puff represents a neutron.
3. Bring two protons together. One proton decays into a neutron and gives off energy. This forms deuterium. To model this reaction, crush one proton—to represent the release of energy—and replace it with a neutron.
4. Combine the deuterium (the proton and neutron) with a proton to make helium-3.
5. Repeat steps 3 and 4 to make two helium-3s.
6. Combine two helium-3s and make beryllium-6.
7. Beryllium-6 becomes one helium-4 (two protons and two neutrons) and two protons. The helium-4 is stable. The two protons start the process over again.

Think About This

1. Draw a picture showing how nuclear fusion in the cores of stars makes energy.
2. When hydrogen is gone, what will be left?
3. **Key Concept** How do you think stars shine?

Stars

Do you know the song "Twinkle, twinkle, little star"? Have you ever wondered what stars really are or why they twinkle? *A* **star** *is a large sphere of hydrogen gas hot enough for nuclear reactions to occur in its core.* A star's core heats as gravity pulls gas inward. Once the gas becomes hot enough, nuclear reactions begin and energy begins to travel outward. When the energy reaches the star's surface, the star shines. A star appears to twinkle because its light passes through Earth's atmosphere before reaching your eyes. As particles in the atmosphere move, the star's light slightly changes directions.

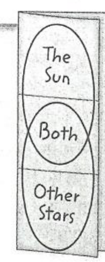
Key Concept Check What is a star?

Light from Stars

When measuring distances to stars, astronomers often use a unit based on the speed of light rather than astronomical units. A **light-year** *is the distance light travels in one year.* Light travels 300,000 km/s. One light-year equals 9.46 trillion km. Because it takes time for light to travel, stars are not seen as they are now, but as they were in the past. Proxima Centauri, the star nearest the Sun, is 4.2 light-years away. The light from Proxima Centauri we see today left the star 4.2 years ago.

FOLDABLES®

Make a vertical three-tab Venn book. Label it as shown. Use it to compare the Sun to other stars.



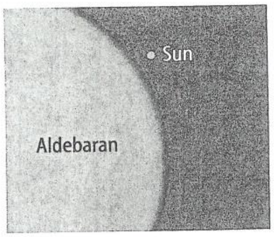


Figure 12 The star Aldebaran is 44 times wider than the Sun. The largest known star is 1,000 times wider than the Sun.

Types of Stars

At first glance, all stars appear white. But if you look closely at the brightest stars in the night sky, you will see that some stars are red, some are orange, and some even appear blue. The color of a star indicates its temperature. Blue stars are the hottest stars, followed by blue-white, white, yellow, and orange stars. Red stars are the coolest stars. The Sun is a yellow star.

When you look at stars, they appear to be the same size. But stars vary in size. The Sun is larger and more massive than 90 percent of other stars. But the Sun is tiny compared to the giant star shown in **Figure 12.**

Key Concept Check How does the Sun compare in size to other stars?

The Sun is a solitary star. Many other stars are members of binary star systems or multiple-star systems. In a binary star system, two stars orbit each other's center of mass. In a multiple-star system, two or more stars orbit the entire system's center of mass. Stars differ in other ways, too. For example, stars called variable stars change in brightness over time.

Earth's Star—the Sun

The Sun is the closest star to Earth. It has been shining for nearly 5 billion years. Scientists **estimate** that it has a lifetime of approximately 10 billion years, so it will continue to shine for 5 billion more years. When it stops shining, it will become a small, dense star that emits little light called a white dwarf star.

ACADEMIC VOCABULARY
estimate
(verb) to determine roughly the value, size, or extent of something

Inquiry MiniLab — 20 minutes

How does mass affect a star?

Stars vary in size and mass. Mass affects many properties of most stars, including their temperatures and their expected life spans.

1. The Sun is one solar mass. Find the Sun on the table. How does the Sun compare to other stars in the table? Record your observations in your Science Journal.
2. Use the data to make a graph plotting mass v. temperature and another graph plotting mass v. expected life span.

Mass (in solar masses)	Temperature (K)	Expected life span (millions of years)
40	38,000	1
18	30,000	7
6.5	16,400	93
3.2	10,800	550
2.1	8,620	1,560
1.7	7,240	2,650
1.3	6,540	5,190
1	5,920	10,000
0.78	5,150	18,600
0.47	3,920	66,000

Analyze and Conclude

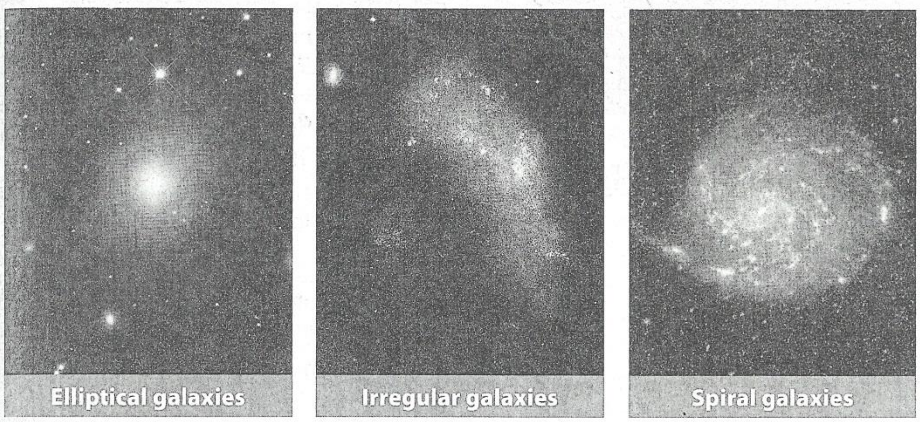
Key Concept How is the mass of a star related to the star's temperature and expected life span?

Figure 13 There are three main types of galaxies in the universe.

Visual Check Which galaxy type has a well-defined center?

Types of Galaxies

Concepts in Motion **Animation**



Elliptical galaxies: Shaped like basketballs or footballs, elliptical galaxies contain older, redder stars and have little gas or dust. Because stars form from gas and dust, elliptical galaxies contain few young stars.

Irregular galaxies: These oddly shaped galaxies contain large amounts of gas and dust. They exhibit the highest rate of star formation of any galaxy type. Irregular galaxies have many young stars. These galaxies do not have bright centers.

Spiral galaxies: These galaxies are shaped like disks. They contain dust, gas, and young stars in their bluish arms. Older, redder stars are in their central bulges. Spiral galaxies are surrounded by spherical halos containing older stars.

Galaxies

Stars are not randomly scattered throughout the universe. Most stars are bound by gravity into galaxies. A **galaxy** *is a huge collection of stars, gas, and dust.* Astronomers classify galaxies by their shapes. Examples of the three main types of galaxies—elliptical, irregular, and spiral—are shown in **Figure 13.**

The universe contains hundreds of billions of galaxies. Each galaxy can contain hundreds of billions of stars. The solar system where you live is part of the Milky Way, a spiral galaxy. The Milky Way is larger than most galaxies in the universe. It contains over 100 billion stars.

Because Earth is inside the Milky Way, scientists cannot see the Milky Way from the outside as they can see other galaxies. Even though they cannot see all of the Milky Way, scientists have determined that the Milky Way has at least two major spiral arms. The Sun is near one of the arms a little more than halfway from the Milky Way's center.

Key Concept Check In which galaxy is Earth located?

WORD ORIGIN

galaxy
from Latin *galactos,* means "milk"

Figure 14 Gravity causes galaxies to gather in clusters, where they interact and sometimes merge with one another.

Concepts in Motion Animation

Math Skills

Use Dimensional Analysis

Light-years (ly) describe distances to nearby stars. Astronomers often use parsecs (pc) to describe greater distances in space.

1 pc = 3.26 ly
1 ly = 9.46 trillion km

The star Proxima Centauri is 4.2 ly from Earth. What is that distance in parsecs?

1. Select a conversion factor with the unit you want in the numerator and the given unit in the denominator.

$$\frac{1 \text{ pc}}{3.26 \text{ ly}}$$

2. Multiply the starting quantity and units by the conversion factor.

$$\frac{4.2 \text{ ly} \times 1 \text{ pc}}{3.26 \text{ ly}}$$

3. Complete the calculation.

$$\frac{4.2 \text{ pc}}{3.26} = 1.3 \text{ pc}$$

Practice

The nearest galaxy to the Milky Way is the Andromeda galaxy. It is approximately 2.5 million ly from Earth. What is that distance in parsecs?

Review

- Math Practice
- Personal Tutor

The Universe

Most galaxies, such as those shown in Figure 14, are pulled by gravity into clusters of galaxies. The Milky Way is part of a cluster called the Local Group, which contains about 30 galaxies. The Local Group, in turn, is part of a supercluster of galaxies called the Local Supercluster. Superclusters are some of the largest structures in the universe. Some superclusters contain thousands of galaxies. But even superclusters are parts of larger structures. Superclusters form enormous sheetlike walls in space.

Key Concept Check How is the universe structured?

By studying the rotations and the interactions of galaxies in clusters, astronomers can determine how much mass the galaxies contain. Astronomers have discovered that only 5–10 percent of the mass in galaxies emits light. They hypothesize that the rest of the mass in galaxies—and in the universe—is invisible dark matter or dark energy.

Recycled Matter

Most of the elements in your body were originally made in stars. Hydrogen is combined into more-complex elements during nuclear reactions in stars. When a massive star explodes, such as the star in the photo at the beginning of this lesson, it releases those elements into space. This material can then form new stars and planets. In this way, matter in the universe is recycled.

Big Bang Theory

Most scientists agree that the universe formed 13–14 billion years ago and that it had a hot and dense beginning. The **Big Bang theory** *states that the universe began from one point and has been expanding and cooling ever since.* Will the universe expand forever, or will gravity cause it eventually to contract? These questions remain unanswered. Scientists have not yet been able to determine the fate of the universe.