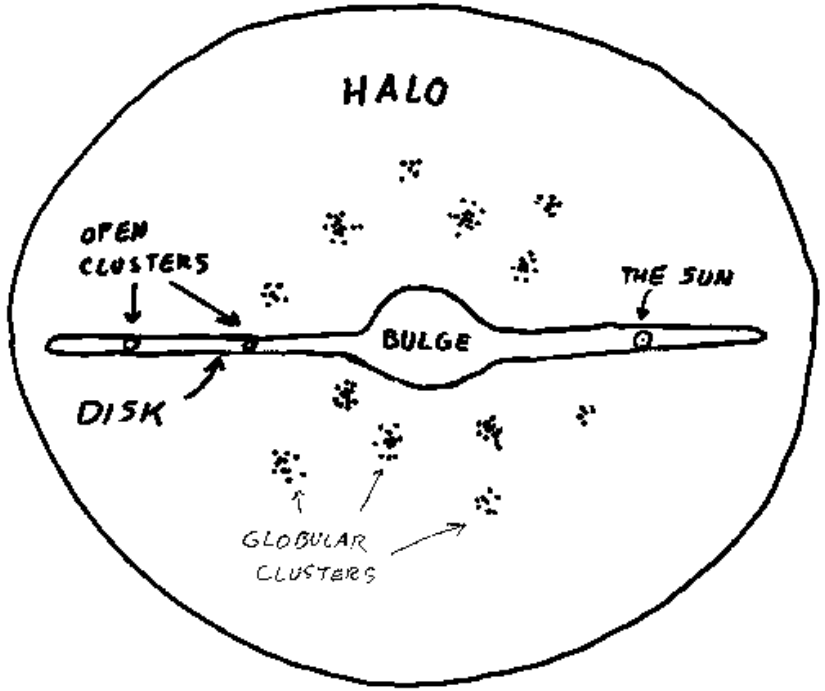
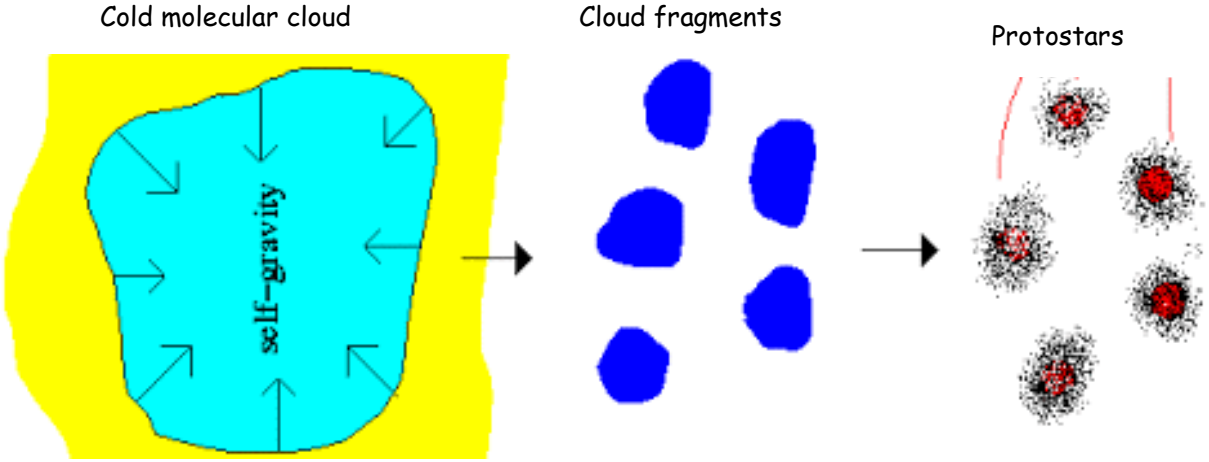
Astronomy **Summary Knowledge Organiser** – Chapter 14 (Topic 14) **Stellar evolution (i) Nebulae & Messier**

The '**faint and fuzzy objects**' we can see in the night sky with our naked eyes were originally called **NEBULAE**. However, once optical aids such as binoculars and telescopes were invented, it could be seen that these nebulae could be divided into **4 different types** of celestial objects;
OPEN CLUSTERS of young blue stars within the arms of our own galaxy
GLOBULAR CLUSTERS of old red stars that orbit close to the center of our galaxy
LARGE CLOUDS of **INTERSTELLAR DUST & GAS**
GALAXIES such as Andromeda & the 2 Magellanic Clouds



The **MESSIER CATALOGUE (see image right)** was published in **1781** by the French astronomer Charles Messier. It contained **103 extended objects** (fuzzy patches of light) that were classified into the 4 groups listed above and given a Messier number, eg. **M16** the Eagle nebula (see image right).



The story of stars of all sizes begins with a **COOL DENSE MOLECULAR CLOUD** of dust & gas in the spiral arm of a galaxy (see above).
At some point, the cloud will begin to **COLLAPSE into smaller clumps** due to **GRAVITY**. Each fragment of the original cloud will form a **PROTOSTAR** that may become the core of a true star in the future.
As a protostar itself collapses, gravitational potential energy (GPE) is being converted into kinetic energy (KE) and so its **core temperature will increase**.

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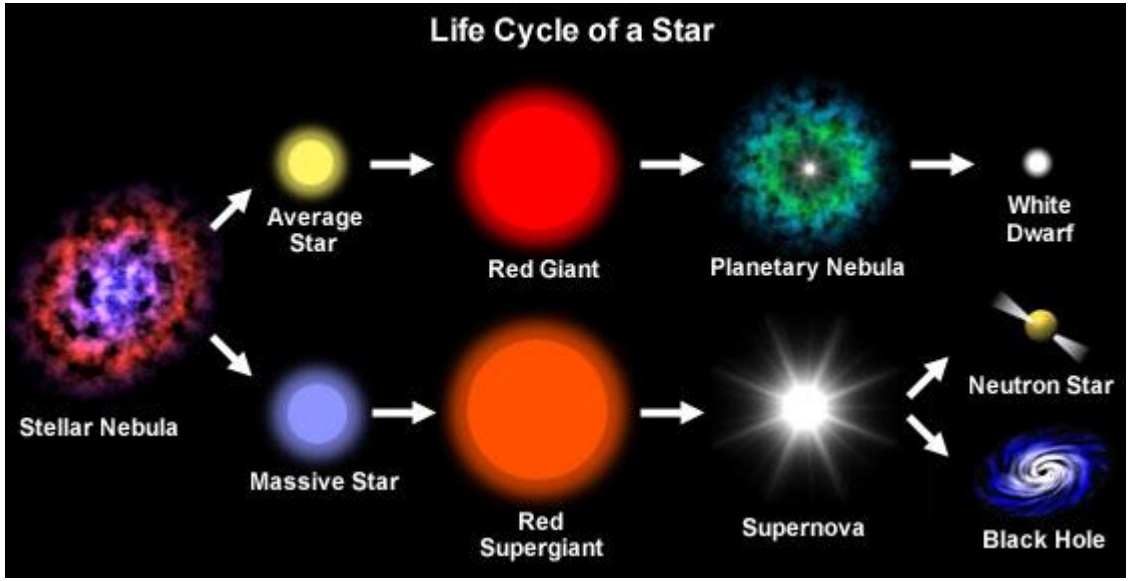
If the core temperature is high enough **nuclear fusion** (**Hydrogen into Helium**) will begin and the protostar becomes a **MAIN SEQUENCE STAR**. Once fusion begins, the core radiates energy outwards, creating a **RADIATION PRESSURE** that balances the **INWARD GRAVITATIONAL FORCE,** so the star collapses no more. It will now spend **90% of its life** as this **main sequence** star. The **lifetime** of stars depends on their **mass**. Although **high mass stars** have more 'fuel', their **rate of fusion is considerably higher** than low mass stars, therefore they have much **shorter lifetimes**. Eventually all stars run out of Hydrogen and their evolution from that point will depend on their **MASS**!

If the stars **CORE MASS** is less than the **CHANDRASEKHAR LIMIT** (1.4 times the Sun's mass);

it will follow the life cycle of a **LOW-MASS STAR**,

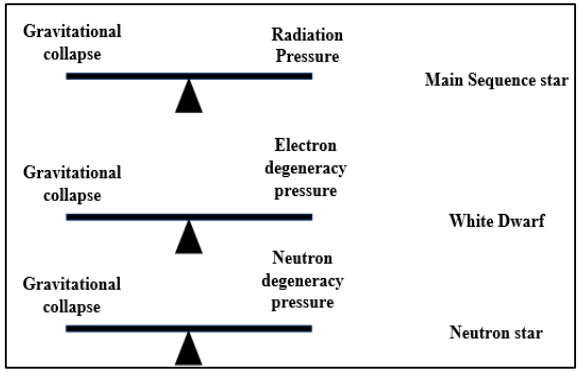
if its core mass is above the **CL** it will evolve as a **MASSIVE STAR!**

When nuclear fusion in a ***low-mass star*** (sometimes called a SOLAR MASS star) ends, the radiation pressure becomes zero and so the core collapses. This causes the **stars temperature to increase** and so **hydrogen fusion begins again**, but this time **in shells surrounding the core**. The **helium core** itself will contract further and get even hotter, causing even more fusion in the shell of hydrogen and so the star **EXPANDS** & **COOLS,** becoming a **RED GIANT**. **If it gets hot enough helium** in the core can be fused to make **carbon**. This high energy fusion generates a radiation pressure much greater than the stars gravity and so the stars outer layers are blown away creating a **PLANETARY NEBULA (expanding SPHERE of GAS)**.



When nuclear fusion in a ***massive star*** ends, the radiation pressure becomes zero and so the core collapses due to **huge gravitational forces** that mean its **temperature gets so high** that **carbon** can be fused into **Neon**! Once all the carbon is depleted, the core will contract again, increase in temperature and so a new heavier element can undergo fusion. This cycle **continues until IRON is formed in the core**. The fusion of iron nuclei does not generate energy so once the core is iron enriched, fusion stops! During this cycle of fusing the **NUCLEI** of different elements in different shells, the star will have expanded to become a **RED** or **BLUE SUPERGIANT**! Finally, the **mass of the core** will determine if the supergiant becomes a **NEUTRON** star or a **BLACK HOLE**.

Finally, core collapse stops due to **ELECTRON (**degeneracy) **PRESSURE balancing the inward GRAVITATIONAL FORCE (see image right)** when electrons resist being squeezed closer together because they have the same charge. At this point the star is very **HOT & SMALL** - it is a **WHITE DWARF** and it will ultimately cool to become a **BLACK DWARF** in the very distance future!



If the **core's mass is < 3 times that of the Sun** collapse is halted by **NEUTRON** (degeneracy) **PRESSURE** which is when neutrons resist being squeezed together (after all the electrons have been forced into protons to form a solid star core of neutrons). The sudden halt (caused by neutron pressure) to the contraction of a star creates a huge **SHOCKWAVE** that blows the star apart in an explosion called a **SUPERNOVA**. The neutron star left behind is approx. **20km** in diameter & **incredibly dense**.

If the **core's mass is > 3 times that of the Sun** collapse even **NEUTRON** (degeneracy) **PRESSURE is not enough to balance the inward GRAVITATIONAL FORCE** and so the core continues to collapse and becomes a **BLACK HOLE**!