The Life Cycle of a Star

*Be detailed with notes - discuss elements, energy etc.

Nebula

2. Protostar

3. Main Sequence → More notes on back.

4a. Giant

5a. White Darf

Black Dwarf OR Nova

4b. Super Giant

5b. Supernova

Neutron Star OR Black Hole

Additional Main Phase Notes:

Why is the star able to remain stable?

How long do stars live? ______________________________

More massive stars:

How long do the most massive stars live for? __________

Less massive stars:

How long do the least massive stars live for? __________

* Define in notes or create index cards:

VOCABULARY UNIT 2.4

UNIVERSAL GRAVITATION & STELLAR EVOLUTION

- Centripetal force
- Law of universal gravitation
- Gravitational constant
- Satellite
- Orbit
- Ellipse
- Nebula
- Protostar
- Planetary nebula
- Nova
- Supernova
- Neutron star
- Pulsars
- Black hole
- Nuclear fusion
- Main sequence star
- Giant star
- Supergiant
- White dwarf
- Black dwarf

27.2 Stellar Evolution

Section Objectives

- **Describe how a protostar develops into a star.**
- **Explain how a main-sequence star generates energy.**
- **Describe the possible evolution of a star during and after the giant stage.**

Since a typical star exists for billions of years, astronomers will never be able to observe one star throughout its entire life. Instead, astronomers have developed theories about the evolution of stars by studying stars in different stages of development.

A star begins as a **nebula** (NEB-yuh-luh; pl: nebulae), a cloud of gas and dust, such as the one shown in Figure 27–7. A nebula is usually composed of about 70 percent hydrogen, 28 percent helium, and 2 percent heavier elements. The particles of material in a nebula have a very weak gravitational attraction for one another. When a force, such as from the explosion of a nearby star, compresses some of the particles, the nebula begins to contract.

According to Newton's law of gravitation, gravitational force increases as distance decreases. Therefore, as the density of the particles increases, their gravitational attraction for one another increases. As these particles come together, a sphere of matter builds up within the cloud.

Gravitational forces cause the nebula to continue to shrink. As the nebula becomes smaller, it begins to spin more rapidly. You may have seen the effect of a decreasing diameter on the speed of a spinning object, such as an ice skater. As a spinning skater pulls his or her arms in closer to the body, the rate of spin increases.

The shrinking, spinning nebula begins to flatten into a disk of matter with a central concentration called a **protostar.** The increase in temperature in the center of a protostar has two causes. One cause

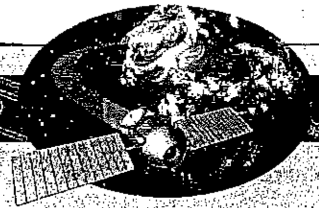
Figure 27–7. The Orion Nebula is a region in which star formation is currently taking place.

is collision. As the particles move toward the center of the nebula, they collide. Whenever solid objects collide, some of the energy of their motion is converted into heat energy. You can demonstrate this principle by rubbing your hands together. The motion of your hands against each other warms them.

Pressure also causes the temperature in the nebula to increase. As the nebula shrinks and the force of gravity pulls matter toward its center, the pressure in the core of the nebula increases. All materials become warmer when compressed. You can observe this principle by again watching an ice skater. The pressure of the skate blade on the ice heats the ice beneath the blade and causes it to melt.

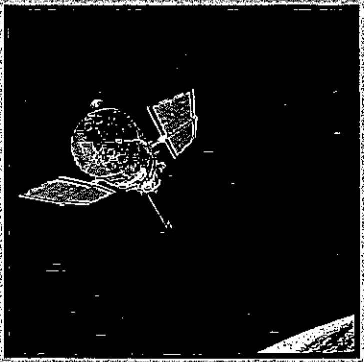
The contracting and heating up of the nebula continues for several million years. As the collisions and pressure raise the temperature in the core of the protostar to over 10,000,000°C, *nuclear fusion* begins. Nuclear fusion is the process through which small atomic nuclei combine to form larger atomic nuclei, releasing energy. When fusion takes place, a protostar begins to generate energy and is considered a star.

A nebula may produce more than a single star. Often two or more stars created out of the same nebula revolve around each other,



SCIENCE & TECHNOLOGY

The Hubble Space Telescope Eyes New Stars



The Hubble Space Telescope has a resolution high enough that it could distinguish two fireflies only 3 m apart, as well as their individual flashes, at a distance comparable to that between Washington, D.C., and Tokyo.

From its orbit around the earth, the Hubble Space Telescope has photographed newborn stars emerging from huge pillars of dense gas and dust. Such events are by no means local. The Hubble Space Telescope recorded the events occurring some 7,000 light-years away, in the Eagle Nebula. The largest of the pillars photographed by the Hubble telescope is shown at right. It is estimated to be 10 trillion kilometers high.

These pillars are thought to result from a process called *photoevaporation*. In this process, high-energy photons from intensely hot stars nearby bombard the nebula. This bombardment strips away the outer layers of gas and dust, leaving pillars of dense material that contain *evaporating gas globules*, or *EGGs*. The gas and dust in these globules is so dense that the globules may further condense to form new stars.

By watching stars form in the Eagle Nebula, astronomers may be able to answer the question, What determines a star's size? After studying Hubble's images, astronomers already have a better idea of how mature stars can affect the growth and size of a developing star. Photoevaporation caused by a mature star may strip away enough gas and dust from around an EGG that the

the force of gravity keeping them close together. A contracting nebula may also produce planets that revolve around a central star. Astronomers think that the sun, the earth, and the other planets in our solar system all formed at about the same time from the same nebula.

Main-Sequence Stars

The second and the longest stage in the life of a star is the main-sequence stage. During this stage, energy is generated in the core of the star as hydrogen atoms fuse to become helium atoms. Fusion releases enormous amounts of radiant energy. For example, when 1 g of hydrogen is converted into helium, the energy released is enough to keep a 100-W light bulb burning for 3,000 years. This energy moves outward in much the same way that energy rises upward through boiling water. The star does not expand, however, because the force of gravity pulls the matter inward. The energy from fusion balances the force of gravity, making the star stable in size. A main-sequence star maintains a stable size as long as it has an ample supply of hydrogen to fuse into helium.

developing star's growth is stunted. If enough gas and dust is stripped away, the star may be prevented from forming in the first place. Photoevaporation may also prevent planets from forming around newborn stars.

However, photoevaporation is not a factor in the growth of all stars. Stars that form in isolation continue to condense, pulling in additional material until nuclear fusion begins. The newborn star's own radiant energy then produces a stellar wind that sweeps away any remaining material.

The Hubble Space Telescope will continue to advance our knowledge of the universe at least until the year 2005, when its guaranteed funding runs out. Already, the telescope has seen farther into space than any preceding it and has provided images in unprecedented detail of almost every type of celestial body known to astronomers.

Why would planets be unlikely to form around the stars in the Eagle Nebula?

The EGGs in the photograph lie at the tips of fingerlike protrusions extending from this pillar. Each EGG is slightly larger in diameter than our solar system. ▶

Giants and Supergiants

A star enters its third stage when almost all of the hydrogen atoms within its core have fused into helium atoms. Without hydrogen as a source of fuel, the core of a star contracts under the force of the star's gravity. This contraction increases the temperature in the core of the star. The higher temperature causes the helium atoms in the core to fuse into carbon atoms. Hydrogen fusion continues to take place in a shell surrounding the helium core.

The combined hydrogen fusion and helium fusion release energy, which causes the outer shell of the star to expand greatly. The star's shell of gases grows cooler as it expands. The star is no longer a main-sequence star. Instead, it has become a giant or a supergiant. Giants are 10 or more times bigger than the sun. Supergiants are at least 100 times bigger than the sun.

The stages in the life of a star cover an enormous period of time. Scientists estimate that over a period of 5 billion years, the sun, a main-sequence star, has converted only 5 percent of its original hydrogen.

White Dwarf Stars

The end of helium fusion marks the end of the giant stage in the evolution of a medium-sized star. With energy no longer available from fusion, the star enters its final stages. The star loses its outer gases, revealing a core, which for a time heats and illuminates the expanding gases, which appear as a **planetary nebula.** Gravity causes the last of the matter in the star to collapse inward. What is left is a hot, dense core of matter—a white dwarf. White dwarfs shine for billions of years before they cool completely.

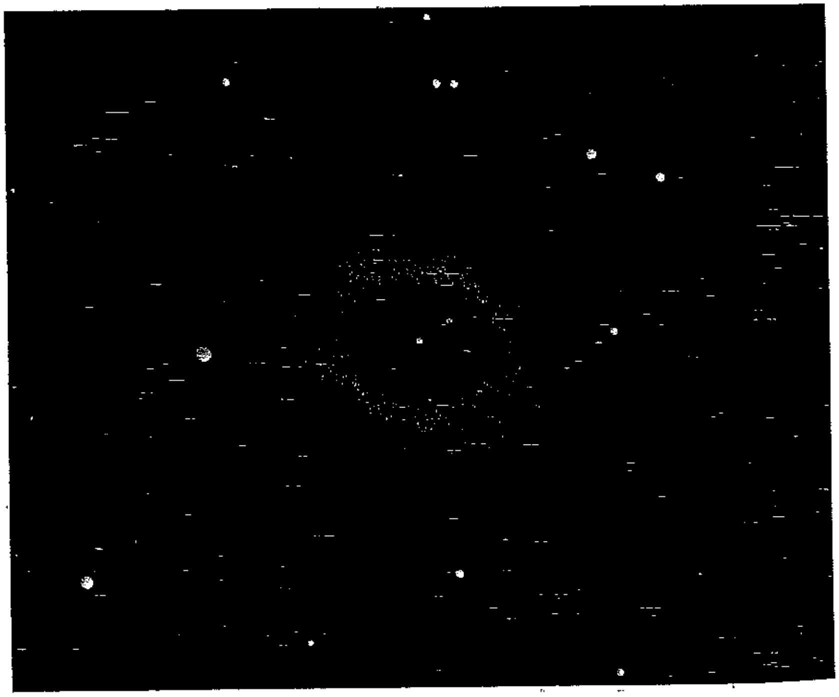


Figure 27–8. The outer shell of expanding gas around a dying star is a planetary nebula. The ring nebula in Lyra is shown here.

As white dwarfs cool, they become fainter and fainter. When a white dwarf no longer emits energy, it may become a dead star or *black dwarf.* Black dwarfs probably do not exist yet, as the universe is not old enough to have produced them. This may be the final stage for many stars.

Novas Some white dwarfs do not just cool and die. During the process of cooling, one or more large explosions may occur that release energy, gas, and dust into space. A white dwarf that has such an explosion is called a **nova.** The explosion may cause the star to become many thousands of times brighter. A nova may appear up to 1 million times brighter than the sun. Then, sometimes within only a few days, the nova begins to fade back to its normal brightness. A white dwarf may become a nova several times.

Astronomers think that a nova is most likely to occur in a white dwarf that revolves around a main-sequence star or a giant star. White dwarfs are denser than main-sequence stars and giants. Therefore, the white dwarf would have a greater surface gravity than its companion. As gases from the companion star accumulate on the white dwarf, the pressure builds until the white dwarf explodes as a nova.

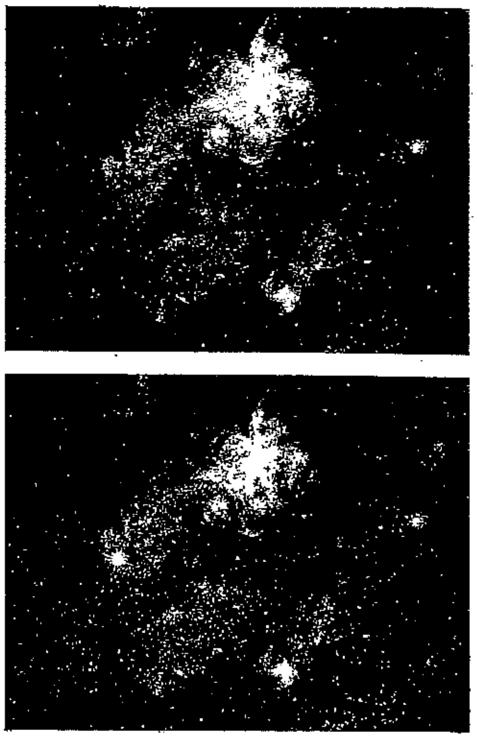


Figure 27–9. Supernova 1987A, shown here before and after, resulted from the explosion of a blue supergiant star. Visible only from the Southern Hemisphere, it was the brightest supernova in nearly 4 centuries.

Supernovas

Stars with masses 10 to 100 times that of the sun may produce explosions up to 100 times brighter than novas. In 1054, Chinese astronomers saw an explosion in the sky that was so bright they could see it during the day for three weeks. The amount of energy radiated during that time was equal to the energy produced by the sun over a period of 500 million years. What the Chinese astronomers saw was a **supernova,** a star that has such a tremendous explosion that it blows itself apart.

Supernovas occur in stars much larger than those that produce novas. After the supergiant stage, these larger stars contract with a gravitational force much greater than that of smaller stars. The collapse produces such high pressures and temperatures that nuclear fusion begins again. This time carbon atoms in the core of the star fuse into heavier elements, such as magnesium. These heavier elements then fuse into iron.

Fusion continues until the core is almost entirely iron. At this point, nuclear fusion stops. The iron begins to absorb huge amounts of energy from gravitational attraction. The iron core collapses, causing the outer part of the star to explode. During the explosion, the energy released approximately equals the amount of energy radiated by an ordinary star over its lifetime.

Neutron Stars After an explosion, the core of a supernova may contract into a very small but incredibly dense ball of neutrons, called a **neutron star.** A spoonful of matter from a neutron star would weigh 100 million tons on the earth. A neutron star with more mass than the sun may have a diameter of only about 30 km. Neutron stars rotate very rapidly.

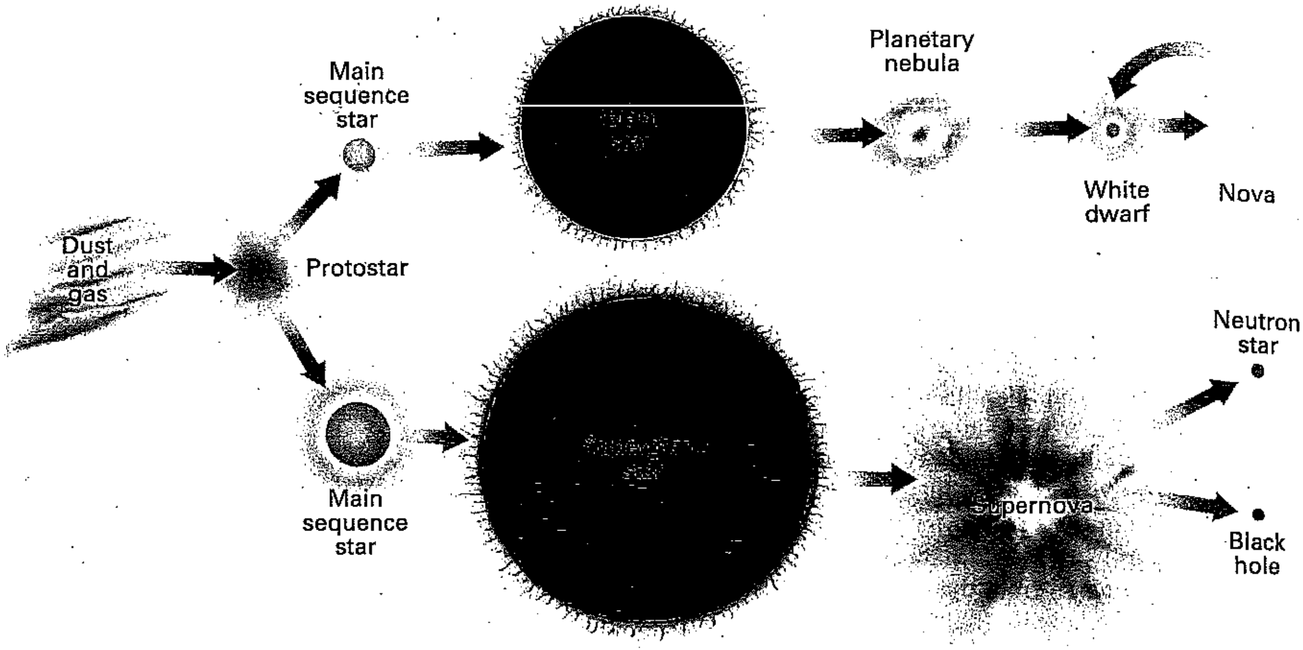


Figure 27–10. A star the size of the sun becomes a white dwarf near the end of its life cycle. A larger star may become a neutron star or a black hole.

Some neutron stars emit two beams of radiation that sweep across space like the light beams from a lighthouse. These neutron stars are called **pulsars.** Astronomers detect the radiation from most pulsars as radio waves.

Black Holes Some massive stars produce leftovers that are too massive to become neutron stars. These stars contract with even greater force. The force of the contraction crushes even the dense core of the star, leaving what astronomers think is a hole in space, or a **black hole.** The gravity of a black hole is so great that not even light can escape from it.

Since black holes do not give off light, locating them is difficult. However, astronomers theorize that a black hole can be observed by its effect on a companion star. Matter from the companion star is pulled into the black hole, disappearing forever from the universe. Just before the matter is pulled in, X rays are given off. Astronomers try to locate black holes by detecting these X rays. In the 1970's, astronomers identified what they think is a black hole within the constellation Cygnus. Today, astronomers speculate that massive black holes may be at the cores of many galaxies.

Section 27.2 Review

1. List two reasons why the temperature of a protostar increases.
2. What is the process that generates energy in the core of a main-sequence star?
3. What form of fusion occurs in a giant star?
4. What causes a nova explosion?
5. Explain why only very large stars can form black holes.

Chapter 27 Review

Key Terms

- absolute magnitude (553)
- apparent magnitude (552)
- barred spiral galaxy (563)
- binary star (564)
- black hole (560)
- circumpolar (549)
- constellation (561)
- elliptical galaxy (563)
- galaxy (562)
- giant (554)
- globular cluster (564)
- H-R diagram (553)
- irregular galaxy (563)
- light-year (550)
- main-sequence star (554)
- nebula (555)
- neutron star (559)
- nova (559)
- open cluster (564)
- parallax (550)
- planetary nebula (558)
- protostar (555)
- pulsar (560)
- quasar (565)
- red shift (550)
- spiral galaxy (563)
- star (547)
- supergiant (554)
- supernova (559)
- white dwarf (554)

Key Concepts

To determine the composition and surface temperature of a star, astronomers study the spectrum of the star. **See page 547.**

The stars appear to move westward around a central point and to move westward on successive nights across the sky. **See page 548.**

To measure the distance to a star from the earth, astronomers use direct and indirect methods. **See pages 550–553.**

Apparent magnitude and absolute magnitude are two ways of characterizing the brightness of a star. **See page 552.**

A protostar is considered a star when it begins to generate energy. **See page 555.**

A main-sequence star generates energy through hydrogen fusion. **See page 557.**

A giant is a large, cool star with a core in which helium fusion is occurring. **See page 558.**

A constellation is a visible star group that was identified by past cultures and is used by astronomers to divide the sky into sectors. **See page 561.**

Astronomers have identified three main types of galaxies. **See page 563.**

The big bang theory is the most widely accepted explanation of the formation of the universe. **See page 564.**

Review

On your own paper, write the letter of the term that best completes each of the following statements.

1. In the majority of stars, the most common element is
   a. oxygen. b. helium. c. hydrogen. d. sodium.
2. The color of the hottest stars is
   a. red. b. yellow. c. green. d. blue.
3. Stars appear to move in circular paths around Polaris because
   a. the earth rotates on its axis.
   b. the earth orbits the sun.
   c. the stars revolve around Polaris.
   d. Polaris is the center of the Milky Way Galaxy.
4. The change in position of a nearby star compared with the position of a faraway star is called
   a. parallax. b. red shift.
   c. blue shift. d. a Cepheid variable.
5. The brightest stars have apparent magnitudes that are
   a. over +20. b. between +10 and +19.
   c. between +1 and +9. d. negative numbers.

6. The absolute magnitude of a star is
a. the relative brightness of the star.
b. the true brightness of the star.
c. the comparative brightness of the star.
d. the apparent brightness of the star.

7. A protostar becomes a star when it begins to
a. develop a red shift.
b. generate energy.
c. shrink and spin.
d. explode as a nova.

8. A main-sequence star generates energy by fusing
a. nitrogen into iron.
b. helium into carbon.
c. hydrogen into helium.
d. nitrogen into carbon.

9. A dying star can shed some of its gases as a
a. planetary nebula.
b. white dwarf.
c. globular cluster.
d. supernova.

10. Black holes are difficult to locate because they
a. move very quickly.
b. do not give off light.
c. have very low gravity.
d. are far away from any stars.

11. A pattern of stars is called a
a. galaxy.
b. nebula.
c. pulsar.
d. constellation.

12. Stars appear in fixed locations in the sky because they
a. are so far from the earth.
b. do not move.
c. are all moving toward the earth.
d. are all in the same galaxy.

13. The basic types of galaxies are
a. spiral, elliptical, and irregular.
b. barred, elliptical, and open.
c. spiral, quasar, and pulsar.
d. open, binary, and globular.

14. Quasar formation is associated with
a. nuclear fusion.
b. main-sequence stars.
c. the explosion of a supernova.
d. the big bang.

Critical Thinking

On your own paper, write answers to the following questions.

1. If the spectrum of a star indicates that the star shines with a red light, approximately what is the surface temperature of the star?
2. Why are different constellations visible during different seasons of the year?
3. Explain why Polaris is considered to be a very bright star even though it is not a bright star in the earth's sky.
4. Why does heat build up more rapidly in a massive protostar than in a less massive one?
5. Explain why an old main-sequence star will be composed of a higher percentage of helium than will a young main-sequence star.
6. If all galaxies began to show blue shifts, what would this indicate about the size of the universe?

Application

1. If you determined that a certain star displayed a large parallax, what could you say about its distance from the earth?
2. Suppose that a scientist has discovered a red-dwarf star. Describe the likely size and surface temperature of such a star.
3. When looking through a nearby university's telescope, you observed a galaxy that has no young stars and contains little dust or gas. What kind of galaxy were you probably looking at?

Extension

1. The modern scale of star magnitudes is based on a system established in 129 B.C. by Hipparchus of Nicea. Conduct library research to find out how the modern scale differs from the one introduced by Hipparchus.
2. In February 1987, astronomers saw a supernova explosion in the Large Magellanic Cloud. Because Ian Shelton was the first astronomer to notice it, the explosion is known as Shelton's Supernova. Write a report on Shelton and his historic discovery.
3. Make a storyboard showing the development of the universe according to the widely accepted big bang theory.