The Nature of Red Giant Stars

- Red giant stars have a composite structure where a very compact interior is joined to an extended hydrogen rich envelope.

- This structure is permitted by the differing intrinsic density of hydrogen as compared to all other nuclear compositions.

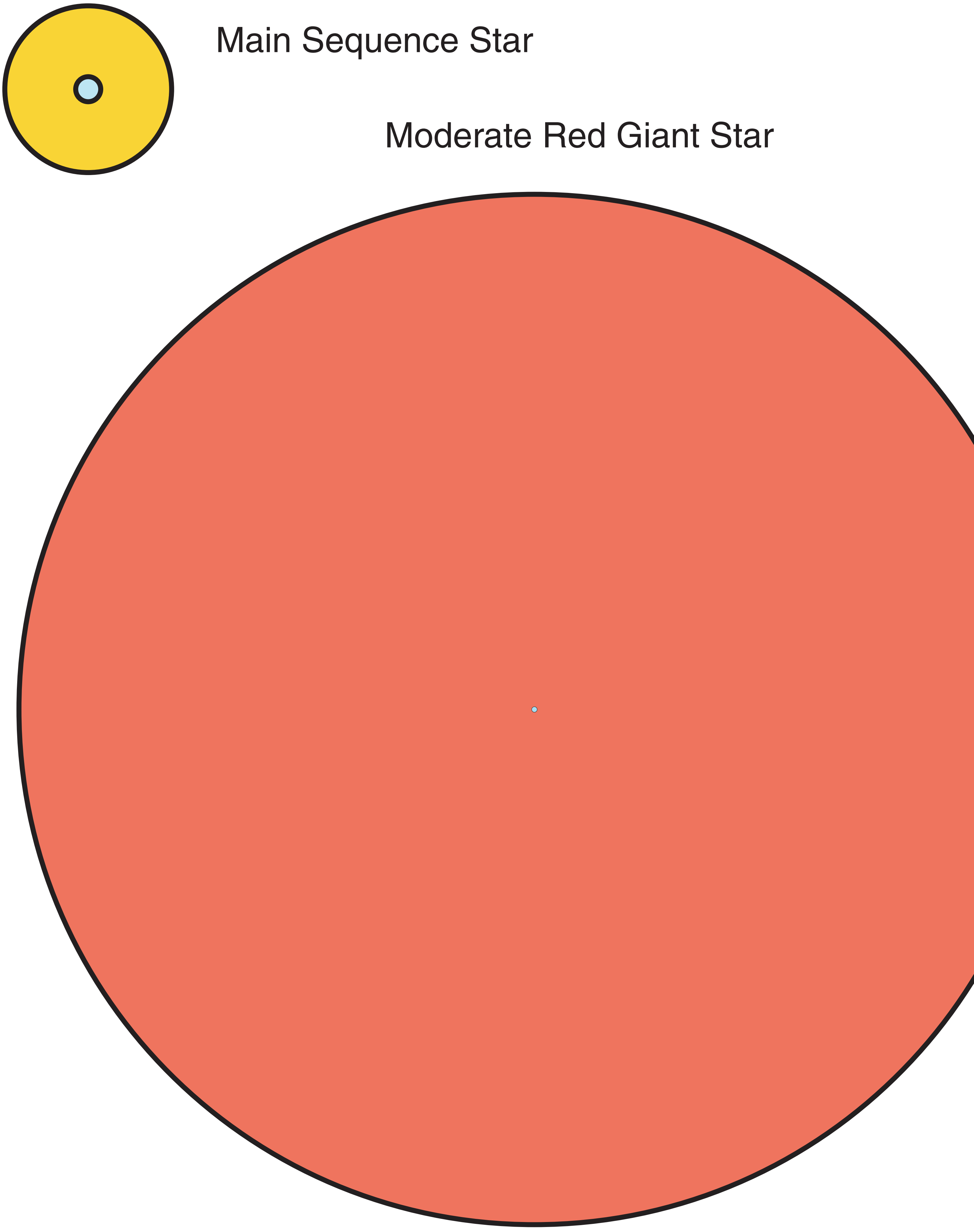
- The low intrinsic density of hydrogen requires the stellar structure to jump to a different mathematical track wherever there is a change in composition from helium to hydrogen.

- The more compact the helium is on the inside of the jump, the more diffuse must be the hydrogen on the outside of the jump. This is called the mirror effect.

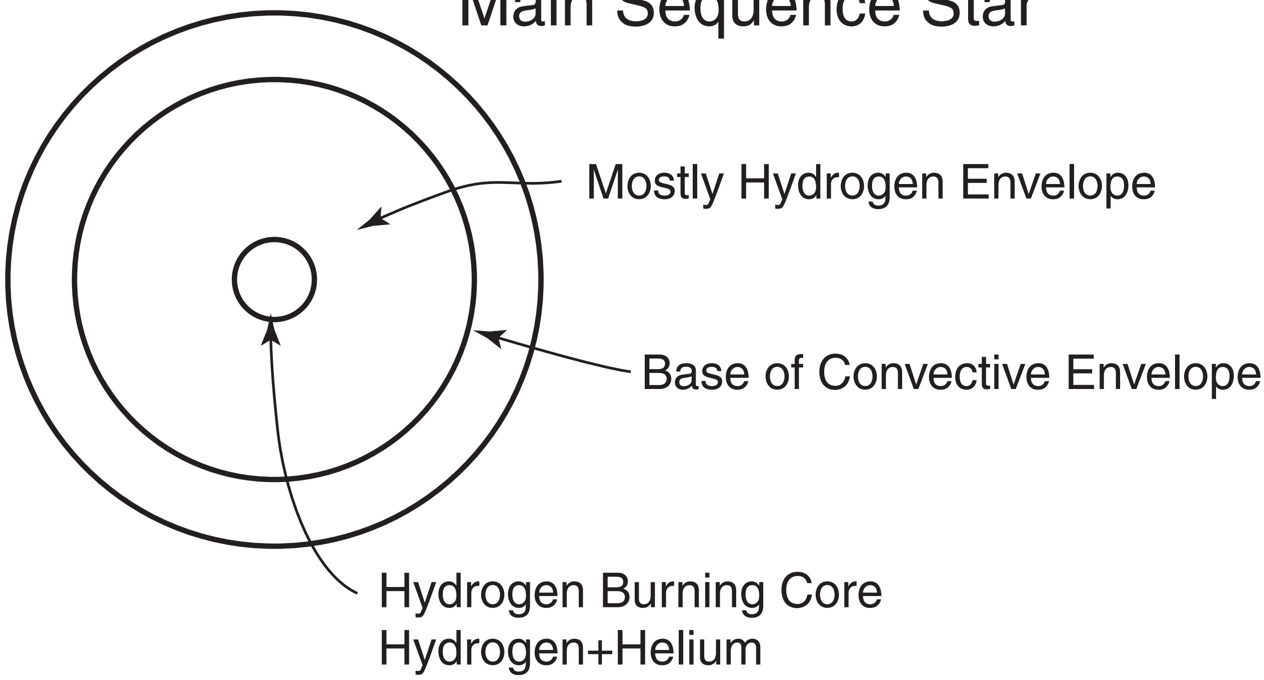
- In a red giant, the matter containing hydrogen at the inner edge of the outer envelope is pulled into the high temperature core and quickly converted into helium in a stationary front called the Shell Source. Most of the energy emitted by the star is generated in this thin region containing very little mass.

- The flow of matter through the shell source increases the mass of the Helium core and causes it to evolve toward a higher density, smaller radius.

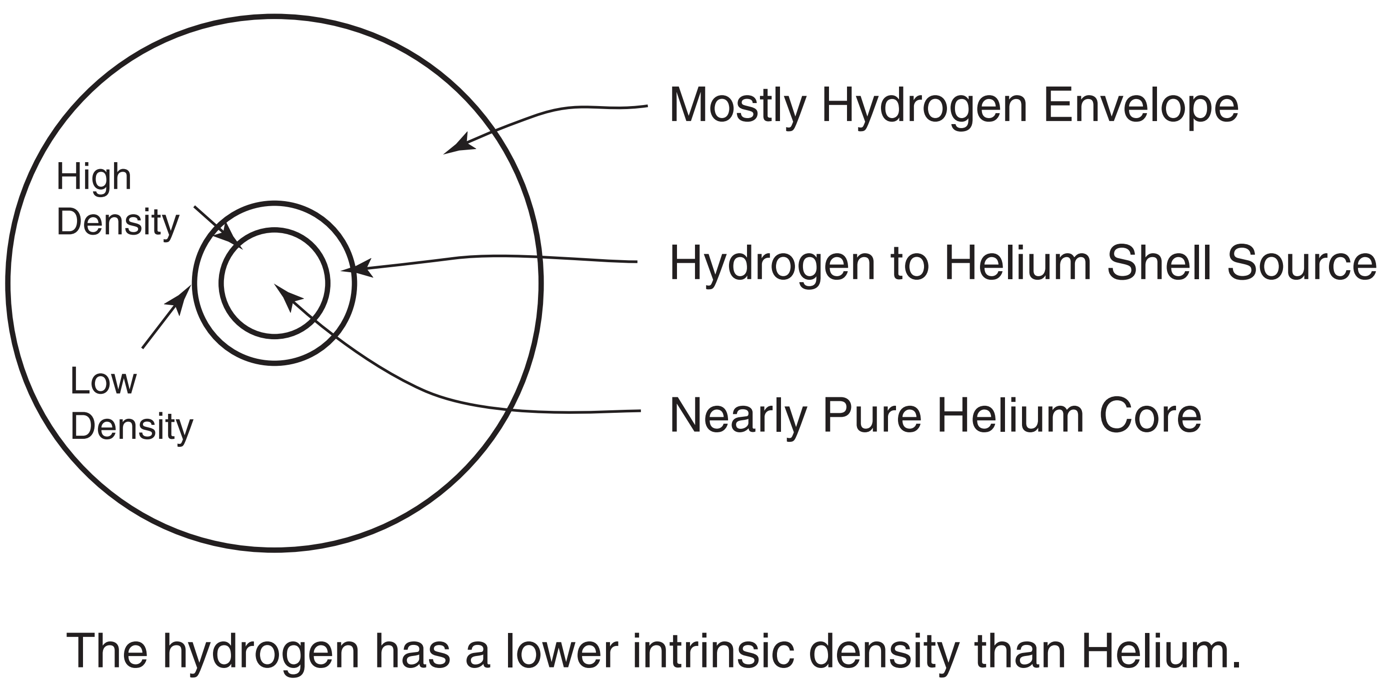
- Through the mirror effect the core contraction produces and envelope expansion and the star grows in size as long as the helium core is gaining mass and is not generating any additional energy.


Main Sequence Star
Moderate Red Giant Star

Main Sequence Star



Red Giant Star



The hydrogen has a lower intrinsic density than Helium.
At the same temperature and pressure, it will have a density less than half that of Helium. This is the property which permits the bloated envelopes of red giant stars.

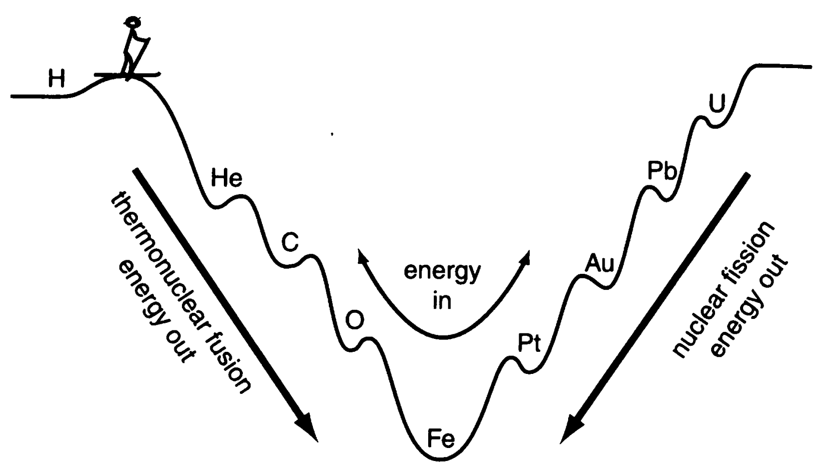
The Growth of Compact Stellar Cores

- The growing mass of the Helium core causes the central density and temperature to increase.
- Depending on the mass reached by the Helium core, it is possible to ignite the Helium and begin Helium Burning.
- the conversion of Helium to Carbon, Oxygen and Neon produces energy which causes the Helium core to increase its size. This reverses the trends experienced by the star previously and the Hydrogen envelope begins to contract.
- In globular clusters, the stars with a Helium burning core and a Hydrogen to Helium shell source are found on what is called the Horizontal Branch. Stars not in globular clusters in this state form a knot near the red giant track.
- Following the exhaustion of Helium, the Carbon/Oxygen/Neon core begins to contract just like the Helium core before.
- This renewed core contraction returns the star to its evolution toward higher radii and luminosities.
- The Carbon/Oxygen/Neon matter has about the same intrinsic density as does the Helium so there is not a need to have a red giant unless there is a Hydrogen rich envelope.
- The Carbon/Oxygen/Neon core may undergo another ignition to carry the star further toward the ultimate state of Iron.
- At very high luminosities, the outer layers of the star are expelled into space by what is known as a Stellar Wind.
- Eventually all the hydrogen rich matter can be expelled into space leaving a star containing only a Helium shell and a Carbon/Oxygen/Neon core.
- Such a star can have a surface radius which is the same as the core radius and becomes a white dwarf when all nuclear burning is completed.

Trends in the Nuclear State

The evolution of the star is driven by the interaction between the ignition of successive nuclear fuels and the requirements of the stellar structure equations which govern the overall size of the star. The nuclear fuels can provide additional energy only as long as there is a lower energy state to which they can make a transition. The potential nuclear energy is governed by the energy of nuclei having different numbers of protons and neutrons.

The addition of more nucleons generally increases the binding due to the nuclear strong force. Eventually the electric repulsion from the fact that all the protons have a positive charge catches up and makes addition of more nucleons less favorable. This turnover comes at the point where there are about 56 nucleons and the element is Iron.



This diagram shows the trend of the binding energy of nuclei as more nucleons are added. In order to produce nuclei having more nucleons than Iron, energy must be added to the nucleus and taken from the stellar gas.

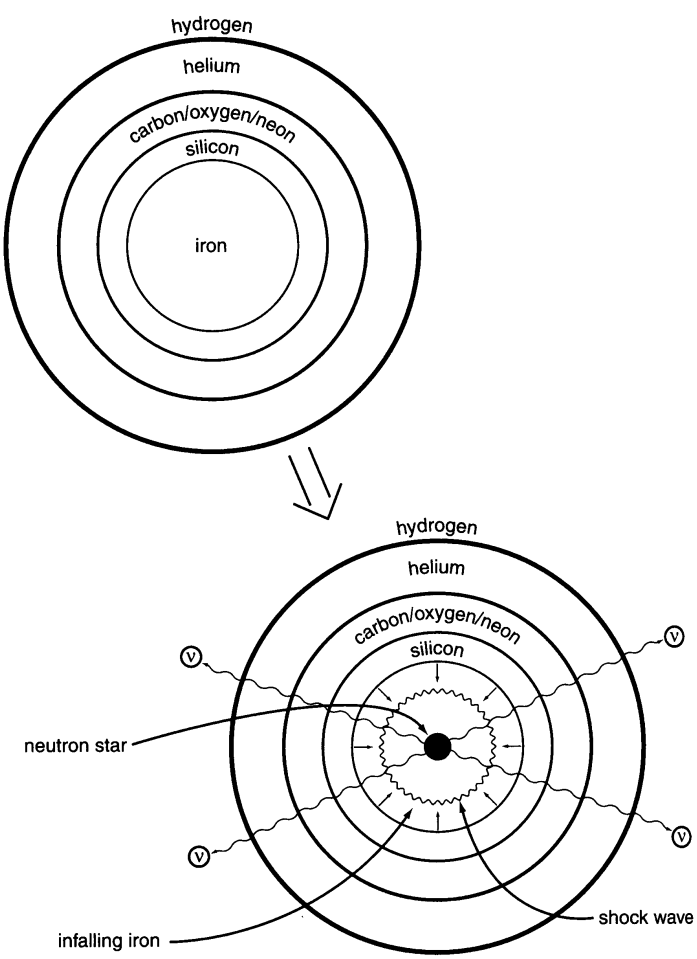
The Final Configuration For Nuclear Evolution

The process of nuclear burning, fuel exhaustion, core contraction, fuel ignition can continue until the center nuclei have become Iron. After that, there are no additional fuels available.

Low mass stars cannot do enough contraction to lead to the formation of Iron.

High mass stars which are not supported by Quantum Pressure can carry the nuclear evolution up the the point where Iron is formed. After that, the temperature continues to rise and eventually the Iron can disintegrate with the absorption of energy from the stellar gas.

This causes the center of the star to collapse and is the cause for the Type II Supernovae.



This sketch shows the series of shell sources and different composition layers present in a star just prior to the occurrance of a Type II Supernova.