Passage VII

A Hertzsprung-Russell (H-R) diagram is used to plot the luminosity (or true brightness) of a star versus its surface temperature. Luminosity is typically expressed in relation to the luminosity of the Sun (solar units). For example, a star with a luminosity of 2 solar units would emit twice as much energy as does our Sun. Surface temperatures of stars are expressed in kelvins (K).

Stars plotted on an H-R diagram generally fall into four main regions: main sequence, red giants, supergiants, and white dwarfs. All main sequence stars (which comprise approximately 90% of all stars) undergo hydrogen fusion in their cores. The heat and pressure created by fusion prevent gravitational forces acting inward from crushing the star.

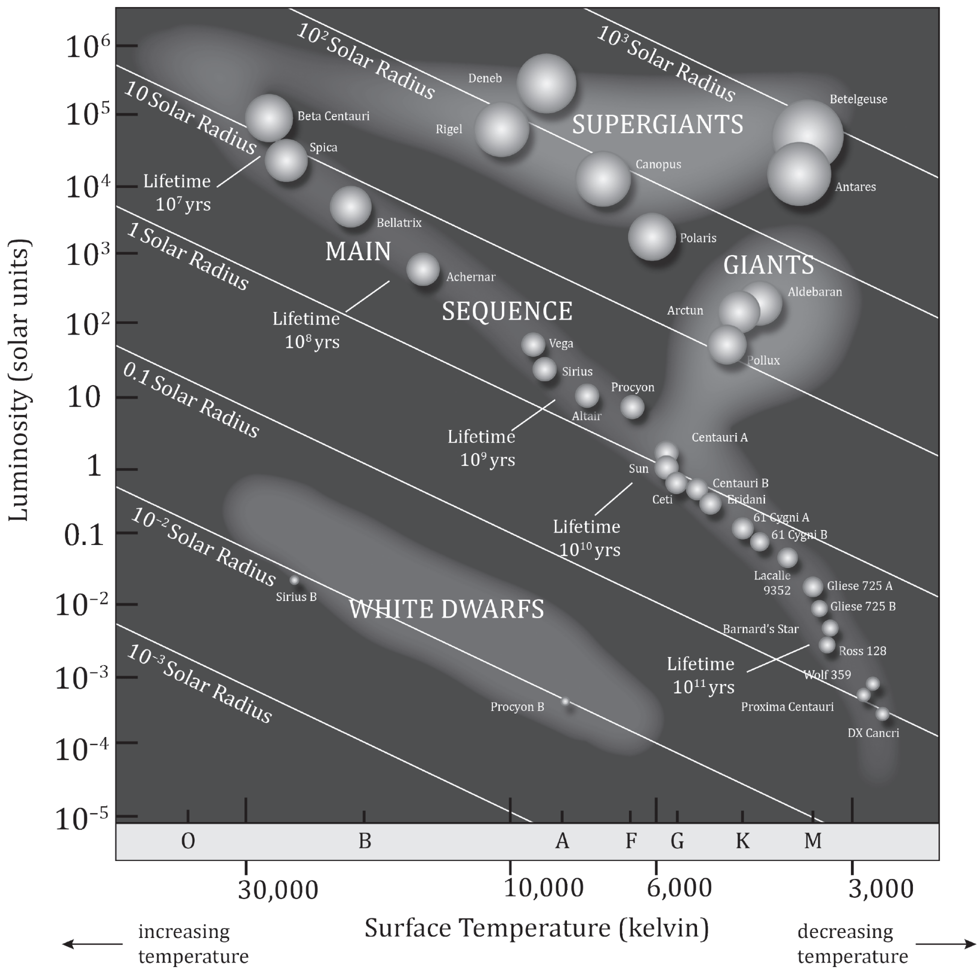

Figure 6

The evolutionary fate of main sequence stars depends on their mass. When mid-mass main sequence stars, such as the Sun, run out of hydrogen in their cores, other fusion reactions occur; and the stars expand to become red giants. When fusion stops altogether, after a brief transitory phase called a planetary nebula, the cores of mid-size stars remain as planet-sized, very hot objects called white dwarfs. From birth to death, mid-mass stars exist on the order of billions of years.

Main sequence stars with much more mass than the Sun appear in the upper left of the H-R diagram. When hydrogen fusion ceases in the cores of these rare stars, other fusion reactions support the star, and they evolve into red supergiants. Eventually, when fusion reactions in their cores cease altogether, gravity begins to crush the stars and runaway thermonuclear reactions cause the outer layers to explode in an event called a supernova. The spent cores of these stars become either neutron stars or black holes. Neither neutron stars nor black holes appear on the H-R diagram. Large mass stars exist for the shortest amount of time—just millions of years—because they burn through their fuel quickly.

Finally, the majority of all main sequence stars have much less mass than the Sun. Fusion reactions in their cores take place at a much slower rate. In fact, these stars will remain on the main sequence for trillions of years. Since the universe is only 13.8 billion years old, not a single low-mass star has yet to evolve off the main sequence.

The diagram below shows the Sun's future evolutionary journey on the H-R diagram.

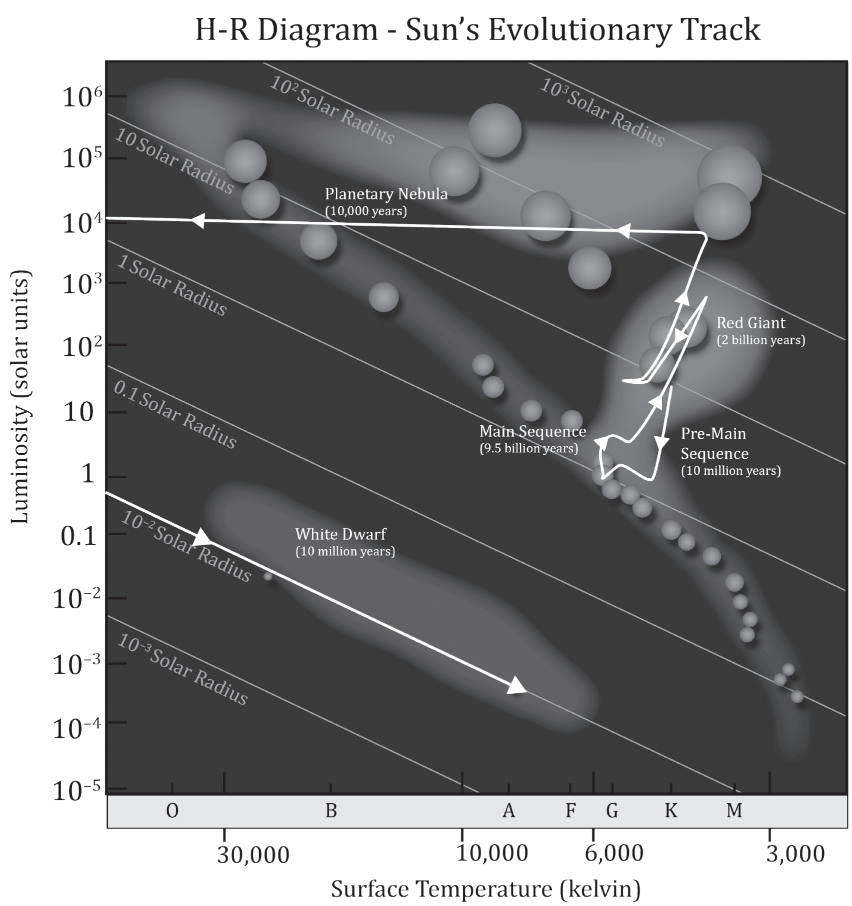

Figure 7

Passage VIII

When an object from space strikes the surface of a solid planet or moon, the result is a crater. The edges of the crater are called the rim of the crater. Surrounding the crater is material called ejecta, which is thrown from the point of impact by the impactor (object striking the surface) (see Figure 8). The size of the crater is a function of both the velocity and mass of the impactor.

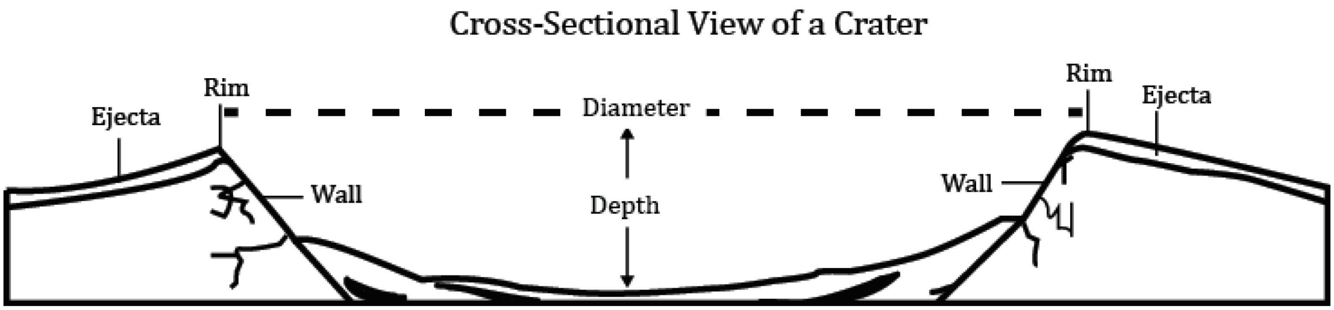

Figure 8

A team of students conducted experiments to determine how mass and velocity affect crater formation.

Experiment 1

The students filled a box with sand. They then dropped smooth spheres made of different materials but with identical diameters into the box. The objects were all dropped from a height of 1.0 meter and therefore had approximately the same velocity upon impact with the sand. (The effect of air resistance is assumed to be negligible.) The students measured the diameter of each crater formed in the sand from rim to rim. The students conducted multiple trials for each sphere, leveling the sand after each trial, and recorded the data in Table 9.

Table 9

Material/ Mass of Impactor (grams)	Crater Diameter (centimeters)				
	Trial 1	Trial 2	Trial 3	Trial 4	Average
Cork (1.8 g)	3.8	3.7	3.9	3.8	3.8
Wood (5.7 g)	5.1	5.1	5.4	4.7	5.1
Glass (21.4 g)	6.2	6.3	6.1	6.5	6.3
Aluminum (27.1 g)	6.5	6.1	6.5	6.4	6.4
Steel (64.1 g)	8.0	8.6	8.5	8.6	8.4

Experiment 2

To determine how velocity affects crater diameter, the students used only the steel sphere, dropped from four different heights. The velocity of the sphere at each height was determined using the equation:

$$v = \sqrt{2gh} \qquad \text{Equation 1}$$

where v is the velocity of the impactor in meters/second as it hits the sand, g is the acceleration due to gravity (9.8 meters/second-squared) and h is the drop height in meters. The data from this experiment are recorded in Table 10.

Table 10

Drop Height (meters)	Velocity of Impactor (meters/second)	Crater Diameter (centimeters)				
		Trial 1	Trial 2	Trial 3	Trial 4	Average
0.5	3.1	5.4	5.6	5.5	5.5	5.5
1.0	4.4	8.4	8.6	8.1	8.5	8.4
1.5	5.4	10.1	9.3	9.9	9.9	9.8
2.0	6.3	11.0	11.3	10.9	10.9	11.0