Lesson 3

The Life Cycle of Stars

ESSENTIAL QUESTION

How do stars change over time?

By the end of this lesson, you should be able to describe the stages of the life cycles of stars.

*Massive stars really go out with a bang. The remains of a supernova called **Cassiopeia** are still glowing with energy long after the star exploded.*

Lesson Labs

Quick Labs
- Star Graphing
- The Age of Stars

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	Our sun is among the most massive stars in our galaxy.
☐	☐	A neutron star is an extremely dense ball of neutrons.
☐	☐	Astronomers use the H-R diagram to predict when comets will travel close to Earth.
☐	☐	Stars develop from white dwarfs.

2 Explain Humans pass through a series of stages called a *life cycle*. Stars go through a series of stages, too. What stage of the human life cycle are you currently in? What stage of the star life cycle do you think the sun is in?

Active Reading

3 Synthesize You can often define an unknown word if you know the meaning of its word parts. Use the words and sentence below to make an educated guess about the meaning of the word *supernova*.

Word part	Meaning
super	large, extreme
novus	fresh, new

Example sentence:
As a part of its normal life cycle, a massive star becomes a supernova.

supernova:

Vocabulary Terms
- nebula
- white dwarf
- supernova
- neutron star
- H-R diagram
- main sequence

4 Identify As you read, create a reference card for each vocabulary term. On one side of the card, write the term and its meaning. On the other side, draw an image that illustrates or makes a connection to the term. These cards can be used as bookmarks in the text so that you can refer to them while studying.

A Star Is Born

What is the life cycle of a star?

The sky is full of stars that are at different stages in their life cycles. A star begins life within a cloud of gas and dust. Gravity pulls parts of this cloud into dense regions. Stars begin life in the cores of these regions when the process of nuclear fusion begins. When stars age, much of their material returns to space to form new stars.

Stars Form in Nebulae

Stars form in nebulae [NEB•yuh•lee]. A **nebula** [NEB•yuh•luh] is a large cloud of gas and dust. Like stars, nebulae are composed of mostly hydrogen and helium. They also contain small amounts of heavier elements. A nebula may be compressed by an outside force, such as the explosion of a nearby star. This causes the nebula to contract and cool. Gravity causes parts of the nebula to collapse.

According to Newton's law of universal gravitation, all objects in the universe attract one another. The force of gravity increases with increasing mass and decreasing distance between objects. As particles within the nebula are pulled closer together, gravitational attraction increases. As a result, dense regions of gas and dust form within the nebula. The densest regions, which are called *dense cores*, form new stars.

Visualize It!

5 Identify What is happening in the circled part of this nebula?

Stars Emit Energy by the Process of Nuclear Fusion

The temperature within dense cores increases. At about 10 million °C, the process of nuclear fusion begins. This process releases enormous amounts of energy. Nuclear fusion takes place when high temperature and pressure cause two or more low-mass atomic nuclei to form a heavier nucleus. A nucleus is an atom's central region, which is made up of neutrons and protons.

The start of hydrogen fusion marks the birth of a star. The active fusion stage is the longest stage in the life cycle of a star. This stage can last for billions of years. The active fusion stage ends when a star runs out of hydrogen.

Active Reading

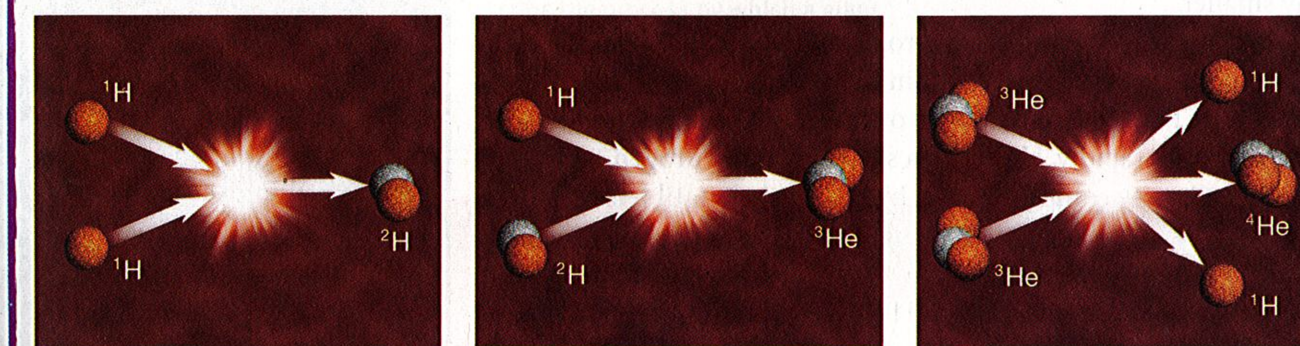
6 Identify What process begins when a star is born?

Visualize It!

For most of its life, a star fuses hydrogen nuclei in a multistep process that releases energy.

Hydrogen nuclei are fused together under great heat and pressure to form helium nuclei.

Some of the energy and nuclei released at the end of the process cause fusion to continue.



7 Examine Look at the start of the first reaction. Compare this to the end of the last reaction. What type of nuclei are found at both ends of the reaction?

Nuclear Fusion in Stars Stops

A star enters the next stage of its life cycle when nearly all of the hydrogen in its core has fused into helium. The core of the star contracts under its own gravity. This contraction increases the temperature of the core. Energy is transferred to a thin shell of hydrogen that surrounds the core. Hydrogen fusion continues in this outer shell. The ongoing fusion radiates large amounts of energy outward. The outer shell of the star expands, which makes the star grow much larger.

When fusion ends completely, stars begin to eject matter. Stars rapidly lose mass until only the core remains. The final stages in a star's life cycle depend on the mass of the star.

The Lightweights

What is the life cycle of a low-mass star?

The mass of a star determines the different stages that it will pass through during its life cycle. Low-mass stars, including our sun, grow larger and become giants. Then, they end their lives as objects called *white dwarfs*.

The Low-Mass Star Becomes a Giant

During the active fusion stage, energy generated by fusion reactions causes an outward pressure. At the same time, gravity pulls inward toward the star's center. These outward and inward forces balance each other, and the star does not get any larger or any smaller.

After a star fuses all the hydrogen in its core into helium, fusion no longer takes place within the core. So, the outward forces are smaller than the inward force of gravity. This causes the star's core to shrink rapidly. However, a shell of fresh hydrogen surrounds the core. Gravity compresses this hydrogen shell until temperatures within the shell become high enough for hydrogen fusion to take place. The outward pressure from the energy of fusion in the shell is now able to overcome gravity. This causes the hydrogen shell to expand greatly. The star becomes much larger and brighter, and is now called a *giant*. Giants are red because the surface temperature of the star becomes cooler as the outer shell expands.

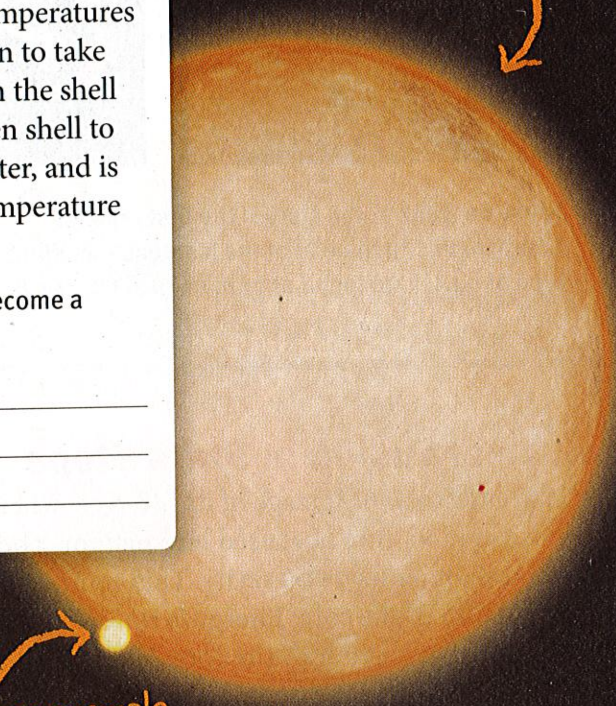
Active Reading **8 Identify** When does a low-mass star become a giant?

____

____

____

Giants are large because gases that surround the core have expanded. The red color is associated with lower surface temperatures than when stars were yellow or orange.



Our sun is an example of a low-mass star. Near the end of its life cycle it will swell into a red giant.

Think Outside the Book **Inquiry**

9 Research If our sun grows to 10 times its current size at the end of its life cycle, how big will it be? Will Mercury be engulfed? Venus? Earth? What if our sun grows to 100 times its current size?

The Giant Loses Material, Leaving a White Dwarf

Over time, a giant's outer gases drift away from the core. The gases appear as a cloud around a dying, sunlike star. Some clouds form a simple sphere or ring around the star. Many form more complex shapes.

As the clouds disperse, gravity causes the remaining matter in the star's core to collapse inward. The core of the star becomes denser and very hot. At this stage, the star is known as a white dwarf. A **white dwarf** is the hot, dense core of matter that remains from the collapse of a low-mass star. White dwarfs are very small. A white dwarf is about the size of Earth.

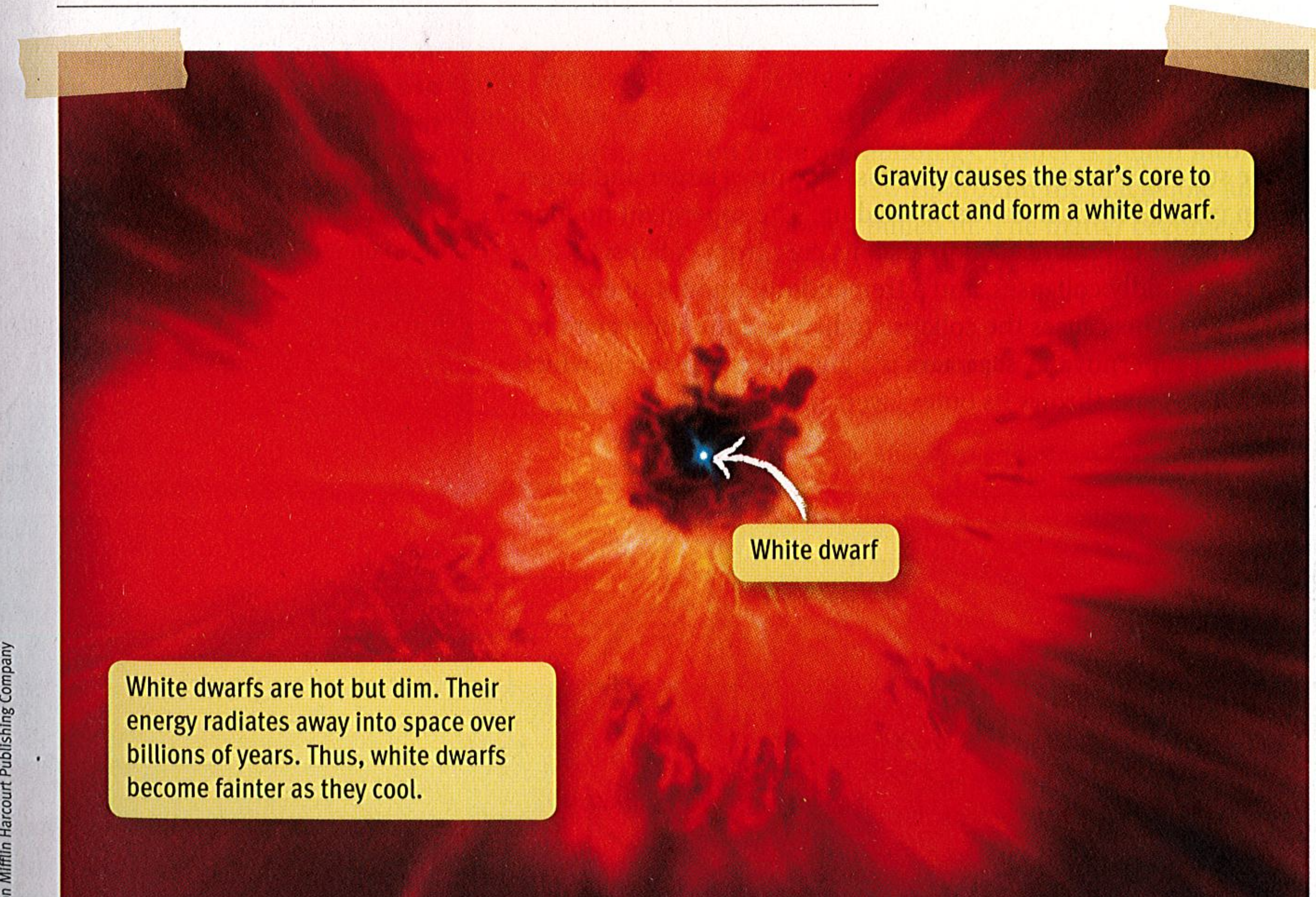
White dwarfs shine for billions of years before they cool completely. As white dwarfs cool, they become fainter. This is the final stage in the life cycle of low-mass stars.

Visualize It!

10 Describe Using the image below, describe the process by which a giant becomes a white dwarf.

____

____



The Heavyweights

What is the life cycle of a high-mass star?

High-mass stars follow a different life cycle than low-mass stars do. High-mass stars become supergiants rather than giants. Following the supergiant stage, the collapse of the star's core at the end of the fusion process causes the formation of very strange objects. These objects include supernovae, neutron stars, and black holes.

The High-Mass Star Becomes a Supergiant

When hydrogen fusion in a high-mass star ends, other types of fusion begin that involve the fusion of nuclei into elements heavier than carbon. The star expands to become a supergiant. The hydrogen fusion stage in high-mass stars ends much sooner than it does in low-mass stars. A star with 10 times the mass of our sun will become a supergiant in just 20 million years. By comparison, it takes 10 billion years for low-mass stars such as the sun to become giants.

The Supergiant Collapses, Triggering a Supernova

In the supergiant stage, the high-mass star fuses larger and larger nuclei until all its nuclear fuel is used up. The supergiant no longer generates the energy needed to keep its core from collapsing. The core rapidly collapses, and a tremendous amount of energy is released. This causes the collapse to halt and the supergiant to become a supernova. A **supernova** is a gigantic explosion in which a high-mass star throws its outer layers into space. But its core remains.

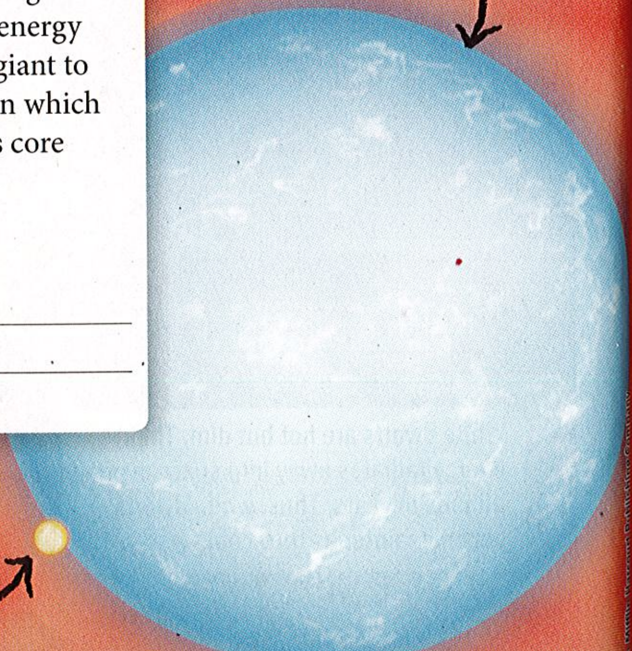
11 Explain What causes a supernova?

____

____

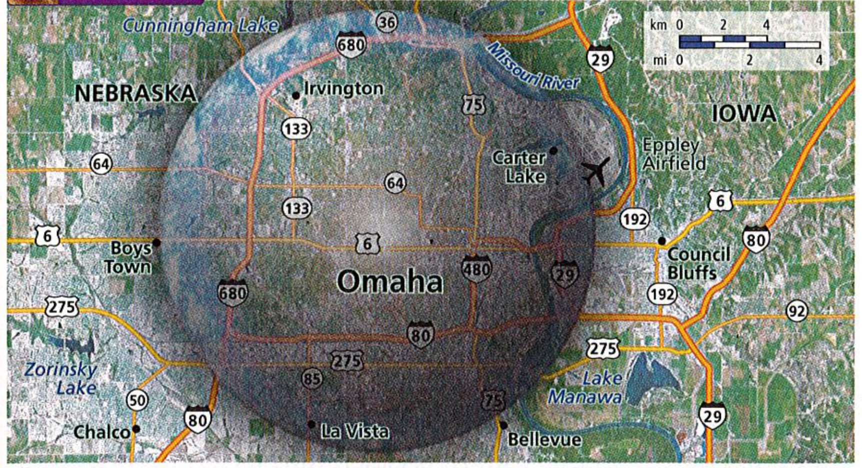
Supergiants are fantastically large and bright. This makes supergiants easy to identify, even though they are rare and distant.

High-mass stars, though larger than the sun, are much smaller than supergiants. The blue color indicates that this is a very hot, active star.



Our sun looks very small when compared to a high-mass blue star. But, it is absolutely tiny when compared to a supergiant.

Visualize It!



A neutron star is a tiny star, but contains 1.4 to 2 times the mass of our sun!

12 Relate Use the scale to find the diameter of this neutron star in miles.

____

____

The Collapsed Supergiant Becomes a Neutron Star

The core of a supernova continues to collapse under the force of gravity. Its protons and electrons smash together to form neutrons. The resulting **neutron star** is a small, incredibly dense ball of closely packed neutrons. A neutron star may have a diameter of only 20 km, yet it may emit the energy of 100,000 suns.

Neutron stars rotate very rapidly. Some emit a beam of electromagnetic radiation that can be detected every time the beam sweeps by Earth. These stars are called *pulsars*.

Active Reading **13 Explain** What is a pulsar?

____

____

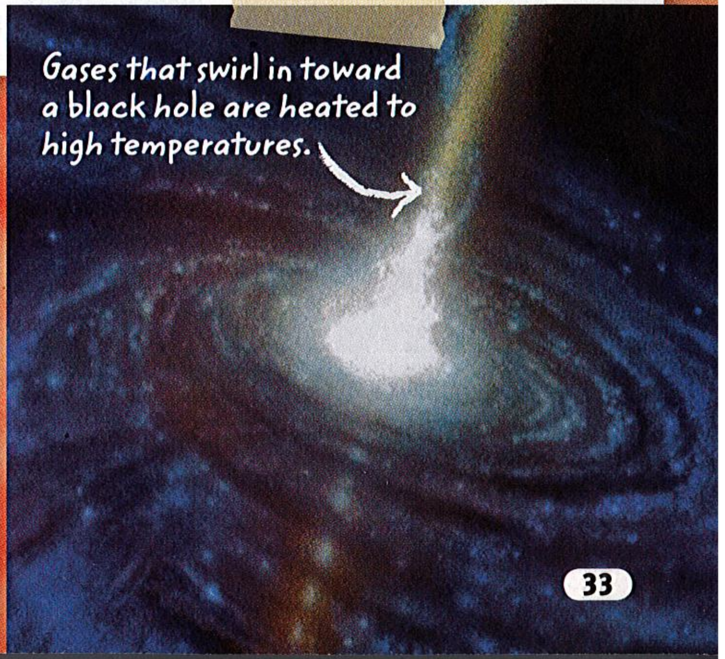
____

The Most Massive Supergiants Collapse to Form Black Holes

There are stars that are so massive that their cores continue to collapse under the force of gravity. As their cores collapse, the mass of the star is compressed into a single point. This point is called a *black hole*. A black hole is an invisible object with gravity so great that nothing, not even light, can escape it.

Though black holes are invisible, they can be observed by the gravitational effect they have on their surroundings. Matter is pulled into a black hole. It swirls around the black hole just before being pulled in. The matter becomes so hot that it emits x-rays. Astronomers use x-rays and other means to locate black holes—even within our own galaxy!

Black holes cannot be seen directly. Instead, black holes are "observed" by the effect that they have on their surroundings.



Gases that swirl in toward a black hole are heated to high temperatures.

A Graphic Display

How are stars plotted on the H-R diagram?

Astronomers refer to brightness as *luminosity*. Luminosity is actually a measure of the total amount of energy a star gives off each second. When the surface temperatures of stars are plotted against their luminosity, a consistent pattern is revealed. The graph that illustrates this pattern is called the Hertzsprung-Russell diagram, or **H-R diagram**.

The hottest stars are located on the left side of the H-R diagram and are blue. Stars become progressively cooler the farther to the right they are located on the diagram. The coolest stars are located on the right side of the diagram and are red. The brightest stars are located at the top of the diagram, and the dimmest stars are located at the bottom.

Visualize It!

14 Identify Where on the H-R diagram are the brightest stars located?

____

15 Identify Where on the H-R diagram are the coolest stars located?

____

© Houghton Mifflin Harcourt Publishing Company

How does the H-R diagram show different life cycle stages?

Most stars fall within a band that runs diagonally through the middle of the H-R diagram. This band extends from hot, bright blue stars at the upper left to cool, dim red stars at the lower right. It is called the main sequence. The **main sequence** is the region of the diagram where stars spend most of their lives. Stars within this band are actively fusing hydrogen and are called *main-sequence stars*.

The sun is a main-sequence star. When nuclear fusion ends in the sun, it will become a giant and will move to the upper right corner of the H-R diagram. When the outer layers of the giant are lost to space, the sun will become a white dwarf and move to the bottom of the diagram.

Active Reading 16 Identify What is the region of the H-R diagram where stars spend most of their lives called?

____

Visualize It!

17 Explain The sun is now at position A. How will the sun change in terms of temperature and brightness as it moves from position A to B and then to C on the H-R diagram?

____

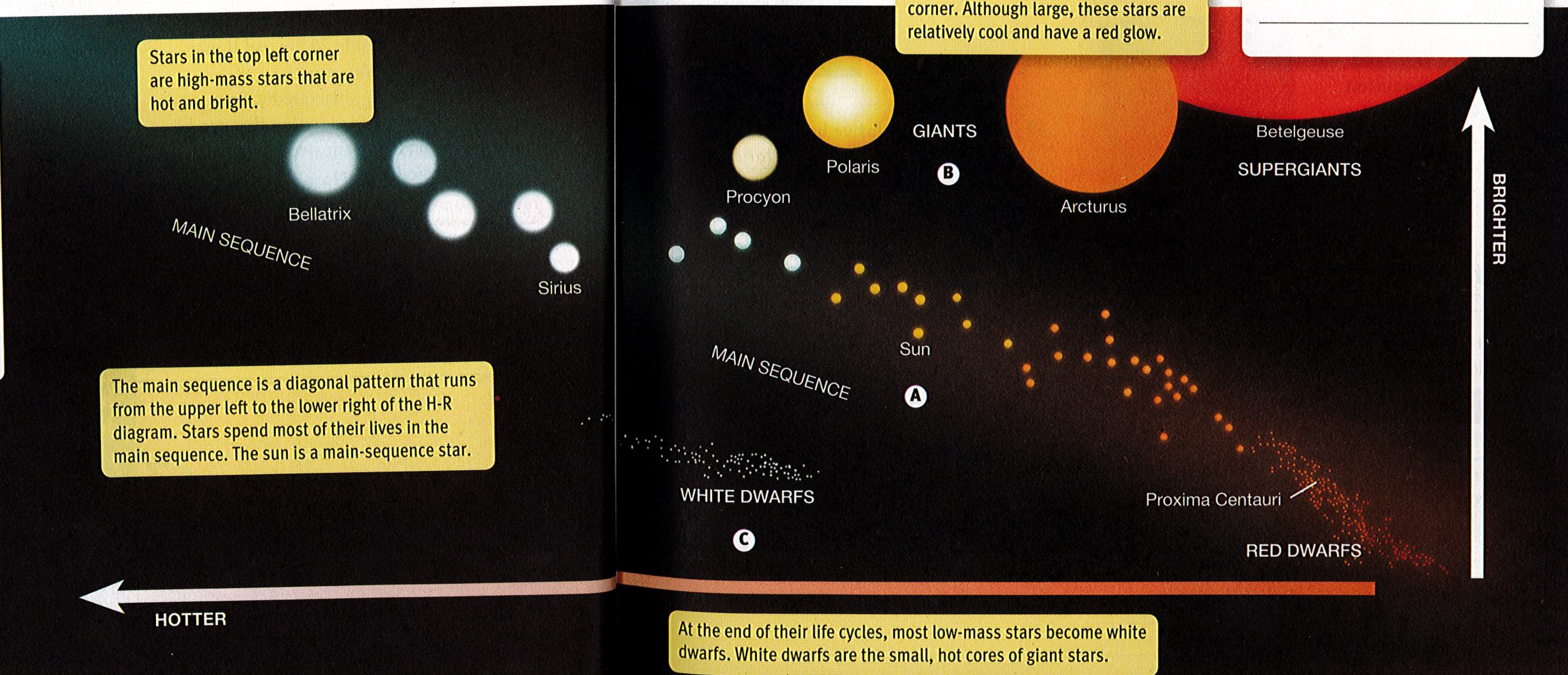
____

____

____

____

____

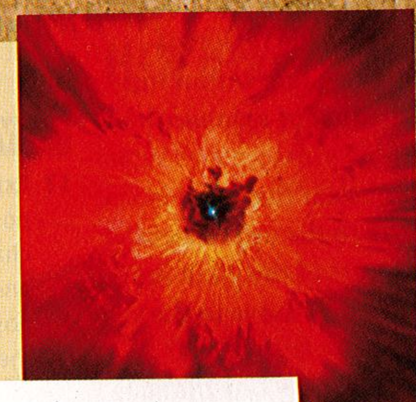


Visual Summary

To complete the summary cards, check the box that indicates true or false. Then, use the key below to check your answers. You can use this page to review the main concepts of the lesson.

The Life Cycle of Stars

Low-mass stars end their lives as white dwarfs.



18 T ☐ F ☐ Carbon and helium combine during nuclear fusion to form hydrogen.

The H-R diagram plots the temperature and brightness of stars.

19 T ☐ F ☐ The relative brightness and temperature of a star change over time.

High-mass stars end their lives as neutron stars or black holes.

20 T ☐ F ☐ High-mass stars spend more time in the main sequence than do low-mass stars.

Answers: 18 F; 19 T; 20 F

21 Synthesize Relate the life stages of a star to the process of nuclear fusion.

Lesson Review

Vocabulary

Draw a line to connect the following terms to their definitions.

1 nebula	**A** a large cloud of gas and dust in space
2 main sequence	**B** an explosion in which the outer layers of a star are thrown off
3 neutron star	**C** a life-cycle stage of stars
4 supernova	**D** a small, very dense star that has formed from the collapsed core of a star

Key Concepts

5 Identify What force causes a star to form from a nebula?

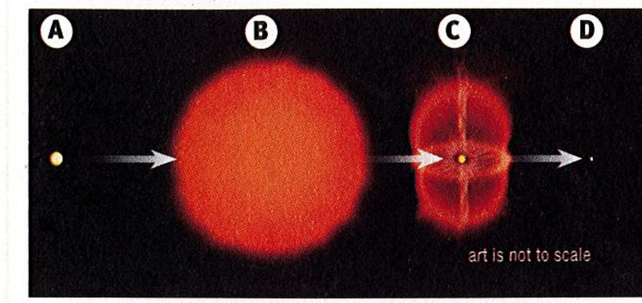
6 Explain What triggers nuclear fusion in stars?

7 Contrast Describe how the life cycle of a low-mass star differs from the life cycle of a high-mass star.

8 Explain Why is the H-R diagram useful in plotting the life cycles of stars?

Critical Thinking

Use this drawing to answer the following questions.



9 Analyze What changes within the star (A) lead to the red giant (B)?

10 Explain Why will the color of the sun change from yellow to red when it becomes a giant?

11 Relate Black holes cannot be seen. However, scientists think that black holes exist because of their effect on surrounding matter. Describe another force or phenomenon that cannot be seen directly. Give examples of the effects of this force on everyday objects.