Fusion and the Main Sequence:
Stars are fusion reactors. In their core region they fuse together light elements into heavier ones. For example, at the core of our sun, hydrogen nuclei (one proton) are fused together to make helium nuclei (two protons and two neutrons). This type of fusion process releases energy and it powers the sun. In the core of stars the outward push of the energy from the fusion process (called radiation pressure) perfectly balances the gravitational forces which attempt to compress the star. A star whose outward radiation pressure balances the inward gravitational force is called a main sequence star.

After the Main Sequence:
The evolution of a star is based mainly on its mass. A low mass star, like our sun, will begin to fuse helium into carbon when all the hydrogen is exhausted in the core. This reaction causes an increase in the radiation pressure which forces the outer layers of the star to expand outwards. This expansion leads to a star called a red giant. Such a star has a cooler surface than the sun (so it appears redder), however the radius of the star increases by a factor of >100, so the star appears larger and more luminous. Once all the helium in the core is exhausted, gravitational forces compress the core and increase the temperature. For a low mass star, this temperature increase is not enough to continue the fusion reaction in the core (e.g. carbon into heavier elements). At this point the fusion which is still occurring in the outer layers of the star will push the stellar material outward, forming a planetary nebula (see Figure 1). Such a nebula has nothing to do with planets or planet formation; Astronomers using early telescopes confused the fuzzy appearance of distant nebula with planets, leading to the
misnomer. The dense carbon core of the star, which remains with a thin shell of helium and hydrogen, will collapse further under its weight without the balancing outward pressure from fusion. The collapse is finally halted when the electrons in the core are so tightly compressed that a quantum mechanical force emerges. This force, called electron degeneracy pressure, results from the fact that electrons do not like to be beside each other or in the same quantum-mechanical state. This force stops further compression of the core. The star is left with a dense carbon core which is not fusing but is supported by electron degeneracy pressure surrounded by a thin layer of hydrogen and helium. Such a star is called a white dwarf and this will be the ultimate fate of our sun in about 6 billion years.

What about Neutron Stars?

Neutron stars form from stars which are >8 times more massive than the sun. The evolution of massive stars is very similar to their low mass counterparts up to the point that carbon has formed in the core. The inward gravitational force from massive stars is so great that it can increase the core temperature to about one billion kelvin. At these temperatures, fusion of carbon into heavier elements can occur and thus fusion in the core continues. The center of a massive star becomes segmented into many layers with the heaviest elements fusing in the core and successively lighter ones fusing in subsequent layers. Eventually iron is formed in the core and this halts the fusion reaction. This is because, unlike the elements lighter than iron, if iron is fused into heavier elements it does not release energy (it absorbs energy). Thus, iron cannot fuel a fusion reaction. When this happens gravity compresses the core with such force that electrons are pushed inside the atom where they combine with the protons, turning them into neutrons. Eventually the iron in the core is turned almost entirely into neutrons which are then compressed into a dense inner core. As in the low mass example, the collapse is finally halted when the neutrons in the core are so tightly compressed that a quantum mechanical force emerges. In this case it is the neutrons which cannot be packed into the same quantum mechanical state and so neutron degeneracy pressure stops the collapse. The collapsing outer layers, unable to compress the core further, rebound off the core causing a shock wave which reverberates outwards. The star explodes. The outer layers are ejected in a massive blast into space, while the core becomes a neutron star. The ejected matter from the explosion forms a supernova remnant (see Figure 2).