Quiz 6 Feedback

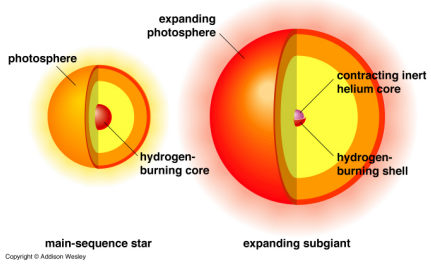
1. Energy sources for a 2 $M_\odot$ Main Sequence star, a red giant far along its path, and a horizontal-branch star.

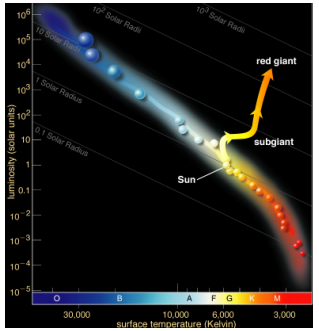
The 2 $M_\odot$ Main Sequence star, like any Main Sequence star, is powered by H fusing into He in the star's core. The horizontal branch star is also powered by fusion, in this case He fusing to C (and O) in the star's core.

The red giant is partly powered by *gravitational potential energy,* released due to the contraction of the core, but it is also generating energy by fusion in a shell around the core (H fusing into He).

Leaving the Main Sequence

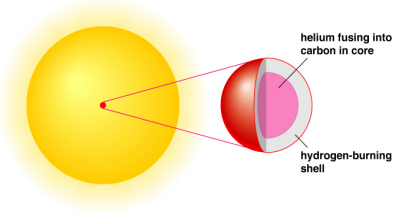
- The core begins to contract
  - the region just above the core heats up & H fusion begins there; this is called a "**hydrogen-burning shell**"
  - the higher pressure in this hot region pushes outward, so the outer layers of the star expand. *It becomes a red giant.*

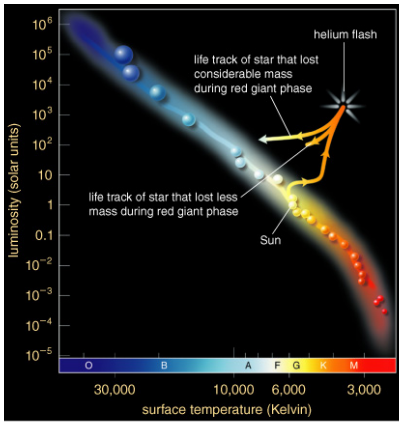




Core Helium-Burning Stage

When He fusion begins in the core, the star becomes smaller and hotter - moves onto what we call the 'horizontal branch.'





From the 10/18 index card feedback file

- "Gravity outweighs outward pressure in a protostar, so it contracts, unlike the Red Giant, whose surface is expanding." Yes, the surface of the Red Giant expands, but in fact *its core is contracting, and this actually supplies much of the star's luminosity.* There is *fusion in a shell around the core*, but that happens only because the contracting core produces energy that heats the H in the shell to fusion temperatures.
- "Helium is fused to carbon in Red Giants." The video implied so, but it's not quite correct. Stars that fuse He to C in the core are *horizontal branch* stars.

Common Misunderstandings

- Most people did not mention the fact that the core of the red giant is contracting. This begins when the star runs out of H fuel in the core and the heat leaks away, lowering the thermal pressure and enabling gravity to "win" the battle against pressure.
- Some students thought that the core of a red giant fuses He. This is not the case; once the core He is ignited, the star is a horizontal branch star.
- Some students thought that horizontal branch stars make elements even heavier than C and O. These later reactions occur only in high-mass stars.

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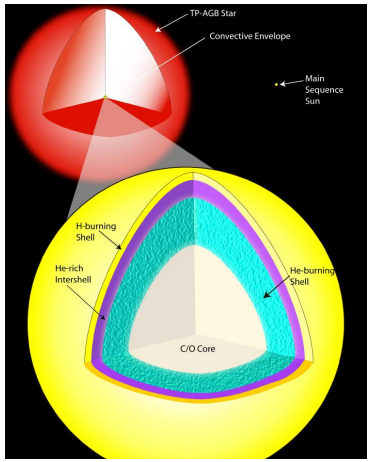
2. Internal structure of an AGB star in its late days.

An AGB star has a complex structure, with a number of layers of different conditions and composition. At the center is a dense core of C and O, the products of He fusion. The core is not contracting because it is supported by electron degeneracy pressure. Above this are two shells in which fusion is taking place: a He-fusing and an H-fusing shell. The outer layers are very extended: remember that the Sun will swallow up the inner planets of the Solar System when it gets to this stage! This surface is cool, yet luminous.

He-Core Exhaustion: The Asymptotic Giant Branch ("AGB" Star)

When all the He is used up in the core, the core begins contracting again, which heats it up, causing He fusion to occur in a shell above the core.

This is the "double shell-burning" phase, which has an inner He-burning and and outer H-burning shell.



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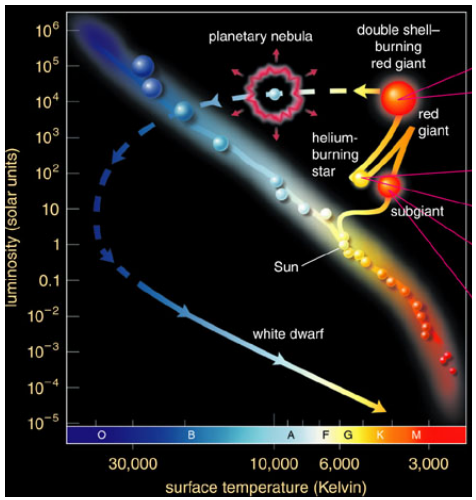
2. What happens next, after the AGB phase?

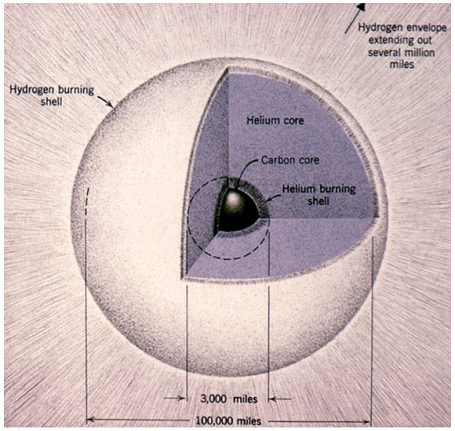
The next thing that happens is that the core and outer layers of the star finally separate from each other. The outer layers come off, and are briefly visible as a *planetary nebula*, while the degenerate core that is left at the center becomes a *white dwarf*. Most students mentioned only one of these objects, and omitted the other. The nebula spreads out into space, mixing with other gas, while the white dwarf slowly cools off, like a baked potato (10/23 card).

The Final Gasps of a Low-Mass Star



The AGB giant phase ends when most of the envelope is removed, revealing the hotter layers deep in the star's interior. Everything except the core is expelled in an outflow, at first in a wind, later as a planetary nebula.

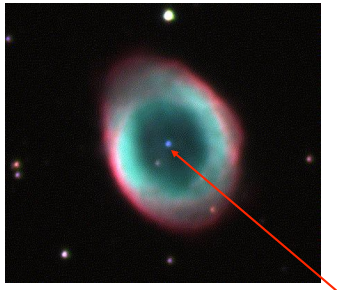
The White Dwarf in the AGB Giant



The structure of a star in the helium-burning phase

The core (composed of C and O made by earlier reactions) contracts to high density, essentially building a white dwarf in the middle of the star. The core is supported by electron degeneracy pressure, which prevents it from contracting any further.

From Red Giant to White Dwarf

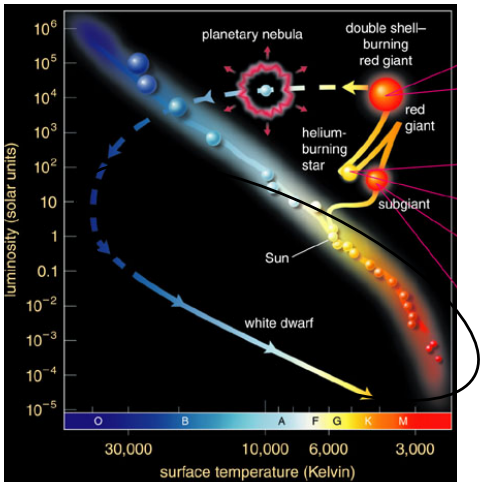


The nebula of hot gas is the cast-off outer layers of the former AGB star, now ionized by the central star

The small, hot central star is a "pre-white dwarf," which is the nearly degenerate stellar core

The collapsing Carbon core becomes a White Dwarf

White Dwarf Cooling Tracks



This summarizes the evolutionary track that eventually produced a white dwarf.

Once the rest of the star's mass has been removed, the white dwarf cools off and grows dimmer with time, sliding down along a line of constant radius in the H-R diagram.