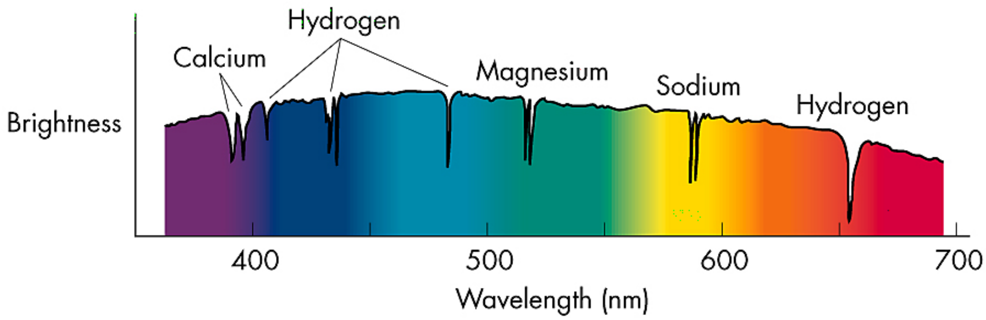
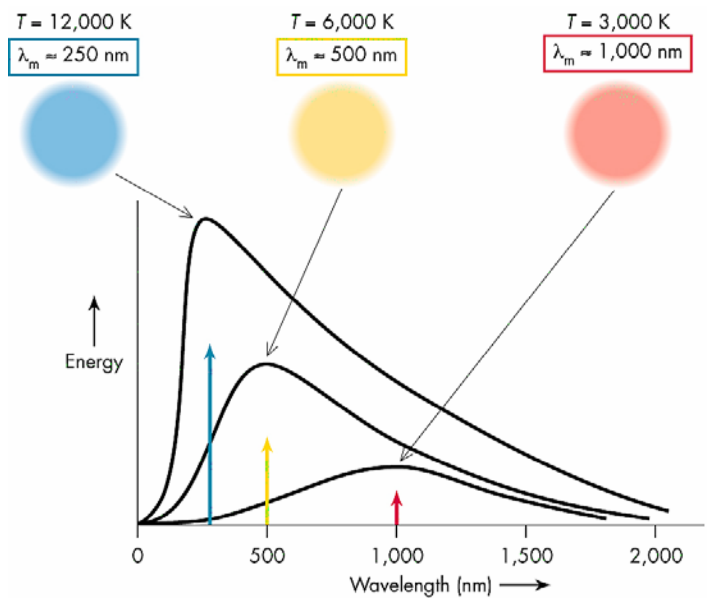
Stars

General Information About Stars

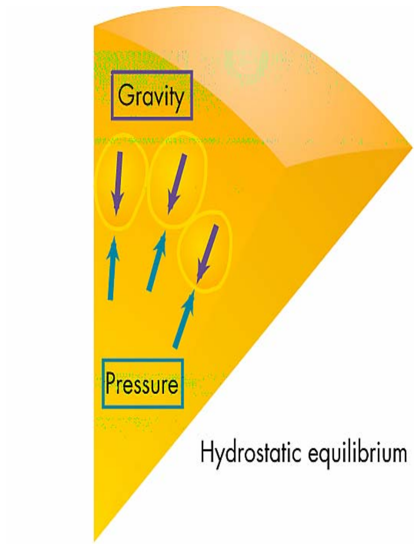
- The nearest star is 4.2 LY away (40 trillion km!)
- The distance to stars may be computed using *parallax* or *apparent brightness*
- Stars appear as point sources in even the most powerful telescopes
- A star's mass may be deduced from interactions with nearby objects
- A star's size is estimated by mass, brightness and color
- Most other useful information (including composition) is acquired through *spectroscopy*





- Stars are gigantic gravity-induced *fusion* reactors
- The core temperatures of all stars are millions of K

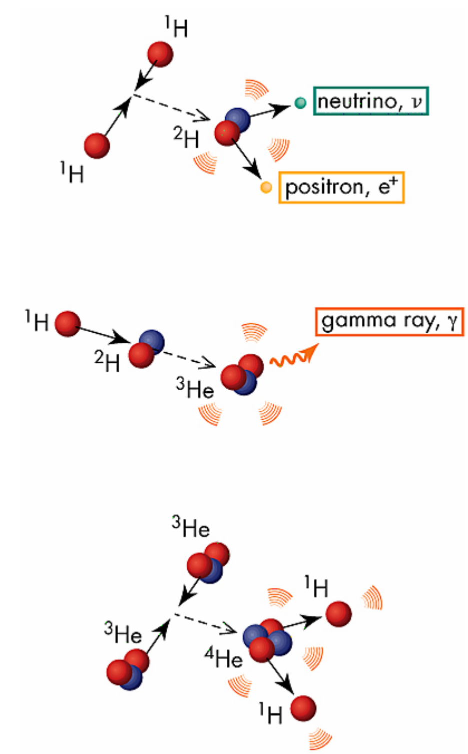
- Stars are in *hydrostatic equilibrium* - the inward force of gravity is balanced by an outward force of pressure generated by the compressive heat of the gas and the fusion reaction at the core of the star



- For the most part the more massive a star the hotter and more *luminous* it is.
- Some of the heat generated within a star escapes in the form of sunlight and starlight
- Most stars are about 71% hydrogen and 27% helium
- Most stars have enough fuel to burn for billions of years
- Red Dwarfs (~0.2 solar masses) are probably the most common stars. As many as 2/3 of the stars in our galaxy may be Red Dwarfs. Most Red Dwarfs are solitary stars. Red Dwarfs are difficult to observe because they are small and not very bright.
- Large objects below 0.1 solar masses are referred to as brown dwarfs and are about as common as normal stars in our own galaxy.

Stellar Evolution in Brief

- Ordinary stars, such as our sun, form when clouds of hydrogen drifting in space acquire enough mass to begin gravity-induced compression.
- As the star acquires enough material the intense gravitational force near its center creates pressures high enough to overcome the Coulomb repulsion between positively charged hydrogen nuclei, squeezing them together to form a helium nucleus and liberating an enormous amount of energy in the process.
- This reaction is known as *fusion*.
- In our sun fusion is accomplished via a reaction known as the proton-proton cycle



- In the proton-proton cycle the fusion of two protons (hydrogen nuclei) eventually produces a helium nucleus (α particle) positrons, neutrinos gamma rays and lots of energy

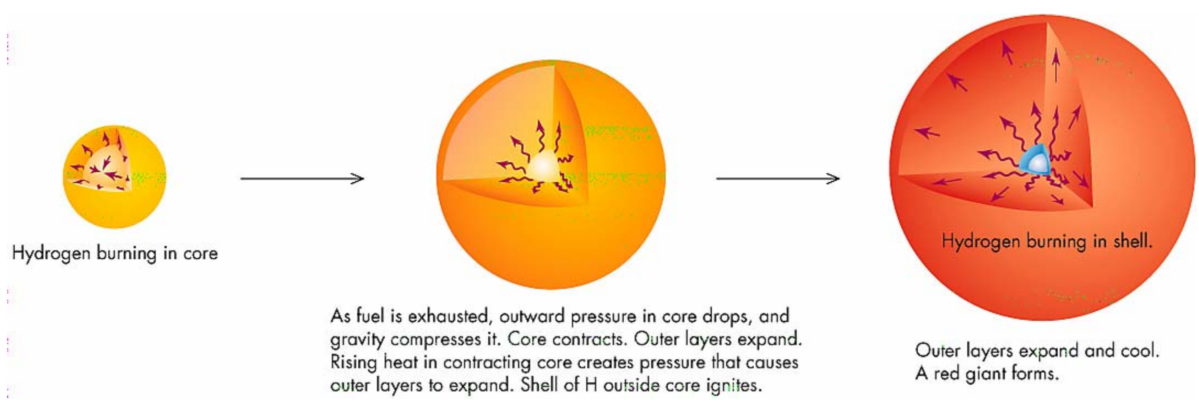
Main Sequence Stars

- Once an ordinary star ignites it enters a stage of evolution known as the *main sequence*.
- Ignition occurs at a temperature of 7 million K.
- The main sequence is the longest stage of evolution for any *active* star.
- A star on the main sequence derives its energy from fusion (primarily hydrogen fusion). A star spends most of its life on the main sequence.
- Main sequence stars and normally quite stable
- The brighter a star is the hotter it is.
- Hotter main sequence stars are also bluer and more massive.
- Cooler, dimmer main sequence stars are redder and less massive.
- Medium-sized stars, like our sun, may spend as long as 10 billion years on the main sequence.
- Very large stars have short main sequence lifetimes
- Very small stars have long main sequence lifetimes
- There are several distinct dénouements for stars that leave the main sequence depending on the mass of the star.

    - Very low-mass stars just gradually cool down when they exhaust their supply of hydrogen fuel
    - Medium-mass stars end up as white dwarfs
    - High mass stars explode and leave behind fragments such as neutron stars or black holes.

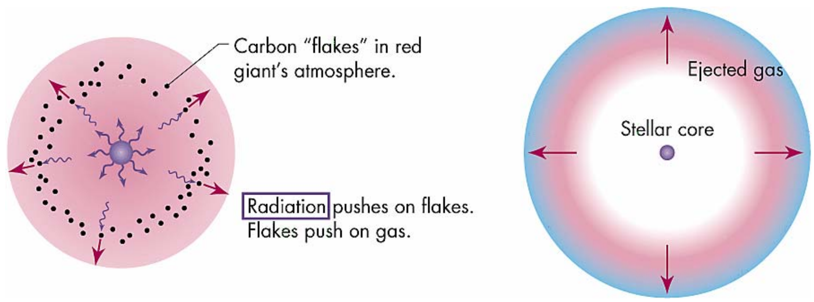
Red Giants/White Dwarfs

- The *red giant* phase of stellar evolution follows the main sequence for medium-sized stars.
- When hydrogen is nearly exhausted in the central core of a star the star begins to undergo a set of convulsions that upset the balance of hydrostatic equilibrium. During this process core temperature, pressure and density increases within the star.
- Energy released during this process causes the outer parts of the star to swell to enormous proportions. The star, as a whole, becomes less dense since all but the central core is expanding.
- This expansion of the outer regions of the star results in surface cooling and results in their red appearance. This occurs because the energy being released from the core is being radiated through a much greater surface area.
- The energy being released by the core heats up the hydrogen in the areas surrounding it to extremely high temperatures. This accelerates hydrogen fusion and the production of helium, causing the star to increase in luminosity.
- Red Giant stars, having nearly exhausted their supply of hydrogen, will fuse helium nuclei into carbon to sustain themselves. Red giants are characterized by very large diameters and relatively low surface temperatures. Their large diameters, and consequently their large surface areas, make them relatively bright.



- Near the end of a Red Giant's life, as it exhausts its supply of helium, it begins to convulse again. At the end of this phase the star becomes extremely large, bright and cool. Cool enough, in fact, that tiny amounts of carbon and silicates may begin to condense in its outer layers.
- Radiation pressure from the shrinking and highly energetic core pushes this material away from the star forming a region of *nebulosity* around the core of the star.
- The now exposed core remains as a dying remnant of the original star

- During this process the core of the star may ultimately attain an enormous density. This is knows as the *white dwarf* stage.
- White dwarf stars are compact objects about the size of Moon but containing about mass of the sun.
- Although white dwarf stars are extremely hot they are not very bright because of their compact size.
- White dwarf stars have very high densities (roughly that of the nucleus of an atom). This is possible because the constituent atoms of the gases residing in the interior of these stars are completely *ionized*, i.e., stripped of all electrons. Most of the mass of an atom (~99.975%) is concentrated in the nucleus but most of the volume is occupied by orbiting electrons. With the electrons stripped away it is possible to pack nuclei very close together resulting in a substance of extremely high density.
- The density of a typical white dwarf star is over a million times that of water.



Red Giants/Neutron Stars/Black Holes

- Some very large stars are massive enough have hot enough cores to fuse carbon atoms into heavier elements.
- Massive stars like these (from the distant past) produced the elements in the air in our atmosphere, the silicates and iron that compose our planet (along with all other elements) in a process known as *nucleosynthesis*.
- The heaviest element that can be fused in the core of a star and still produce energy is iron.
- Once a star acquires an iron core it is at the end of the line.
- As a star with an iron core exhausts its supply of energy it begins a rapid and violent collapse resulting in an explosion known as a *supernova*.
- Sometimes an extremely dense fragment of such a star's core may survive this process and collapse even further into a ball of neutrons about the size of Pocatello! This incredibly dense object is known as a *neutron star*.
- If the remnant core is large enough it may further collapse into a *black hole*.
- Since neither neutron stars nor black holes are very luminous neither are easily seen by direct observation.