Section 26.3

1 FOCUS

Objectives

26.3.1 **Describe** how stars form.

26.3.2 **Estimate** how long a star remains on the main sequence.

26.3.3 **Predict** what happens to a star when it runs out of fuel.

Reading Focus

Build Vocabulary L2

Latin Plural Forms Have students use dictionaries to look up the plural forms of the vocabulary words *nebula (nebulae* or *nebulas)* and *nova (novae* or *novas)*. This will give students an opportunity to study the Latin meaning of the words. *(*Nebula *means "cloud" and* nova *means "new star.")* It will also minimize any confusion they might have when they conduct research about the words and see variations of the plural forms used.

Reading Strategy L2

a. Red giant **b.** Planetary nebula, white dwarf, black dwarf

2 INSTRUCT

How Stars Form

Build Reading Literacy L1

KWL Refer to page **826D** in this chapter, which provides the guidelines for KWL.

Have students make a chart with three columns titled What I Know, What I Want to Know, and What I Learned. Under the first column, they should recall anything they've learned previously about types of stars. The second column should be filled out before students read the text. The third column should be completed after reading the text.
Verbal

26.3 Life Cycles of Stars

Reading Focus

Key Concepts

- How do stars form?
- What determines how long a star remains on the main sequence?
- What happens to a star when it runs out of fuel?

Vocabulary

- nebula
- protostar
- planetary nebula
- supernova
- neutron star
- pulsar
- black hole

Reading Strategy

Sequencing Copy the flowchart below. As you read, extend and complete it to show how a low-mass star evolves. Make a similar flowchart for high-mass stars.

Evolution of a Low-Mass Star

Main sequence → a. __?__ → b. __?__

Do stars change over time? If so, how do they change? To help answer these questions, think about predicting how a baby will look when it grows up. Pictures of the baby's relatives, like Figure 15, would probably help. Astronomers use a similar approach to understand how stars evolve. When astronomers look at an image of a single star, they see a snapshot from a life story that often lasts for billions of years. To learn how a star might change over time, astronomers observe many stars of different ages. These observations provide clues about how stars form, how long they last, and what happens when their fuel runs out.

Most stars fall on the main sequence of the H-R diagram. Among nearby stars, about 10 percent are white dwarfs and fewer than 1 percent are giants or supergiants. Astronomers have inferred that these different types of stars represent different stages of a star's evolution. For most of their lives, stars are very stable. But a star must change when nuclear fusion has used up the supply of hydrogen in its core.

Figure 15 You can often predict how a baby will look as an adult by looking at other family members. In a similar way, astronomers observe stars of different ages to infer how stars evolve.

How Stars Form

The space around stars contains gas and dust. In some regions this matter is spread thinly; in others it is packed densely. A **nebula** is a large cloud of gas and dust spread out over a large volume of space. Some nebulas are glowing clouds lit from within by bright stars. Other nebulas are cold, dark clouds that block the light from more-distant stars beyond the nebulas.

Section Resources

Print
- ***Laboratory Manual*,** Investigation 26B
- ***Reading and Study Workbook With Math Support*,** Section 26.3
- ***Transparencies*,** Section 26.3

Technology
- ***Interactive Textbook*,** Section 26.3
- ***Presentation Pro CD-ROM*,** Section 26.3
- ***Go Online*,** *Science News*, Stars, galaxies, and the universe

Stars form in the densest regions of nebulae, as shown in Figure 16. Stars are created by gravity. Gravity pulls a nebula's dust and gas into a denser cloud. As the nebula contracts, it heats up. A contracting cloud of gas and dust with enough mass to form a star is called a **protostar.** As a protostar contracts, its internal pressure and temperature continue to rise. **A star is formed when a contracting cloud of gas and dust becomes so dense and hot that nuclear fusion begins.** Pressure from fusion supports the star against the tremendous inward pull of gravity. This new energy source stabilizes the young star, and it joins the main sequence.

Figure 16 A group of bright young stars can be seen in the hollowed-out center of the Rosette Nebula.

Adult Stars

Stars spend about 90 percent of their lives on the main sequence. In all main-sequence stars, nuclear fusion converts hydrogen into helium at a stable rate. There is an equilibrium between the outward thermal pressure from fusion and gravity's inward pull. **A star's mass determines the star's place on the main sequence and how long it will stay there.**

The amount of gas and dust available when a star forms determines the mass of each young star. The most massive stars have large cores and therefore produce the most energy. In a large, young star with 30 times the sun's mass, gravity exerts a huge inward force, increasing the star's internal temperature and pressure. High-mass stars become the bluest and brightest main-sequence stars. Typically, these blue stars are about 300,000 times brighter than the sun. But, like gas-guzzling hot rods, large stars pay a price. Because blue stars burn so brightly, they use up their fuel relatively quickly and last only a few million years.

Stars similar to the sun occupy the middle of the main sequence. A yellow star like the sun has a surface temperature of about 6000 K and will remain stable on the main sequence for about 10 billion years.

Small nebulas produce small, cool stars that are long-lived. A star can have a mass as low as a tenth of the sun's mass. The gravitational force in such low-mass stars is just strong enough to create a small core where nuclear fusion takes place. This lower energy production results in red stars, which are the coolest and least bright of all visible stars. A red main-sequence star, with a surface temperature of about 3500 K, may stay on the main sequence for more than 100 billion years.

Reading Checkpoint *Why do red main-sequence stars last longer than blue main-sequence stars?*

Go Online SCIENCE NEWS

For: Articles on stars, galaxies, and the universe
Visit: PHSchool.com
Web Code: cce-3263

Adult Stars

Address Misconceptions L2

Some students may mistakenly think that stars last forever. Use an analogy to dispel this misconception. Tell students that stars are like people—they are born, become adults, and eventually die. The length of a star's life cycle may be billions of years and is determined by its mass.
Verbal

Build Science Skills L2

Classifying As students read about stellar evolution, have them locate on the periodic table the most abundant elements found in stars. Ask, **What do these elements have in common?** *(Except for iron, they are all in the upper part of the periodic table and have low atomic numbers.)* Point out that most are light gases that represent the first elements that formed in the universe.
Visual

Go Online SCIENCE NEWS

Science News provides students with current information on stars, galaxies, and the universe.

Customize for English Language Learners

Build a Science Glossary
Post a list that explains the meanings of common prefixes and suffixes related to stars. Encourage ELL students to study the list. Show them how to divide new vocabulary words into parts (prefix, root word, suffix). Model how you would determine the meaning of a word. For example, *super* means "above," so a supernova is above, or greater than, a nova. *Proto* means "first," so a protostar is a "first star," or the first stage of a star. Pronounce each term without its prefix or suffix and use the word in a sentence. Tell ELL students to do the same for each new vocabulary word, and to compile the words in their own science glossaries. Glossaries should include the pronunciation and definition of each word, as well as diagrams or drawings that illustrate the word's meaning. Tell students to arrange words in alphabetical order to reinforce use of the English alphabet.

Answer to . . .

Reading Checkpoint *Because red main-sequence stars are less massive and therefore much cooler than blue main-sequence stars, they use up their hydrogen fuel at a much slower rate.*

The Death of a Star

Use Visuals **L1**

Figure 17 Point out that stars undergo the same types of changes in the early stages of stellar evolution. Differentiation takes place in later stages. Ask, **What do the arrows show?** *(The path of evolution of low-mass or high-mass stars)* **What stages has the sun already completed?** *(Nebula, protostar)* **What stages will the sun evolve through before it dies?** *(Red giant, planetary nebula, white dwarf, black dwarf)*
Visual

Integrate Physics **L2**

Nuclear energy is generated in power plants through the process of fission. In fission, a heavy element, such as uranium, splits into lighter elements. Fission is the opposite of fusion. In main-sequence stars, fusion (the process that creates energy in stars) "fuses" together hydrogen nuclei to form helium. Fusion could theoretically be used as an energy source on Earth. It would provide abundant power and have only small environmental consequences. As of yet, however, scientists have not been able to develop the technology to conduct fusion in a safe, controlled manner. Have students work in groups to diagram the processes of fission and fusion. *(The diagram of fission should show a large atom being split into two smaller atoms, with energy released. The diagram of fusion should be similar to Figure 2 on p. 829.)*
Kinesthetic, Group

The Death of a Star

Stars don't last forever. When a star's core begins to run out of hydrogen, gravity gains the upper hand over pressure and the core starts to shrink. Soon, the core temperature rises enough to cause the hydrogen in a shell outside the core to begin fusion. The energy flowing outward increases, causing the outer regions of the star to expand. The expanding atmosphere moves farther from the hot core and cools to red. The star becomes a red giant. Eventually, the collapsing core will grow hot enough for helium fusion to occur, producing carbon, oxygen, and heavier elements. In helium fusion, the star stabilizes and its outer layers shrink and warm up. In this period, the star remains in the upper right part of the H-R Diagram. **The dwindling supply of fuel in a star's core ultimately leads to the star's death as a white dwarf, neutron star, or black hole.** As Figure 17 shows, the final stages of a star's life depend on its mass.

Low- and Medium-Mass Stars Low-mass and medium-mass stars, which can be as much as eight times as massive as the sun, eventually turn into white dwarfs. Such stars remain in the giant stage until their hydrogen and helium supplies dwindle and there are no other elements to fuse. Then the energy coming from the star's interior decreases. With less outward pressure to support the star against gravity's inward pull, the star collapses. The dying star is surrounded by a glowing cloud of gas. Such a cloud is called a **planetary nebula,** because the first ones found looked like planets when viewed through a small telescope. Figure 18A shows a planetary nebula.

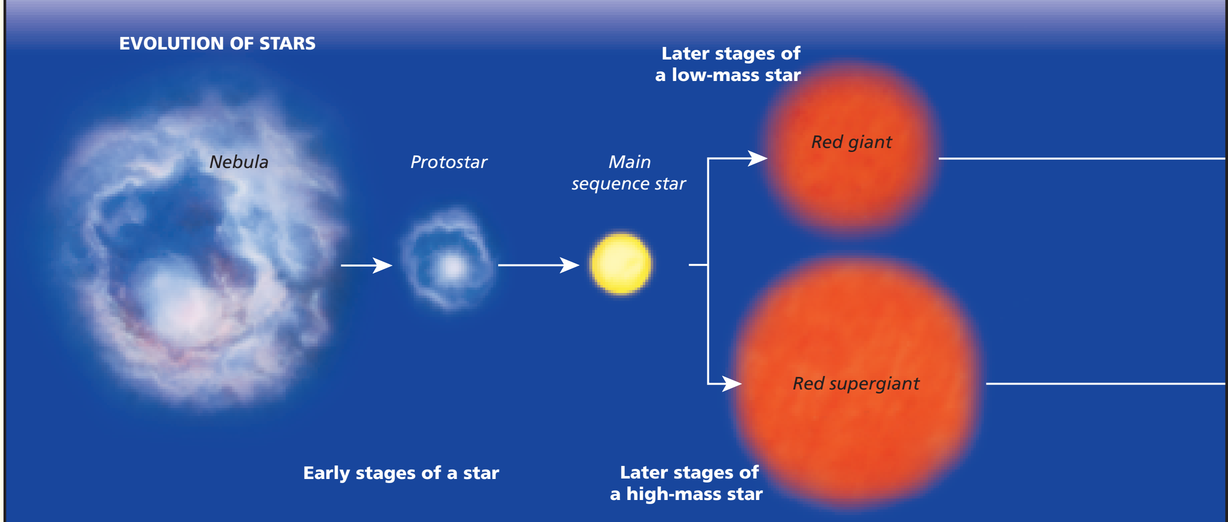


Figure 17 The mass of a star determines the path of its evolution. **Interpreting Diagrams** *What are two possible end-stages of a high-mass star?*

As the dying star blows off much of its mass, only its hot core remains. This dense core is a white dwarf. A white dwarf is about the same size as Earth but has about the same mass as the sun. White dwarfs don't undergo fusion, but glow faintly from leftover thermal energy. It takes about 20 billion years for a white dwarf to cool down completely. The universe hasn't been here long enough for this to happen yet.

High-Mass Stars The life cycle of high-mass stars (those with a mass of more than eight times that of the sun) is very different from the life cycle of lower-mass stars. As high-mass stars evolve from hydrogen fusion to the fusion of other elements, they grow into brilliant supergiants. This creates new elements, the heaviest being iron. A high-mass star dies quickly because it consumes fuel very rapidly.

As fusion slows in a high-mass star, pressure decreases. Gravity eventually overcomes the lower pressure, leading to a dramatic collapse of the star's outer layers. This collapse produces a **supernova,** an explosion so violent that the dying star becomes more brilliant than an entire galaxy. Supernovas produce enough energy to create elements heavier than iron. These elements, and lighter ones such as carbon and oxygen, are ejected into space by the explosion. The heavier elements in our solar system, including the atoms in your body, came from a supernova that occurred in our galaxy billions of years ago.

Reading Checkpoint *What is a supernova?*

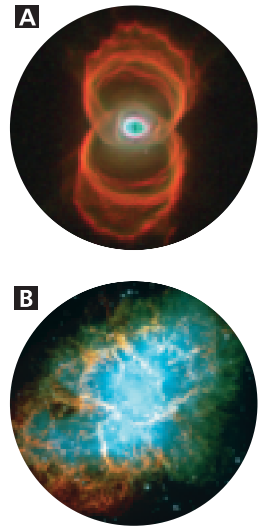
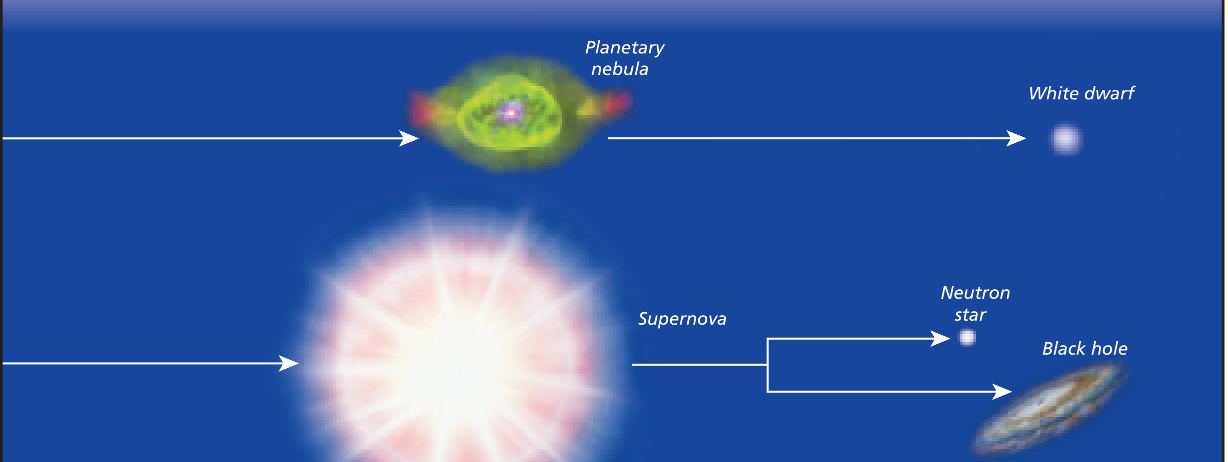


Figure 18 Nebulas are associated with the birth and death of stars. **A** Planetary nebulas, such as the Hourglass Nebula, are clouds of gas that surround a collapsing red giant. **B** The Crab Nebula is the remnant of a supernova explosion that was observed on Earth in A.D. 1054. The supernova was so bright that people could see it in the daytime.



Teacher Demo

Brown Dwarfs

L2

Purpose Students observe how astronomers detect a brown dwarf by observing the effect it has on a star's motion.

Materials dark clay, pencil, string, aluminum foil, flashlight

Procedure Use the clay to make two balls. One ball (5 cm in diameter) represents a star. The second ball (2.5 cm in diameter) represents a brown dwarf. Cover the star in aluminum foil. Attach the star to one end of a pencil and the brown dwarf to the other end. Tell students that the pencil represents gravity, which keeps the brown dwarf and star orbiting each other. Then, tie a string to the pencil at the center of mass so that the pencil is balanced (horizontally) when suspended. Twist the string so that the brown dwarf and star orbit each other. Darken the room and shine a flashlight on the apparatus to emphasize that the star is visible but the brown dwarf is not. Repeat the demonstration using a smaller brown dwarf (1 cm in diameter).

Expected Outcome Students will observe that the star "wobbles" as the brown dwarf orbits it. From the size of a star's wobble, astronomers can estimate the size of the brown dwarf and its distance from the star. Explain that astronomers use this same method to locate planets orbiting other stars.
Visual, Logical

Facts and Figures

Crab Nebula The supernova explosion associated with the Crab Nebula had the brilliance of more than a billion suns. It was observed in 1054 by Chinese, Arabic, and Japanese astronomers, and was recorded in paintings by the Anasazi, who lived in the area that is now New Mexico. The star in the center of the Crab Nebula is a tiny dense pulsar. It rotates 30 times every second and sends powerful radio beams flashing through space. These intense emissions light up the surrounding cloud.

Answer to . . .

Figure 17 *Neutron star, black hole*

Reading Checkpoint *A supernova is the dramatic explosion of a high-mass star in which the star ejects elements formed from a lifetime of fusion into space.*

Section 26.3 (continued)

Use Visuals

L1

Figure 19 Have students examine the diagram. Ask, **Where do the beams of radiation originate from?** *(The magnetic poles)* **Why do we detect pulses on Earth?** *(The beams don't pulse on and off, but we detect them as pulsing as the beams periodically sweep across Earth.)*
Visual

3 ASSESS

Evaluate Understanding

L2

Have students diagram the life cycle of a massive star. Tell them to put captions on their diagrams that explain the stages of stellar evolution.

Reteach

L1

Use spectra to illustrate the different temperatures and compositions of high-mass and low-mass stars.

Writing in Science

Students' paragraphs should include a description of the formation of heavy elements and their ejection into space in a supernova explosion. Students should also describe how such elements became part of Earth as the solar system formed.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 26.3.

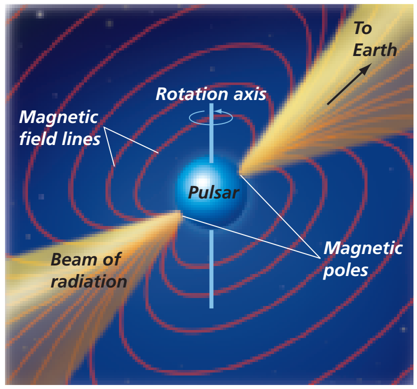


Figure 19 Pulsars emit steady beams of radiation that appear to pulse when the spinning beam sweeps across Earth.

As a supernova spews material into space, its core continues to collapse. If the remaining core has a mass less than about three times the sun's mass, it will become a neutron star. A **neutron star** is the dense remnant of a high-mass star that has exploded as a supernova. In a neutron star, electrons and protons are crushed together by the star's enormous gravity to form neutrons. Neutron stars are much smaller and denser than white dwarfs. A spoonful of a neutron star would weigh nearly a billion tons on Earth! A neutron star with the mass of the sun would be only about 25 kilometers across, the size of a large city.

Like a spinning ice skater pulling in his arms, a neutron star spins more and more rapidly as it contracts. Some neutron stars spin hundreds of turns per second! As shown in Figure 19, neutron stars emit steady beams of radiation in narrow cones. If the neutron star is spinning, these emissions appear to pulse on and off at regular intervals, like the spinning beacon on a lighthouse. Each time one of these beams of radiation sweeps across Earth, astronomers can detect a pulse of radio waves. A spinning neutron star that appears to gives off strong pulses of radio waves is called a **pulsar.**

As impressive as pulsars are, very massive stars can have even more dramatic ends. If a star's core after a supernova explosion is more than about three times the sun's mass, its gravitational pull is very strong. Gravity causes the core to collapse beyond the neutron-star stage. As the collapse continues, the pull of gravity increases and the speed required to escape the star's core reaches the speed of light. Beyond this point, nothing can escape and a black hole is formed. A **black hole** is an object whose surface gravity is so great that even electromagnetic waves, traveling at the speed of light, cannot escape from it.

Section 26.3 Assessment

Reviewing Concepts

1. How does a star form?
2. What factor determines the length of a star's life?
3. Why do some stars become white dwarfs while others become neutron stars or black holes?

Critical Thinking

4. **Predicting** A main-sequence star has a mass 5 times that of the sun. What will be its final stages?
5. **Comparing and Contrasting** How are a protostar and a star different?
6. **Comparing and Contrasting** Why do low-mass stars remain on the main sequence longer than high-mass stars?

Writing in Science

Explain a Sequence Write a paragraph explaining the sequence of events that resulted in the creation of the elements that make up your body.

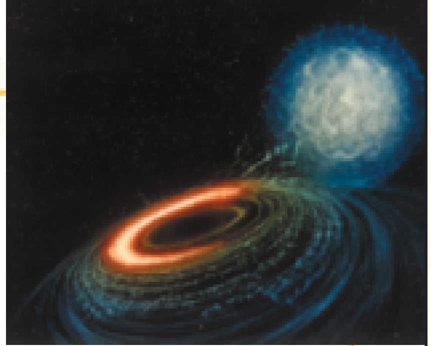
Section 26.3 Assessment

1. A star forms when a contracting nebula becomes dense and hot enough that nuclear fusion begins.
2. The star's mass
3. The end-stage of a star depends on its mass. Low-mass and medium-mass stars evolve into white dwarfs as they run out of elements to fuse. High-mass stars eventually evolve into neutron stars or black holes.
4. Such a medium-mass star will evolve into a white dwarf and, eventually, a black dwarf.
5. A protostar is a contracting cloud of gas and dust with sufficient mass to become a star. Once fusion begins, the protostar is then considered a star.
6. Low-mass stars are cooler and use up their supply of elements to fuse at a much slower rate.

DK HOW It Works

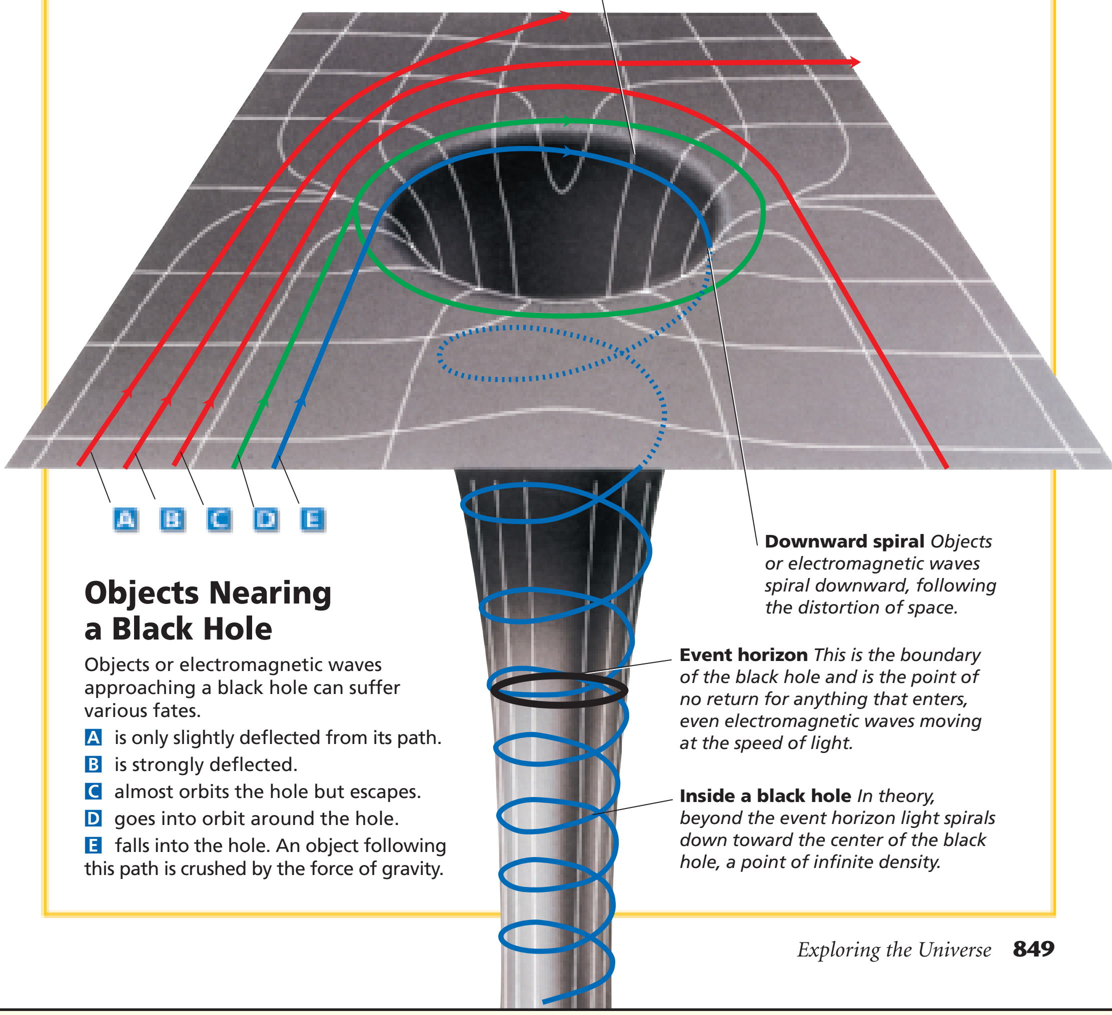
Black Hole

A black hole is a region of space containing so much matter that it collapses to an infinitely dense point. The force of gravity in a black hole is so great that anything falling into it, including electromagnetic waves, becomes trapped. **Interpreting Diagrams** ***What happens to an object trapped by a black hole?***



Detecting a black hole As matter swirls into a black hole, it can emit X-rays, gamma rays, and other radiation. Astronomers analyze this radiation to discover more about black holes.

Warped space *According to Einstein's theory of general relativity, gravity is a distortion of space and time. The warping of space near a black hole is shown here by the gray plane and white lines.*



Downward spiral *Objects or electromagnetic waves spiral downward, following the distortion of space.*

Event horizon *This is the boundary of the black hole and is the point of no return for anything that enters, even electromagnetic waves moving at the speed of light.*

Inside a black hole *In theory, beyond the event horizon light spirals down toward the center of the black hole, a point of infinite density.*

Objects Nearing a Black Hole

Objects or electromagnetic waves approaching a black hole can suffer various fates.

- **A** is only slightly deflected from its path.
- **B** is strongly deflected.
- **C** almost orbits the hole but escapes.
- **D** goes into orbit around the hole.
- **E** falls into the hole. An object following this path is crushed by the force of gravity.

DK HOW It Works

Black Hole L2

Astronomers now think that many large galaxies, including the Milky Way, have black holes in their centers. The Milky Way's center is hidden from view by interstellar dust in the spiral arm lying between the sun and the galaxy's center. Radio and infrared telescopes can penetrate the dust, however. Images show a cluster of several million stars and great turbulence at the Milky Way's core in a region about three light-years across. The high mass of this region indicates the presence of a black hole. However, the area does not exhibit many typical black-hole behaviors, such as X-ray emissions, detected in the centers of other galaxies.

Interpreting Diagrams An object that falls into a black hole would be crushed by its intense gravitational forces.
Visual, Logical

For Enrichment L3

Have interested students research and present oral reports on Einstein's general theory of relativity.
Verbal, Portfolio