Events in the Life of a Star
A Self-Paced Workshop
(C)

It is now time to read through the life stages of a star, starting with that thing that was created at the end of the creation of the universe. Use chapter 25 in your textbook, as well as the Useful Research Information", to research each of the life stages of a star and answer the following information portions.

Star Birth

Where:

What are these mostly made of?

What causes the change?

Name one famous example:

Where did you find your information?

Protostars

What is this?

When will the star exit this phase?

What temperature is necessary?

Where did you find your information?

Newborn Unstable Star
(not a heading in the textbook, but you should be able to figure it out)

What is this?

What two forces are locked in epic battle within this star, and what are they trying to accomplish?

When will the star exit this phase?

Where did you find your information?

<u>Main-Sequence Stars</u>

What is this?

For what percentage of a star's life is it a main sequence star?

What is wrong with saying that the star is hydrogen *burning*?

What determines the different speeds for which stars go through this phase?

How long will the sun be a main sequence star?

What type of star can prolong its life, and how?

What is happening internally, during this phase?

What ends this phase?

Thinking about the opposing forces, how does the star move into the next phase?

Where did you get your information?

Red-Giant Star

What is this stage?

What leads to the "giant" in the phase name?

What leads to the "red" in the phase name?

What is happening internally during this phase?

What ends this phase?

Where did you get your information?

White Dwarf Star

What is this?

Interesting factoid: A spoonful of white dwarf would weigh several tons.

How hot is a white dwarf initially?

What happens to the temperature of a white dwarf over time?

What happens to transition a star out of this phase?

Where did you get your information?

<u>Black Dwarf Star</u>
What is this?

Has anyone ever seen one?

What happens to the star when it exits this phase?

Where did you get your information?

<u>Planetary Nebula</u>

What is this?

Name one famous example:

What happens to the rest of the star?

Where did you get your information?

<u>Supernova</u>

What is this?

How do you get from Red Giant to Supernova?

1. **The carbon core contracts and**

2. **Each element then fuses**
3. **Eventually the core is made out of which can no longer heat the star as it fuses.**

Why is iron different?

Which of the two forces is diminished by iron fusion? How?

How heavy does a star have to be to go supernova?

What happens when the star starts contracting? How does that lead to an explosion? Tell me in terms of our cosmic forces.

How does a supernova explosion relate to elements with atomic numbers greater than 26?

Where did you get your information?

Interesting factoid: A supernova may emit as much light energy as an entire galaxy.

<u>Neutron Star</u>

What is this?

How heavy does a star have to be to go neutron?

Where did you get your information?

Interesting factoid: If the Earth were as dense as a neutron star, it would fit inside of a football stadium.

[Extra Credit – 2 pts] What is a pulsar? How does it relate to stars? Where did you get your information?

<u>Black Hole</u>

How heavy does a star have to be to become a black hole?

What is a black hole?

Why is a black hole called "black"?

Why is a the word "hole" misleading?

What other word besides "hole" cold you substitute?

Are black holes predatory?

Can the sun become a black hole?

If the sun became a black hole, how would this affect our orbit?

Where did you get your information?

Events in the Life of a Star
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(D)

The next step of this self-paced workshop is to use a blank sheet of white paper to construct a flow chart for the life of a star, starting with nebula, and then ending with any of the different conclusions to a star's life.

Along each branch point, make sure to note the different conditions necessary for going down that path such as *the required mass*.

Make sure to hit each category of stellar evolution from portion C.

You are welcome to exercise as much creativity as you would like on this portion of the activity, so long as all headings from part C are included, as well as requisite solar masses.

If you are a computer guru and/or perfectionist, you have the following additional resources to help you make a flow chart that won't stress you too much. Will using the computer help your grade? Not one bit.

http://gliffy.com/ -- An online flow chart environment. (get in free from www.bugmenot.com)

http://cmap.ihmc.us/ -- CMAP tools. Free. Download. Use offline. I lived off of this software in graduate school. Saves serious $$ on "Kidspiration" or "Inspiration".

USEFUL RESEARCH INFORMATION

From Earth Science and the Environment (third edition) by Graham R. Thompson and Jonathan Turk

24.3 The Birth of a Star

The cosmic background radiation emanated from the primordial sea of atoms, particles, and energy of the big bang. This radiation is called **first generation energy**. When you look up into the sky on a clear, moonless nigh, you see stars sparkling in the blackness. If you owned a powerful telescope, you could peer deeper into space and detect distant galaxies, or even curious structures called quasars. All of these objects will emit what astronomers call **second generation energy**. They use the term *second generation* because this light is emitted by concentrated matter – stars, galaxies, or quasars. To understand our Universe, we must learn how matter in the subtly nonhomogenous early Universe clumped together to form concentrated bodies that emit light and energy of their own.

Over time, denser regions of the Universe drew matter inward by gravity to form huge clouds of hydrogen and helium, called **nebulae**. Within each cloud, matter further agglomerated into billions of smaller bodies. As the atoms in a nebula accelerated inward under the force of gravity, they collided rapidly with one another. Thus, the center of each cloud became very dense and hot. Under the intense heat, electrons were stripped away from their atoms, leaving a plasma of positively charged nuclei and negatively charged electrons. If the cloud were originally large enough, the gravitational attraction accelerated the nuclei until they collided with enough energy to fuse. When fusion started, the collapsing portion of the original nebula became a star.

Fusion generates energetic photons and tremendous quantities of heat. If a dense sphere of hydrogen the size of a pinhead were to fuse completely, it would release as much energy as is released by burning several thousand tons of coal. Both the photons and the hot particles generated by fusion accelerate outward against the force of gravity. Thus, two opposing processes occur in a star. Gravity pulls particles inward, but at the same time fusion energy drives them outward. The balance between these two processes determines the diameter and density of a star of a given mass. At equilibrium, a star with an average mass has a dense core surrounded by a less dense shell.

USEFUL RESEARCH INFORMATION

From Earth Science and the Environment (third edition) by Graham R. Thompson and Jonathan Turk

24.6 The Life and Death of a Star

Stars About the Same Mass As Our Sun

In a mature star, such as our Sun, hydrogen nuclei fuse to form helium but the helium nuclei do not fuse to form heavier elements. For fusion to occur, two nuclei must collide so energetically that they overcome their nuclear repulsion. Hydrogen nuclei contain one proton, but helium contains two. Therefore the repulsion between two helium nuclei is much greater than that between two hydrogen nuclei. This stronger repulsion can be overcome if the nuclei are moving very rapidly. Because higher temperature causes nuclei to move more rapidly, helium fusion occurs only when a star become much otter than the temperature at which hydrogen fusion occurs.

The sun is now midway through its mature phase as a main-sequence star. It ha been shining for about 5 billion years and will continue to shine as much as it is today for another 5 billion years. During this entire period, the Sun produces energy by hydrogen fusion and remains on the main sequence.

After about 10 billion years, the outer shell of a star, such as our Sun still contains large quantities of hydrogen, but most of the hydrogen in the core has fused to helium. The star's behavior now changes drastically. Because the hydrogen in the core is nearly used up, hydrogen fusion slows down, less nuclear energy is produced, and the core cools. As it cools, the outward pressure of the particles and energy decreases. Then the core starts to contract under the force of gravity. This gravitational contraction causes the core to grow hotter. It seems a paradox that when the nuclear reactions decrease, the core becomes hotter, but that is what happens.

As the core heats up, the rising temperature initiates hydrogen fusion in the outer shell. The star is now heated by both the gravitational coalescence in the core and the hydrogen fusion in the outer shell. As a result, the star releases hundreds of times as much energy as it did when it was mature. The intense energy output now causes the outer parts of the star to expand and become brighter. The star has become a **red giant**. A red giant is hundreds of times larger than an ordinary star. Its core is hotter, but its surface is so large that heat escapes and the surface fools. This cool surface emits red light (recall that the red wavelengths have the lowest energy of the visible spectrum). These sudden changes in energy production and diameter move the star off the main sequence. Thus, a red giant is brighter and cooler than a main sequence star of the same mass.

Five billion years from now, the hydrogen in our Sun's core will be exhausted and the Sun will expand into a red giant. It will engulf Mercury, Venus, and Earth. Perhaps the heat will blow much of Jupiter's atmosphere away, exposing a rocky surface.

The core of a red giant condenses under the influence of gravity and gets hotter until its temperature reaches 100,000,000 K. At this temperature, helium nuclei begin to fuse to form carbon nuclei.[1] When helium fusion starts, radiant energy pushes outward once again, and the core expands. The star cools, its outer layers contract, and it enters a second stable phase. Gradually, as more helium fuses to carbon, the carbon accumulates in the core just as helium did during the earlier life of the star. When the helium is used up, fusion ceases again and the carbon core contracts. This gravitational contraction causes the core to heat up again.

What happens next depends on the star's initial mass. Astronomers express the mass of a star relative to that of the Sun. One **solar mass** is the mass of the Sun. In a star as massive as our Sun, contraction of the carbon core is not intense enough to raise its temperature sufficiently to initiate fusion of the carbon nuclei. However, gravitational contraction of the carbon core does release enough energy to blow a shell of gas out into space. This shell is called a **planetary nebula**. Meanwhile, the material remaining in the star contracts until atoms are squeezed so tightly together that only the pressure exerted by the electrons prevents further compression. A dying star as massive as our Sun will eventually shrink until its diameter is approximately that of the Earth. Such a shrunken star no longer produces energy, and it glows solely from its residual heat produced during past eras. The star has become a **white dwarf**. It will continue to cool slowly over tens of billions of years, but will never change diameter again. No further nuclear reactions will occur. Its gravitational force is not strong enough to overcome the strength of the electrons, so it will never contract further.

[1] Helium nuclei consist of 2 protons and 2 neutrons. Carbon nuclei consist of 6 protons and roughly 6 neutrons. So it takes **three** heliums to make a carbon.