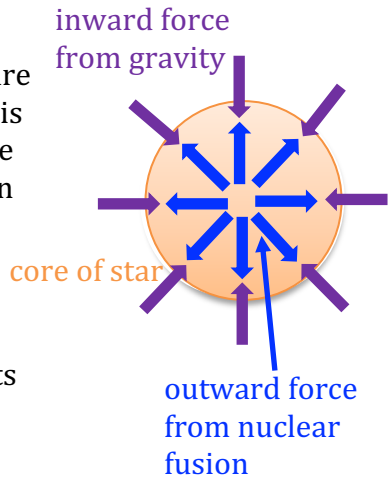
8.2 The life cycle of stars

Stars can form when cold clouds of dust ('nebula') and gas collapse due to the attractive force of gravity. As the dust and gas falls inwards, the temperature and pressure at the centre increases. Eventually, the temperature and pressure is high enough that nuclear fusion of hydrogen occurs. Hydrogen nuclei are fused together to form helium. This releases the energy that powers the star.

(1) Why are high temperatures and pressures needed for nuclear fusion? (Hint: Think about the charge on hydrogen nuclei and how they might be brought close enough together for fusion to occur.)

Stars which are fusing hydrogen in their cores are called 'main sequence' stars. Most of a stars life is spent as a main sequence star. During this stable period, the gravitational force acting inwards (in the core of the star) is balanced by the outward force produced by nuclear fusion.



The subsequent life cycle of a star depends on its mass.

Stars similar in size to the Sun

When these stars have run out of hydrogen to fuse in their core, the outward force from nuclear fusion ceases and the gravitational force causes the core to contract. As hydrogen in layers surrounding the core fall inwards, the rate of fusion increases considerably and the star expands enormously into a 'red giant' star. When the star has run out of hydrogen in its core, the huge pressures and temperatures produced by further gravitational collapse, cause helium to fuse to form carbon. This happens in bursts and the outwards forces produced cause the outer layers of the star to be 'puffed' away. What remains is the white-hot core of the star, which we call a 'white dwarf' star. After considerable time the star will cool down and become a 'black dwarf' star.

(2) Complete the following diagram for the lifecycle of a star similar in size to the Sun.

1) cloud of dust and gas (nebula)	⇨	2)	⇨	3) red giant star	⇨	4)	⇨	5)

(3) What two forces are balanced when the star is in stage 2), above?

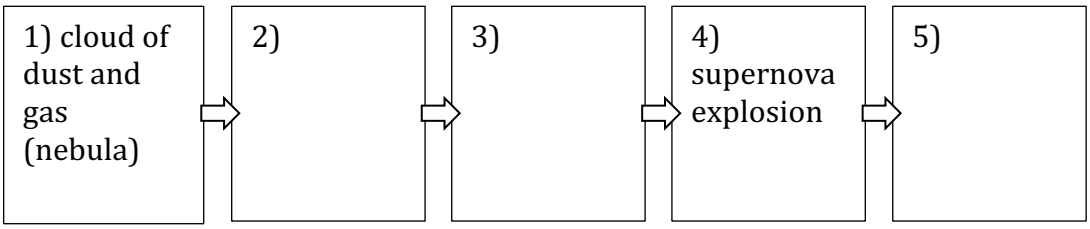
(4) What is responsible for the change from stage 2) to stage 3), above?

(5) What causes the star to lose its outer layers when it passes from stage 3) to 4), above?

Stars much larger than the Sun

Stars which are much larger than the Sun, spend a shorter time as a main sequence star. They are much brigher and bluer in colour. Once a star has used up the hydrogen in its core, it experiences gravitational collapse, a vastly increased rate of fusion of the hydrogen from surrounding layers, and a massive increase in size. At this stage it is known as 'red supergiant' star. These much more massive stars also have high enough temperatures and pressures to fuse heavier elements (all the way up to iron) in their cores. When fusion ceases, the gravitational forces cause the star to collapse which such force that electrons are forced to combine with protons forming neutrons. The rebound from this inward collapse and the enormous amount of energy released from futher fusion causes the outer layers of the star to be blasted into space in what is called a 'supernova explosion'. The core that remains in mostly neutrons and is known as a 'neutron' star.

(6) Complete the following diagram for the lifecycle of a star much larger than the Sun.



(7) What is the heaviest element that can form during stage 3), above?

(8) What causes a supernova explosion?

(9) What is a neutron star and how does it form?

Extremely large stars

Extremely large stars will have a much shorter life than the Sun. They will follow the same life cycle as the large stars discussed above. However, after the supernova explosion stage, what remains is so dense that even light can't escape beyond a boundary known as the 'event horizon'. The object is known as a 'black hole'.

(10)✎ Why are black holes 'black'?