Module 3: Astronomy – The Universe

Topic 3 Content: The Evolution of Stars Presentation Notes

You may have noticed that all stars are not the same. Some stars are large, while some are quite small. Some stars are blue, while some are red. Like humans, stars change over time. Stars vary in composition and in temperature based on the mass that they gather during their birth and their different stages of stellar evolution.

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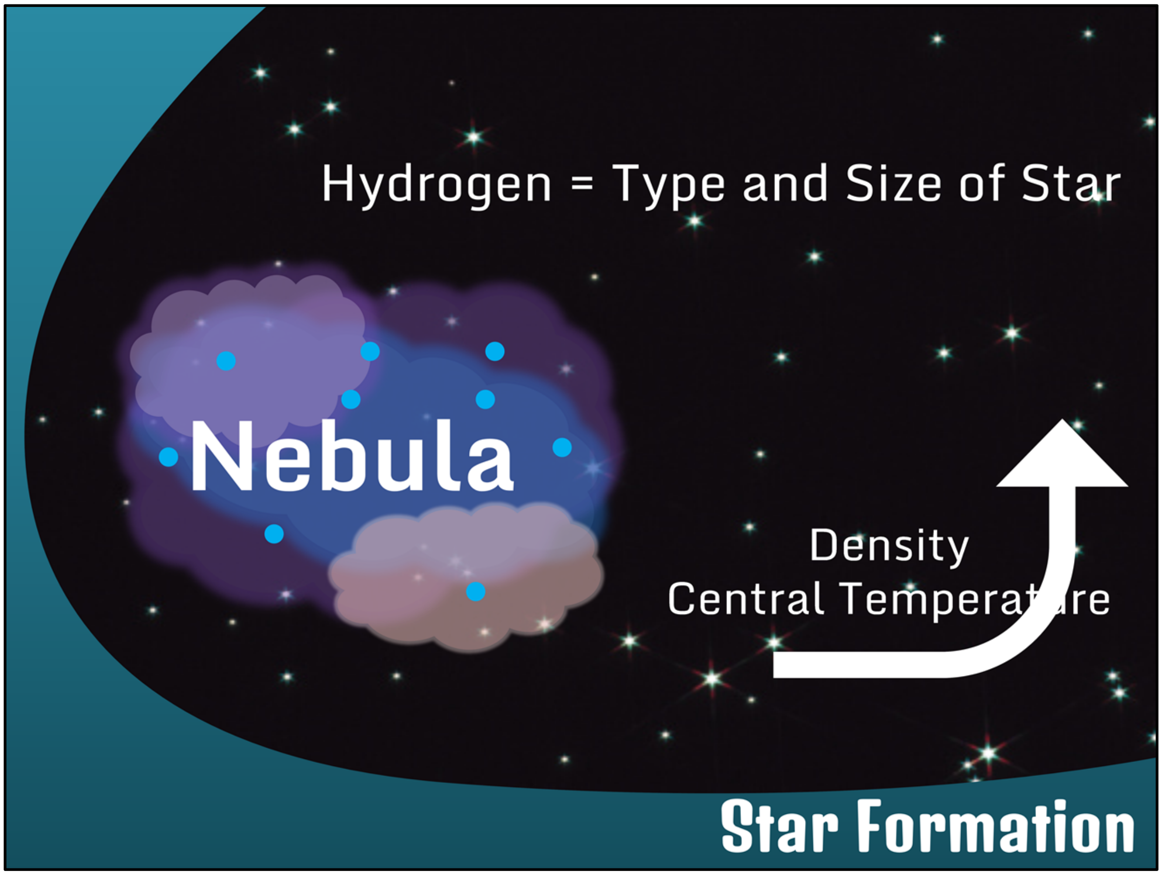
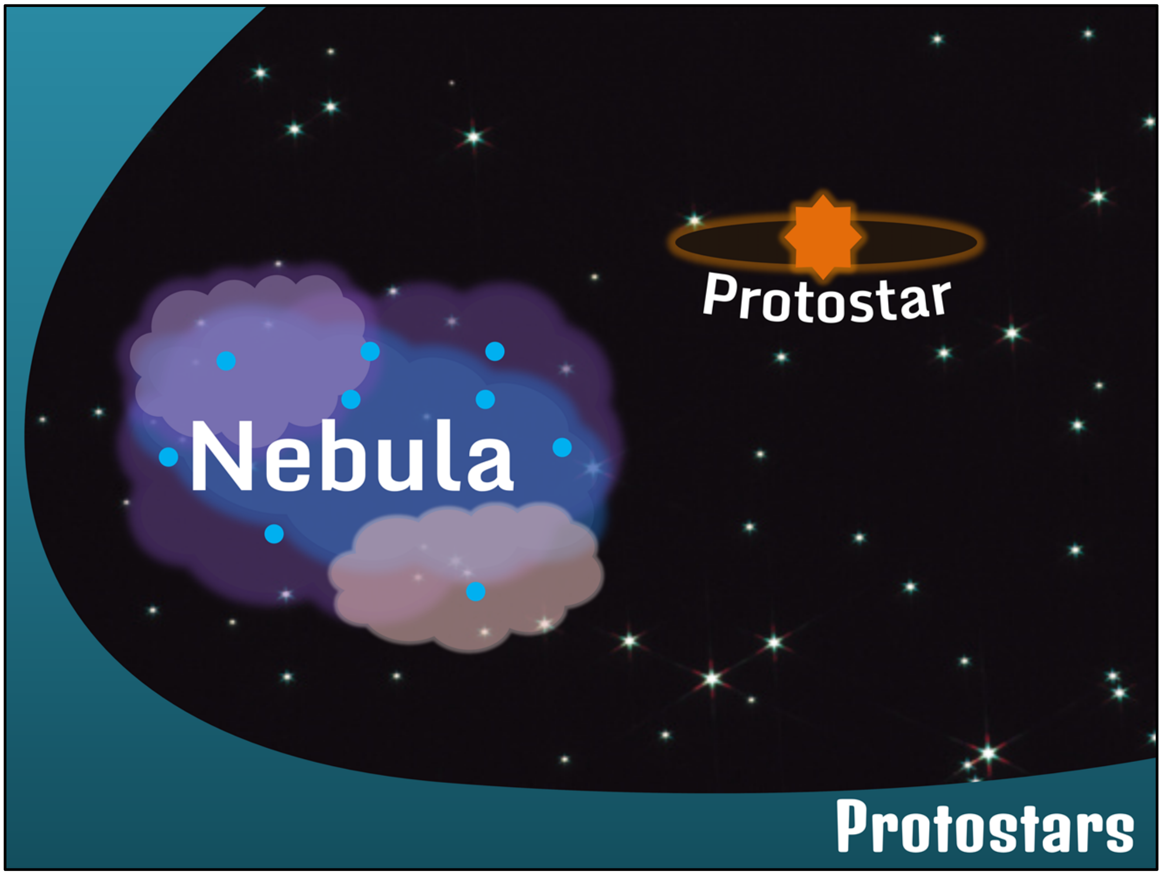
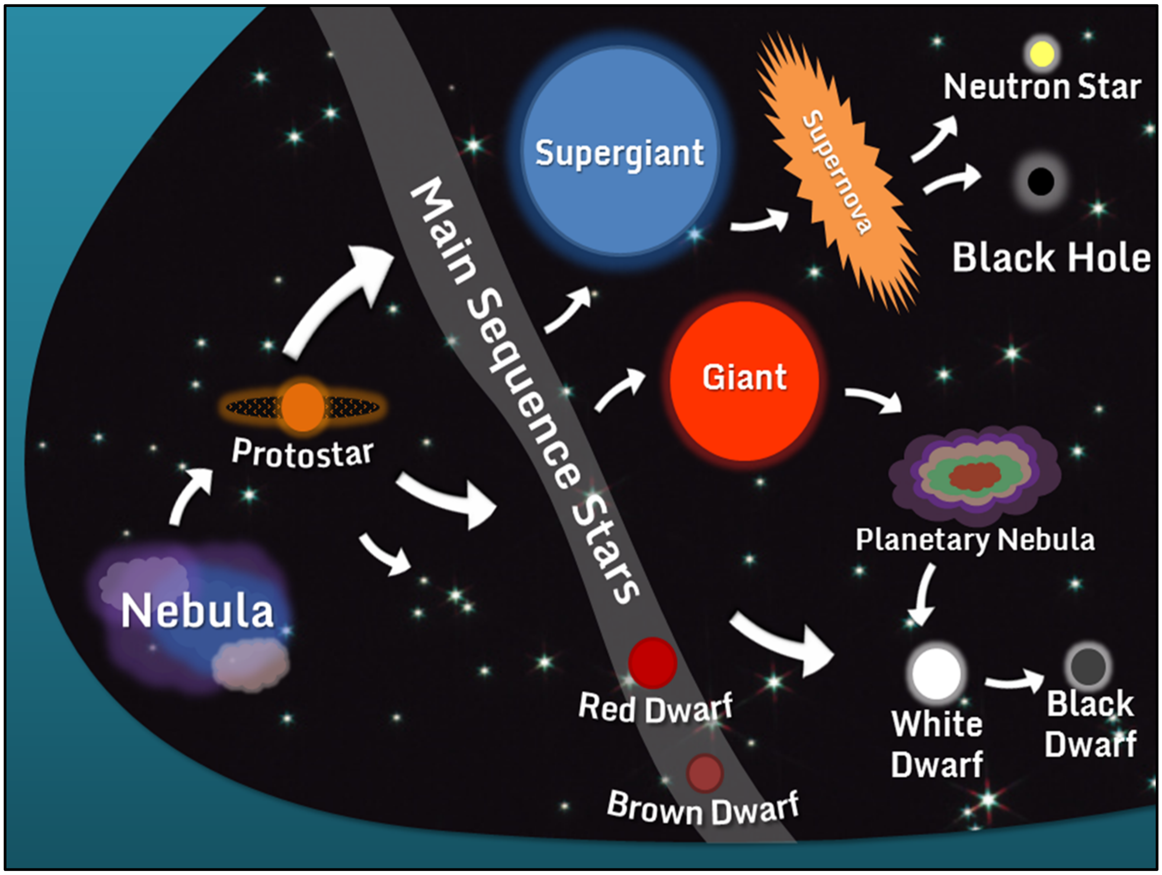


Star formation begins in one of the darker regions of an interstellar cloud, or nebula. The dark cloud starts to collapse due to its own weight. Over time, this larger interstellar cloud will end up being broken down into multiple smaller clouds of gas and dust. The amount of hydrogen gas that is present in each smaller cloud fragment will play a large role in a star's ultimate spectral type and size. The amount of pressure and high temperature correlate to how fast the molecules in the cloud are moving. The pressure of the molecules pushing outward prevents the gravity of the cloud from collapsing in on itself. As the cloud fragment continues to go through these outward changes, its interior is also going through a lot of changes. Its central density and central temperature are increasing at an exponential rate.



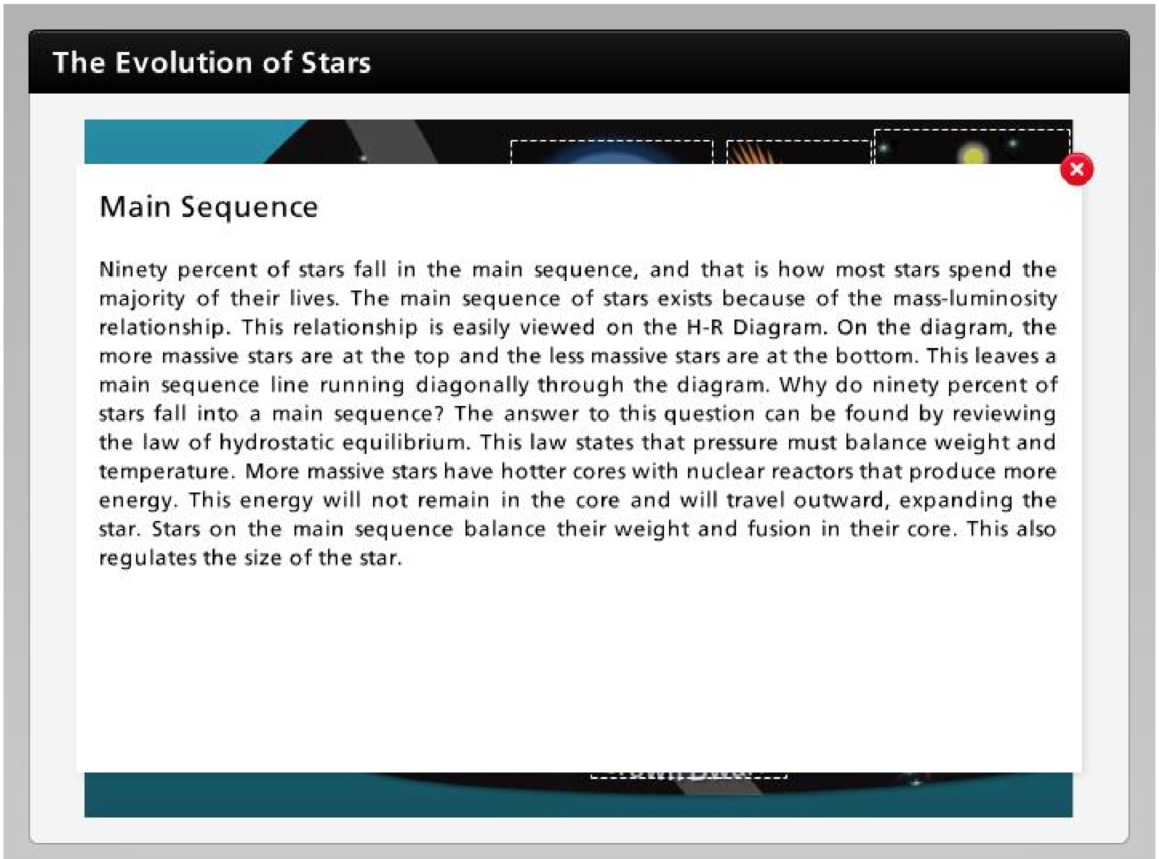
As the nebula continues to contract upon itself, the temperature in the cloud will increase. This heats the dust to temperatures that range from 60 to 100 Kelvin. The heated dust makes the cloud collapse even further. The cloud continues to get hotter, and thus pressure increases until the temperature and pressure are so high that the cloud can no longer contract upon itself. It is at this time that a protostar is born. During this stage in the formation of a star, the composition is constantly changing. The protostar accretes materials from the cloud. This means that the protostar grows from the collection of materials it gathers from the cloud. Astronomers have a difficult time studying this stage in star development. The cloud blocks a lot of the visible light needed to analyze the elements that make up the composition of the protostar.



At a certain temperature, the star begins the fusion process. The hydrogen gas from the cloud will now begin to fuse into helium. A star is formed and will follow a path of stellar evolution. Stars evolve based on how much material they accrete, becoming a low-mass star, a medium-mass star, or a high-mass star. Stars of different masses produce different elements in the fusion process. This happens because different mass stars have different temperatures. At high temperatures, helium begins to fuse into carbon and oxygen. At even higher temperatures, carbon begins to fuse into neon, sodium, magnesium, and oxygen. Neon will fuse into oxygen and magnesium. Oxygen will fuse into silicon, sodium, and phosphorus. Silicon will fuse into nickel and iron.

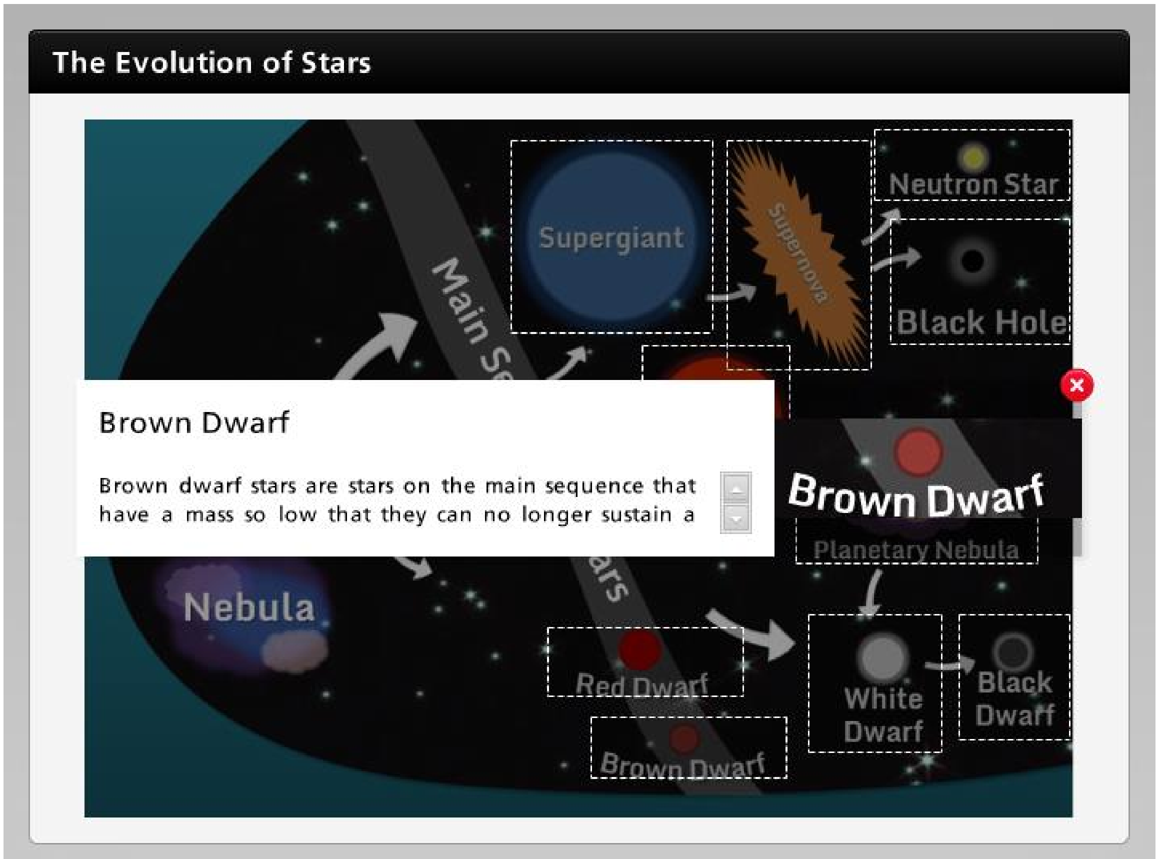
From birth, a star's life is planned. Eventually, all stars will run out of the fuel that they need to produce energy. Some stars are more efficient and can last for much longer periods of time than others. There are a variety of options that can occur when a star loses the fight between gravity and pressure. This occurs when the gravity of the core can no longer prevent the outward push of pressure. Truly, a star's life depends on the amount of material it acquires from the nebula in the initial phase of its life. Just like the birth of stars, the death of stars will depend on the mass of the star. Low-mass stars will ultimately have a different outcome from high-mass stars.

Main Sequence



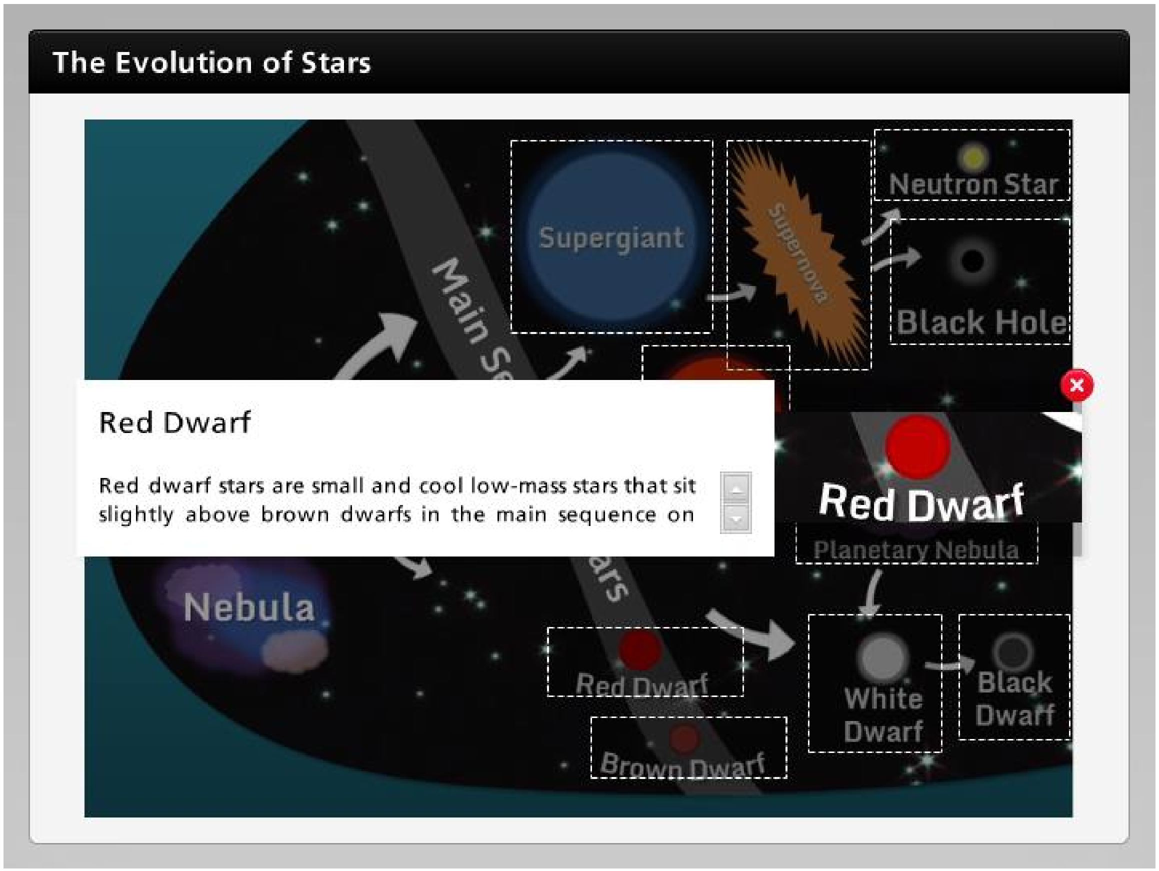
Ninety percent of stars fall in the main sequence, and that is how most stars spend the majority of their lives. The main sequence of stars exists because of the mass-luminosity relationship. This relationship is easily viewed on the H-R Diagram. On the diagram, the more massive stars are at the top and the less massive stars are at the bottom. This leaves a main sequence line running diagonally through the diagram. Why do ninety percent of stars fall into a main sequence? The answer to this question can be found by reviewing the law of hydrostatic equilibrium. This law states that pressure must balance weight and temperature. More massive stars have hotter cores with nuclear reactors that produce more energy. This energy will not remain in the core and will travel outward, expanding the star. Stars on the main sequence balance their weight and fusion in their core. This also regulates the size of the star.

Brown Dwarf



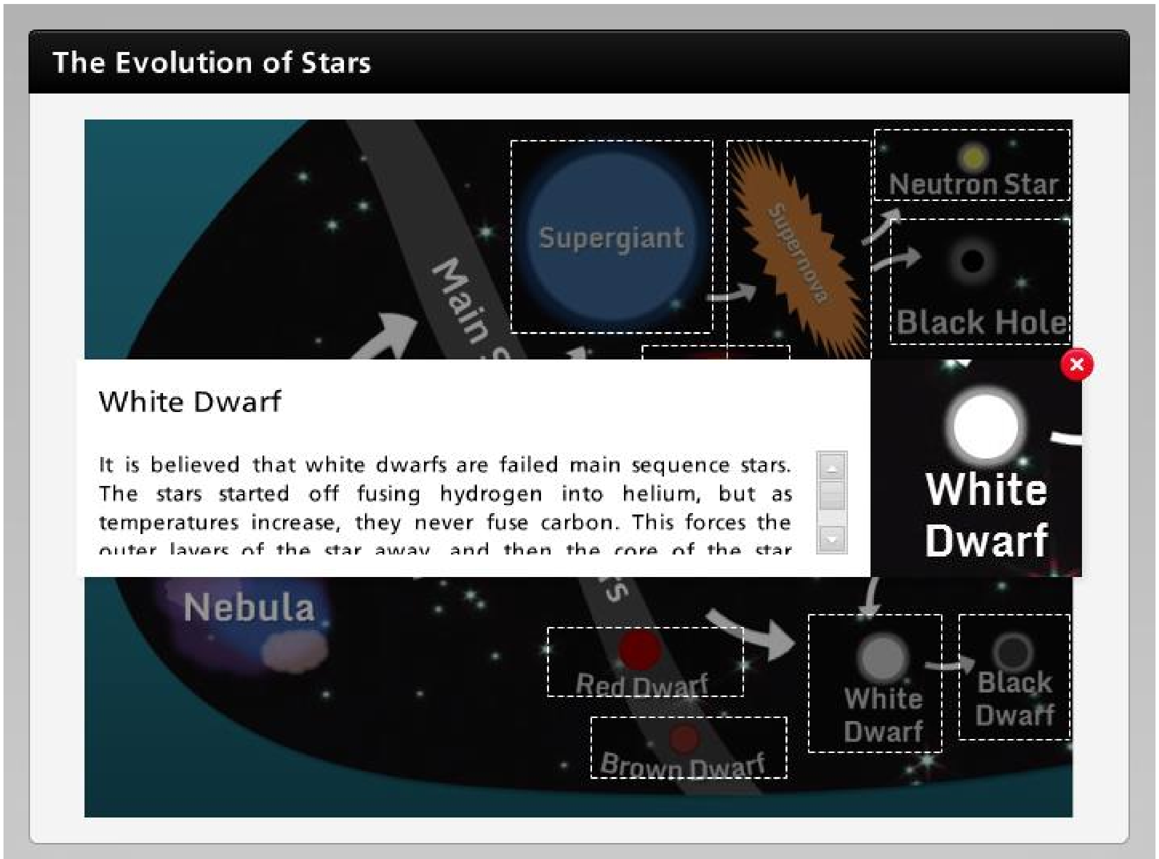
Brown dwarf stars are stars on the main sequence that have a mass so low that they can no longer sustain a fusion reaction in their core. They are about the size of a large gas giant planet. Some astronomers disagree about whether or not these stars should actually be considered giant gaseous planets, rather than stars. On the H-R Diagram, brown dwarf stars are located below the red dwarfs. Brown dwarfs are very cool and not very luminous.

Red Dwarf



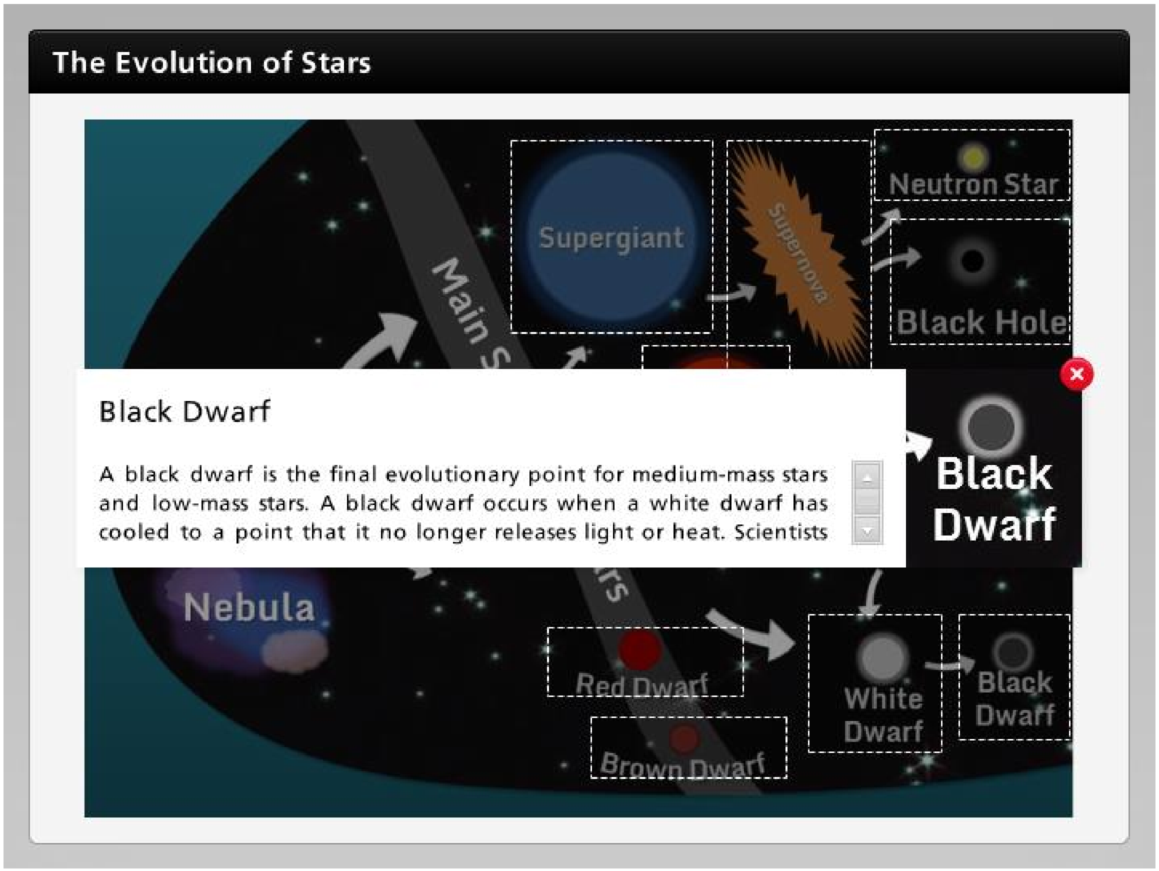
Red dwarf stars are small and cool low-mass stars that sit slightly above brown dwarfs in the main sequence on the lower right corner of the H-R Diagram. These stars actually account for the majority of stars. They contain less than half of the Sun's mass. Red dwarf stars are well-balanced, and fusion takes place very slowly, so they can live for billions of years. This is due to the small amount of weight that these stars have to support. Astronomers have not found any evidence that these stars advance to another evolutionary stage.

White Dwarf



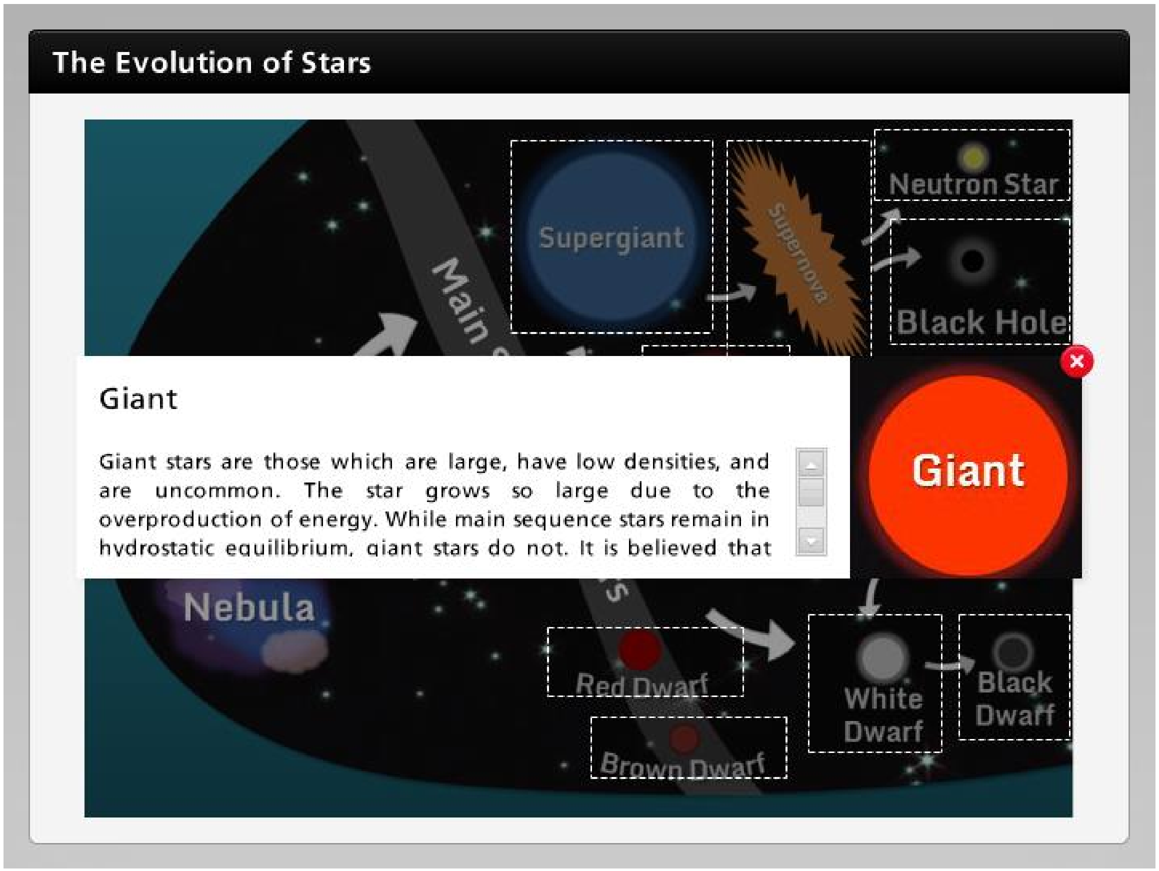
It is believed that white dwarfs are failed main sequence stars. The stars started off fusing hydrogen into helium, but as temperatures increase, they never fuse carbon. This forces the outer layers of the star away, and then the core of the star collapses and cools, forming the white dwarf star. These stars shed some light because they have some stored heat energy. On the H-R Diagram, white dwarf stars are located off of the main sequence. They are less luminous then a main sequence star. Their lack of luminosity occurs because these stars no longer undergo the process of fusion.

Black Dwarf



A black dwarf is the final evolutionary point for medium-mass stars and low-mass stars. A black dwarf occurs when a white dwarf has cooled to a point that it no longer releases light or heat. Scientists hypothesize that the amount of time that it would take for a white dwarf to cool this significantly would be longer than the current age of the Universe. Therefore, scientists have not been able to observe a black dwarf, since none currently exist.

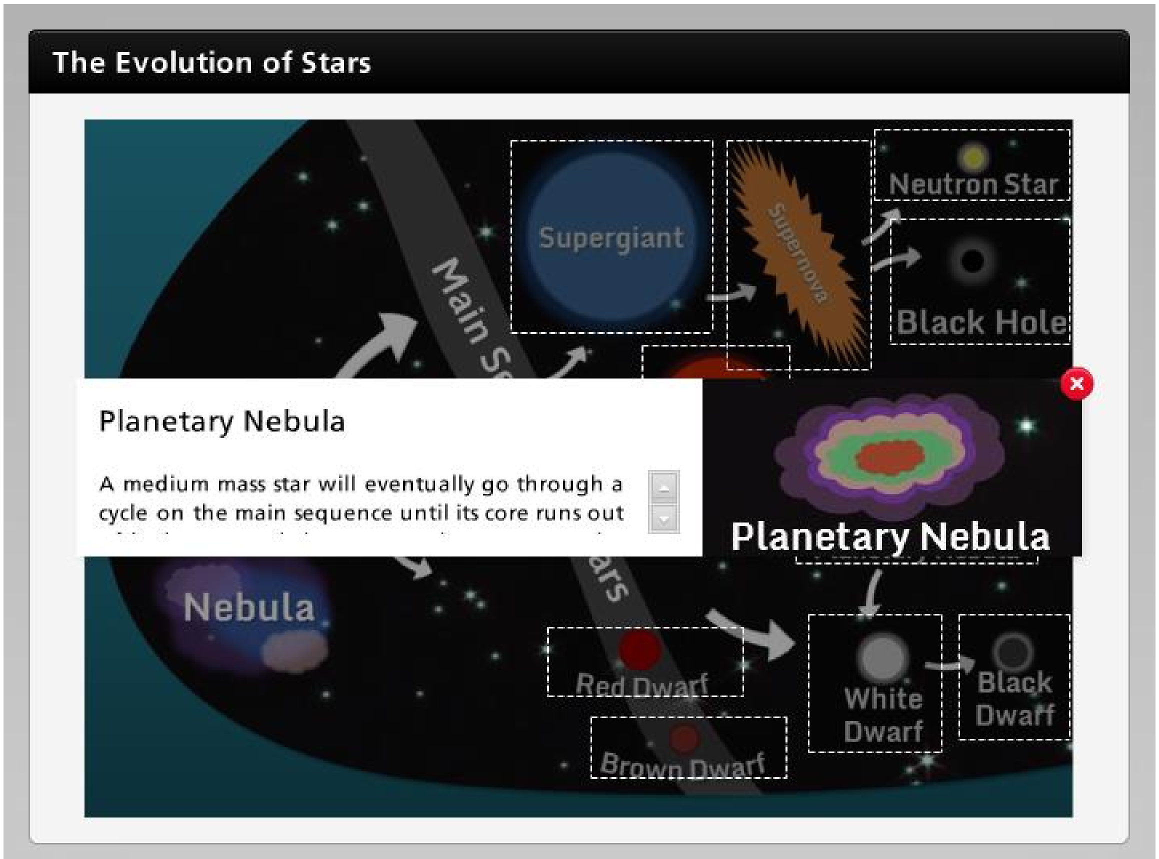
Giant



Giant stars are those which are large, have low densities, and are uncommon. The star grows so large due to the overproduction of energy. While main sequence stars remain in hydrostatic equilibrium, giant stars do not. It is believed that the core of these massive stars contracts on itself, producing tremendous amounts of energy. This energy is forced into outer layers of the star forcing the star to grow larger and larger.

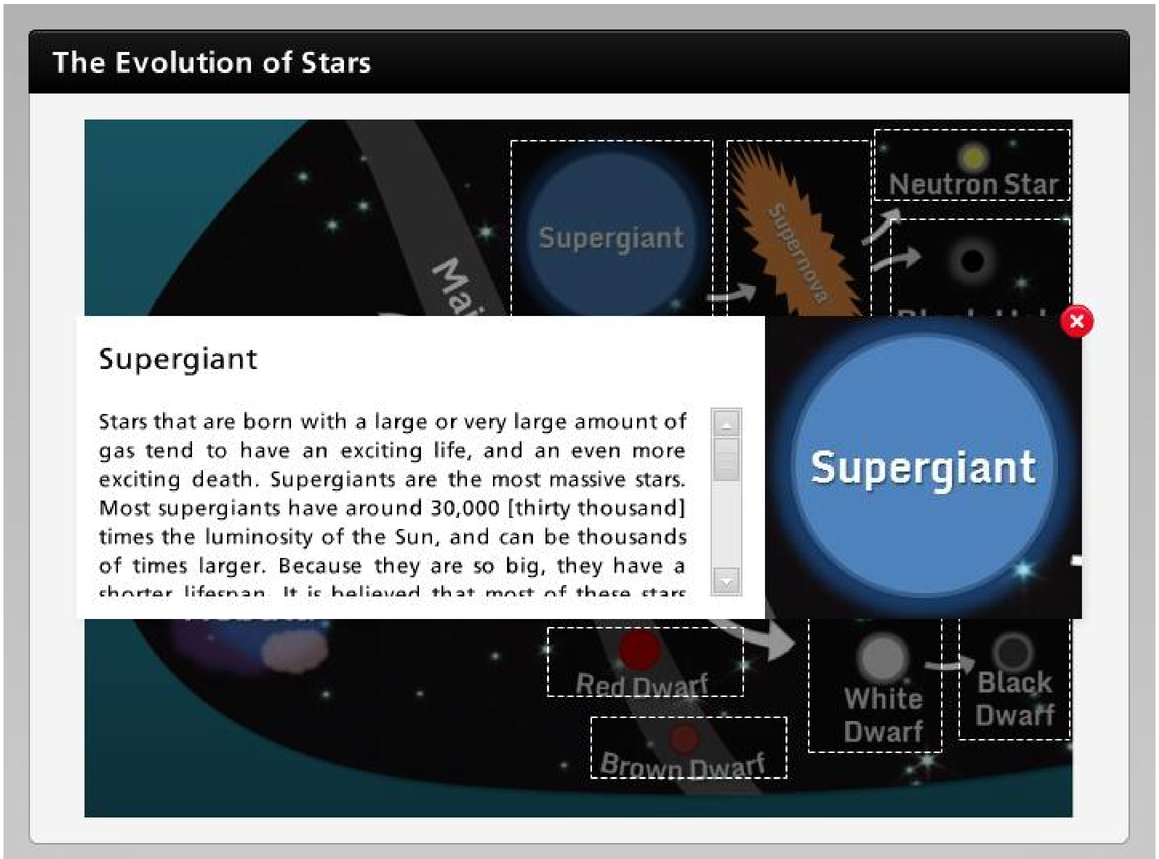
A giant is a luminous star in the later phases of stellar evolution. The surface temperature of these stars is around 5,000 Kelvin. Most giant stars are still going through the fusion process. Giants are tens to hundreds of times larger than the Sun. Because of their temperatures, giant stars move to the right side of the H-R Diagram; however, due to the giant stars' luminosity, they fall off the main sequence. As the surface area of the star increases, so does the star luminosity, and this causes the star to have a higher luminosity than most main sequence stars.

Planetary Nebula



A medium mass star will eventually go through a cycle on the main sequence until its core runs out of hydrogen and the core weakens. Due to the core becoming weak, it will also be unstable. In this unstable state, the star will flare and push the outer layers of its atmosphere outward. This continued flare this will cause what is known as a planetary nebula. Planetary nebulae are composed of gas and plasma. Ultimately, a planetary nebula can give birth to more stars.

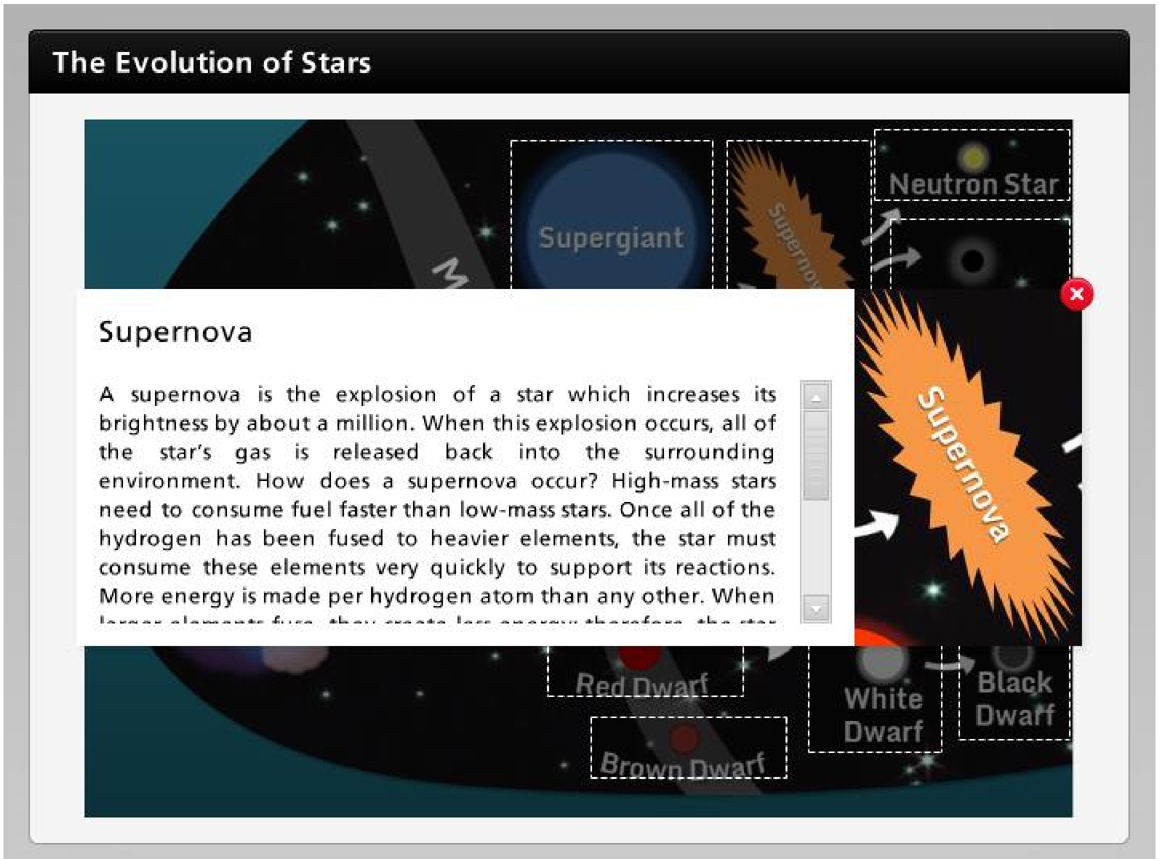
Supergiant



Stars that are born with a large or very large amount of gas tend to have an exciting life, and an even more exciting death. Supergiants are the most massive stars. Most supergiants have around 30,000 [thirty thousand] times the luminosity of the Sun, and can be thousands of times larger. Because they are so big, they have a shorter lifespan. It is believed that most of these stars only live a few thousand years; however, some may live a few million years.

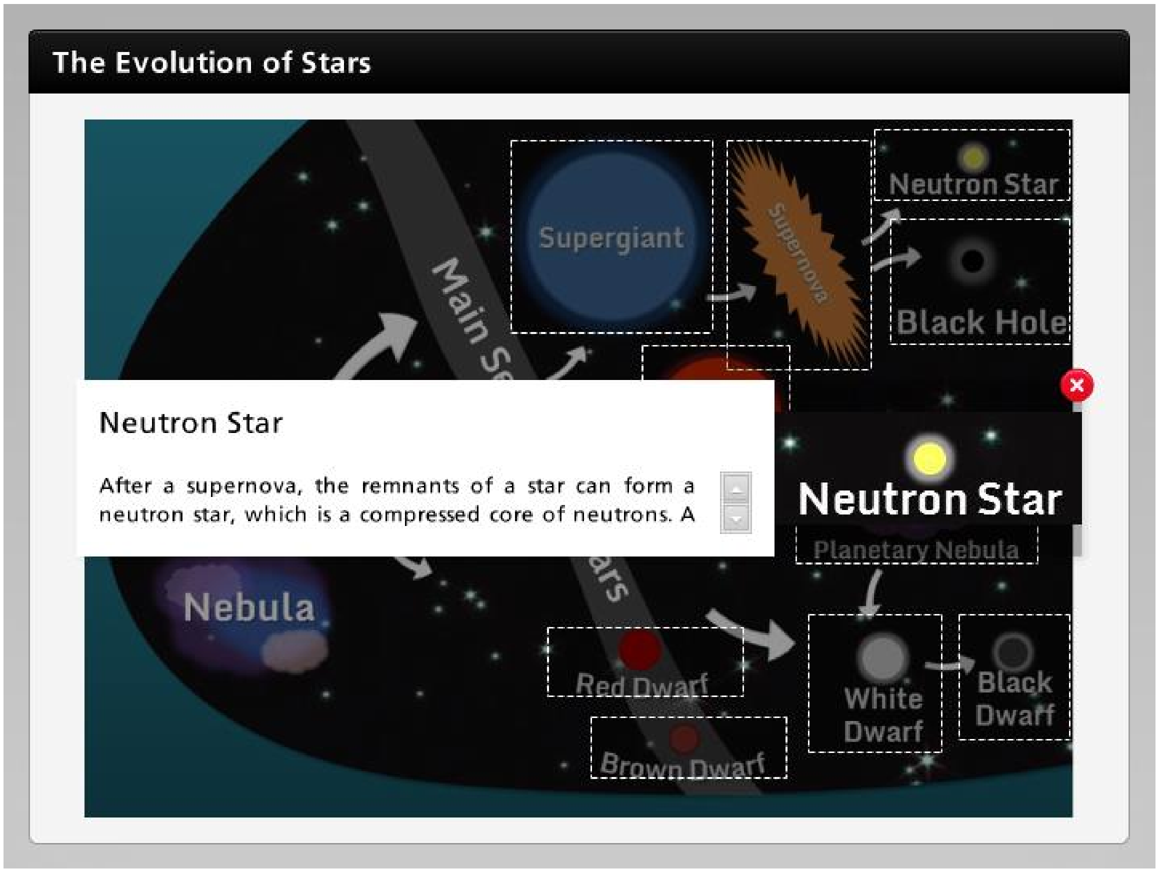
Supergiants grow in a fashion similar to giants. These stars overproduce energy, and then their cores contract and collapse. This sends a tremendous amount of energy into the outer layers of the star. The star grows to a very large size and becomes very luminous. On the H-R Diagram, supergiants are placed on the right side directly above giants. They are off of the main sequence, and above giants on this diagram because supergiants have a very high luminosity.

Supernova



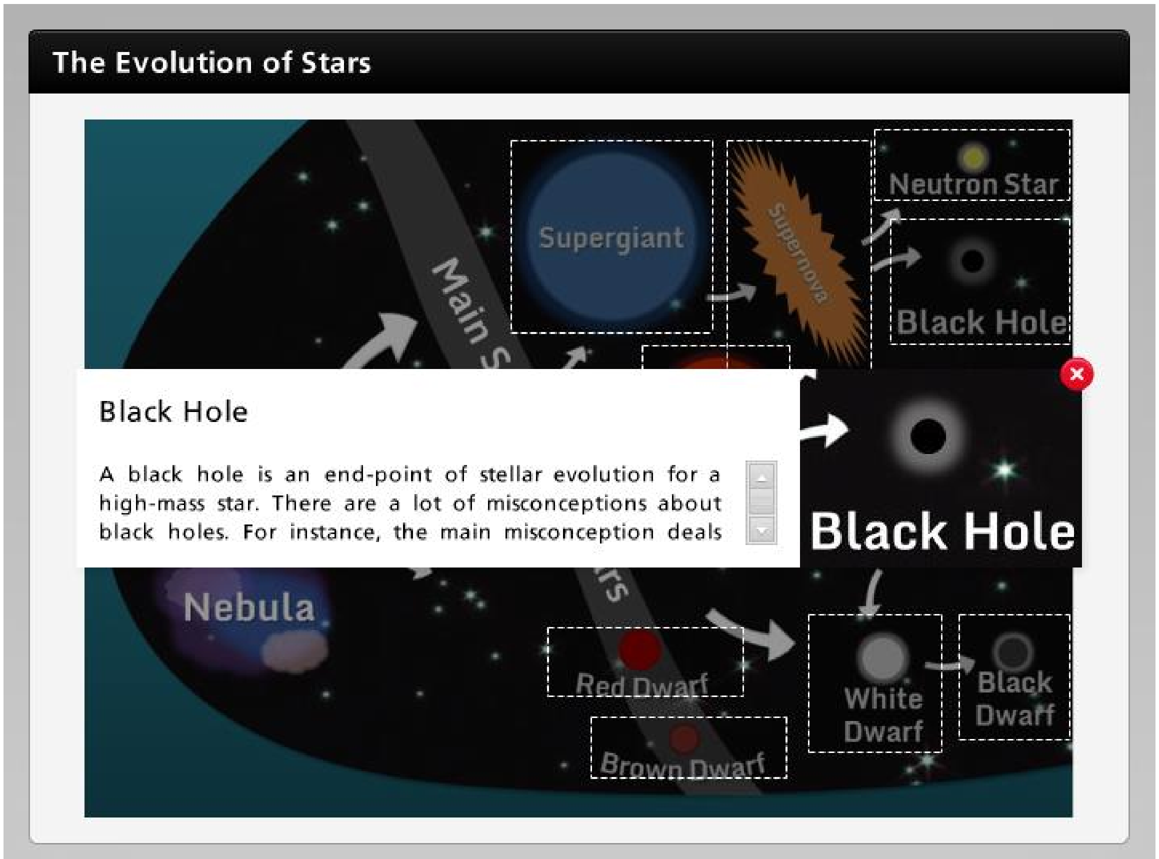
A supernova is the explosion of a star which increases its brightness by about a million. When this explosion occurs, all of the star's gas is released back into the surrounding environment. How does a supernova occur? High-mass stars need to consume fuel faster than low-mass stars. Once all of the hydrogen has been fused to heavier elements, the star must consume these elements very quickly to support its reactions. More energy is made per hydrogen atom than any other. When larger elements fuse, they create less energy; therefore, the star uses these heavier elements much faster than hydrogen in order to support its large mass. Finally, the star reaches a point when it is producing iron. At this point, the nuclear reactions in the core cease, the star becomes unstable and collapses on itself. The collapsing of the star causes a release of energy and the star explodes into a supernova. The amount of mass will determine its fate after the supernova. After the supernova, the star will become either a neutron star or a black hole.

Neutron Star



After a supernova, the remnants of a star can form a neutron star, which is a compressed core of neutrons. A neutron star is a small, high-mass ball around 12 to 20 km in diameter. There is a limit to the mass that a neutron star can have in order to stay stable. A neutron star cannot have a mass of greater than 3 solar masses. If the mass of the neutron star reaches this point, it will collapse on itself in one single point. This single point is called a singularity, and a black hole will form.

Black Hole



A black hole is an end-point of stellar evolution for a high-mass star. There are a lot of misconceptions about black holes. For instance, the main misconception deals with the gravitational pull of a black hole. Most people assume anything near the black hole is being sucked in and eventually everything will be pulled into the black hole over time. Actually, black holes only affect the objects very close to their large gravitational pull. A large amount of information dealing with black holes is theoretical, since nothing can escape the event horizon. The event horizon is the outer limit of the black holes gravitational pull. At this point, time will slow down. This is known as time dilation.