

SECTION 3 Lives of Stars

DISCOVER

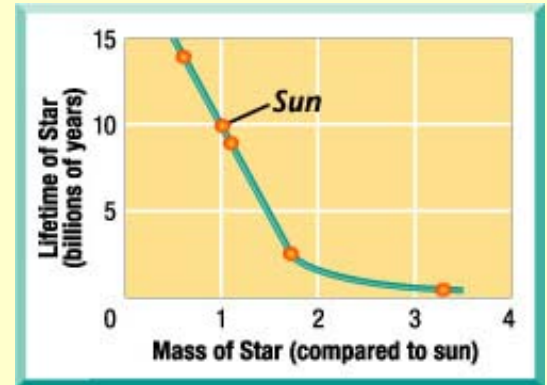
ACTIVITY

What Determines How Long Stars Live?

1. This graph shows how the mass of a star is related to its lifetime—how long the star lives before it runs out of fuel.
2. How long does a star with 0.8 times the mass of the sun live? How long does a star with 1.7 times the mass of the sun live?

Think It Over

Drawing Conclusions Describe the general relationship between a star's mass and its lifetime.



GUIDE FOR READING

- How does the life of a star begin?
- What determines how long a star will live?
- What happens to a star when it runs out of fuel?

Reading Tip As you read, make a flowchart showing the stages in the life of a medium-sized star.

Key Terms • [pulsar](#) • [nebula](#)
 • [protostar](#) • [white dwarf](#)
 • [supernova](#) • [neutron star](#) • [black hole](#) • [quasar](#)

In 1967, Jocelyn Bell Burnell, an astronomy student, detected an object in space that appeared to give off regular pulses of radio waves. Some astronomers hypothesized that the pulses might be a signal from an extraterrestrial civilization. At first, astronomers even named the source LGM, for “Little Green Men” in science-fiction stories. Eventually, astronomers concluded that the source of the radio waves was a neutron star. A neutron star is a tiny star left over when a giant star explodes. Neutron stars like the one Burnell discovered are called [pulsars](#)—pulsating radio sources.



Studying the Lives of Stars

Stars do not last forever. Each star is born, goes through its life cycle, and eventually dies. (Of course, stars are not really alive. The words *born*, *live*, and *die* are just helpful comparisons.) How did astronomers figure out that the neutron star Burnell discovered had been a larger star earlier in its life?

Imagine that you want to study how people age. You wish you could watch a few people for 50 years, but your assignment is due next week! You have to study a lot of people for a short time, and classify the people into different age groups. You may come up with groups like *babies*, *children*, *teenagers*, *young adults*, *middle-aged people*, and *elderly people*. You don't have time to see a single person go through all these stages, but you know the stages exist.

Astronomers have a similar problem with stars. They can't watch a single star for billions of years, so they study many stars and see how they differ from one another.

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A Star Is Born

A star is made up of a large amount of gas in a relatively small volume. A [nebula](#), on the other hand, is a large amount of gas and dust spread out in an immense volume. All stars begin their lives as parts of nebulae.

Gravity can pull some of the gas and dust in a nebula together. The contracting cloud is then called a protostar. *Proto* means “earliest” in Greek, so a [protostar](#) is the earliest stage of a star’s life. **A star is born when the contracting gas and dust become so hot that nuclear fusion starts.** Nuclear fusion is the process by which atoms of hydrogen combine to form helium. During fusion, enormous amounts of energy are released.

Star Factory



Protostars The Orion Nebula (top) is a giant cloud of gas and dust. The Hubble Space Telescope took this photo of a protostar (bottom) in the Orion Nebula. A protostar is a star in the earliest stage of its life.

Applying Concepts How do some of the gas and dust in a nebula become a protostar?

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EXPLORING *the Lives of Stars*

A star's life history depends on its mass. The sun is a medium-mass star that will become a white dwarf, then a black dwarf.

A star's life begins when gas and dust in a nebula contract to form a protostar.

Protostar
Nebula

The remains of the most massive stars collapse into black holes. Not even light can escape from a black hole.

Black Hole

Giant and supergiant stars can blow up into supernovas.

Supernova

The remains of the supernova become a neutron star.

Neutron Star

Red Giant or Supergiant

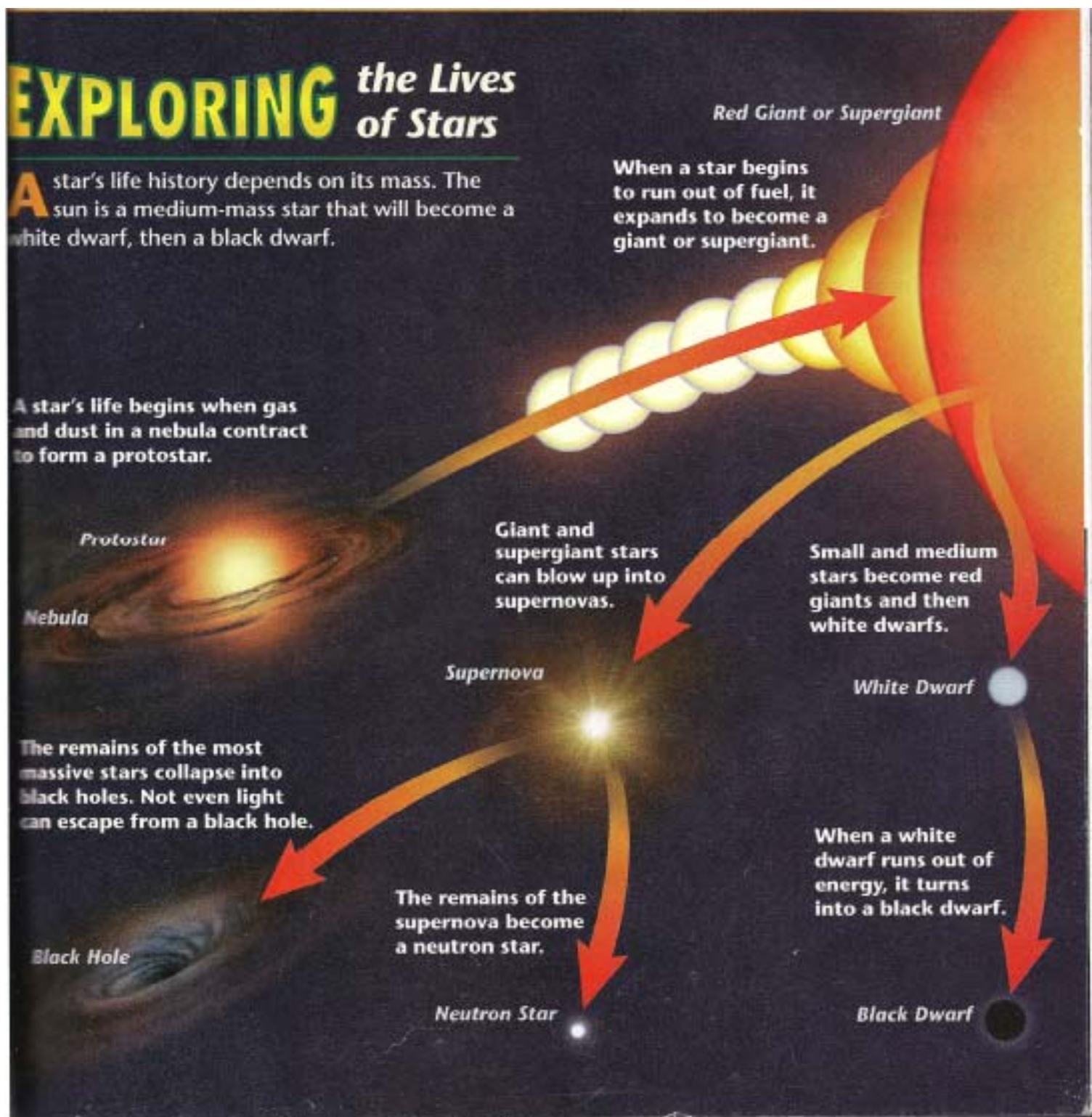
When a star begins to run out of fuel, it expands to become a giant or supergiant.

Small and medium stars become red giants and then white dwarfs.

White Dwarf

When a white dwarf runs out of energy, it turns into a black dwarf.

Black Dwarf





Lifetimes of Stars

Before they can tell how old a star is, astronomers must determine its mass. **How long a star lives depends on how much mass it has.**

You might think that stars with more mass would last longer than stars with less mass. However, the reverse is true. You can think of stars as being like cars. A small car has a small gas tank, but it also has a small engine that burns gas slowly. A large car, on the other hand, has a larger gas tank, but it also has a larger engine that burns gas rapidly. So the small car might be able to travel farther on one small tank of gas than the larger car can on one large tank of gas. Small stars use up their fuel more slowly than large stars, so they have much longer lives.

Generally, stars that have less mass than the sun use their fuel slowly, and can live for up to 200 billion years. Medium-mass stars like the sun live for about 10 billion years. Astronomers think the sun is about 4.6 billion years old, so it is almost halfway through its lifetime.

Stars that have more mass than the sun have shorter lifetimes. A star that is 15 times as massive as the sun may live only about ten million years. That may seem like a long time, but it is only one tenth of one percent of the lifetime of the sun.





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Deaths of Stars

When a star begins to run out of fuel, the center of the star shrinks and the outer part of the star expands. The star becomes a red giant or supergiant.

All main sequence stars eventually become red giants or supergiants. However, what happens next depends on the mass of the star, as *Exploring the Lives of Stars* shows. **When a star runs out of fuel, it becomes a white dwarf, a neutron star, or a black hole.**

Exploring the Lives of Stars



White Dwarfs Small and medium stars take 10 billion or more years to use up their nuclear fuel. Then their outer layers expand, and they become red giants. Eventually, the outer parts grow bigger still and drift out into space. The blue-white hot core of the star that is left behind is a [white dwarf](#).

White dwarfs are only about the size of Earth, but they have about as much mass as the sun. Since a white dwarf has the same mass as the sun but only one millionth the volume, it is one million times as dense as the sun. A spoonful of material from a white dwarf has as much mass as a large truck. White dwarfs have no fuel, but they glow faintly from leftover energy. When a white dwarf stops glowing, it is dead. Then it is called a black dwarf.

Neutron Stars A dying giant or supergiant star can suddenly explode. Within hours, the star blazes millions of times brighter. The explosion is called a [supernova](#). After a supernova, some of the material from the star expands into space. This material may become part of a nebula. The nebula can then contract to form a new, “recycled” star. Astronomers think the sun began as a nebula that contained material from a supernova explosion.

After the star explodes, some of the material from the star is left behind. This material may form a neutron star. [Neutron stars](#) are even smaller and denser than white dwarfs. A neutron star may contain as much as three times the mass of the sun but be only about 20 kilometers in diameter, the size of a large asteroid or a town on Earth.

Black Holes The most massive stars—those having more than 40 times the mass of the sun—become [black holes](#) when they die. After this kind of star becomes a supernova, more than five times the mass of the sun may be left. The gravity of this mass is so strong that the gas is pulled inward, packing the gas into a smaller and smaller space. Eventually five times as much mass as the sun becomes packed within a sphere 30 kilometers in diameter. At that point, the gravity is so strong that nothing can escape, not even light. The remains of the star become a black hole.

No light, radio waves, or any other form of radiation can ever get out of a black hole, so it is not possible to detect a black hole directly. But astronomers can detect black holes indirectly.

For example, gas near a black hole is pulled so strongly that it rotates faster and faster around the black hole. Friction heats the gas up. Astronomers can detect X-rays coming from the hot gas and infer that a black hole is present. Similarly, if another star is near a black hole, astronomers can calculate the mass of the black hole from the effect of its gravity on the star. Scientists at the Chandra X-ray Observatory are looking for black holes by studying sources of X-rays.

Quasars In the 1960s, astronomers discovered objects that are unusual because they are very bright and also very far away. Many of these objects are about 12 billion light-years away, making them among the most distant objects in the universe. These distant bright objects looked almost like stars. Since *quasi* means “something like” in Latin, these objects were given the name **quasi-stellar** objects, or [quasars](#).

What could be so bright even though it is so far away? Astronomers have concluded that quasars are actually distant galaxies with giant black holes at their centers. Each black hole has a mass a billion times or more as great as that of the sun. As enormous amounts of gas revolve around such a black hole, the gas heats up and shines brightly.

Sharpen your Skills

Predicting

Find Algol, Polaris, and Sirius B in the [H-R diagram](#). For each star, write a sentence predicting what the next stages in its life will be.



Section 3 Review



Checkpoint

1. What is the earliest stage in the life of a star? [hint](#)
2. Why do small stars have longer lifetimes than large stars? [hint](#)
3. What is the difference between stars that become white dwarfs and stars that become neutron stars? [hint](#)
4. What evidence do astronomers use to detect black holes? [hint](#)
5. **Thinking Critically Inferring** What will happen to the sun when it dies? Explain your answer. [hint](#)



Check Your Progress

Draw and label the stars in your constellation *without* the connecting lines that form the usual image. What different patterns can you see? (*Hint:* Use a pencil to “doodle” different connections among the stars.) What does each pattern look like? Choose one pattern, and use it to name your constellation. Then write an outline of a brief story that explains why this constellation is in the sky.