# Topic Guide:

## Stellar Evolution

**GCSE (9-1) Astronomy**

**Pearson Edexcel Level 1/Level 2 GCSE (9-1) in Astronomy (1AS0)**

# Stellar Evolution

## Contents

# Specification Points

**14.3** Understand the effects of the interaction between radiation pressure and gravity in a main sequence star

**14.4** Understand changes to the radiation pressure-gravity balance at different stages in the life cycle of a star with a mass similar to the Sun

**14.5** Understand the balance between electron pressure and gravity in a white dwarf star

**14.6** Understand changes to the radiation pressure-gravity balance at different stages in the life cycle of a star with a mass much greater than the Sun

**14.7** Understand the balance between neutron pressure and gravity in a neutron star

**14.8** Understand the effect the Chandrasekhar Limit has on the outcome on the final stages of the life cycle of a star

**14.9** Understand the principal stages and timescales of stellar evolution for stars of similar mass to the Sun, including:

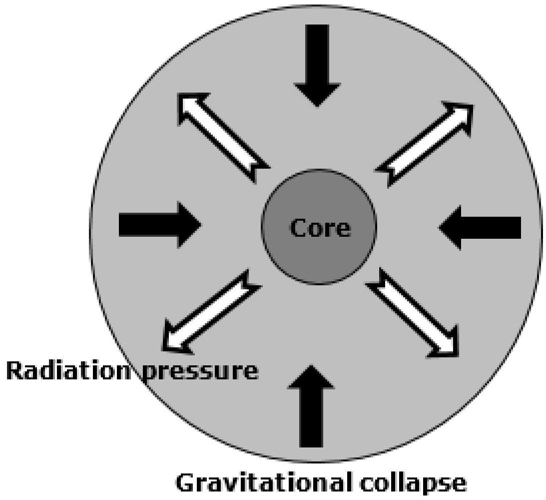
- a emission and absorption nebula
- b main sequence star
- c planetary nebula
- d red giant
- e white dwarf
- f black dwarf

**14.10** Understand the principal stages and timescales of stellar evolution for stars of much larger mass than the Sun, including:

- a emission and absorption nebula
- b main sequence star
- c red giant
- d white dwarf
- e supernova
- f neutron star
- g black hole

# The Astronomy

**Main Sequence** stars are in a stable equilibrium (known as hydrostatic equilibrium), where the force of gravitational collapse is balanced by the radiation pressure caused by photons generated during nuclear fusion within the stellar core.




*This could be illustrated by hanging a mass on a spring; the weight of the mass is balanced by the tension produced in the spring. Boyle's law demonstrations (a large sealed syringe with a fixed volume of air) can also be modified to illustrate the force required to squash a gas and the resulting increase in pressure*.

If gravity was the dominant force, the star would begin to collapse. This would raise the core temperature and result in an increase in the rate of fusion. Therefore, the radiation pressure increases to balance the gravitational collapse; we have a stable equilibrium! Cepheid variables oscillate about this equilibrium point.

*This could be demonstrated by displacing the mass on the spring, an increase in tension gives a resultant upward force, thus the mass accelerates upwards and begins to oscillate about the equilibrium position.*

The lifetime of stars depends on their mass. Although high mass stars have more 'fuel', their rate of fusion is considerably larger than their low mass companions - they have much shorter lifetimes. However, up to 90% of a star's life is spent as a main sequence star irrespective of its mass.

**Red Giants** form when the hydrogen in the core becomes depleted. Reduction in nuclear fusion leading to much less radiation pressure, resulting in gravitational collapse of the core. This increases core pressure and temperature, allowing a shell of hydrogen around the core to start fusing and, with more massive red giants, the fusion of helium into carbon (the triple alpha process). For low mass stars (less than approximately 8 solar masses) this dramatic, high energy fusion is too great for the stars relatively weak gravity and the outer layers of the star are blown away to form a **planetary nebula**.

**The Chandrasekhar Limit** (named after the Nobel prize winning Indian astronomer Subrahmanyan Chandrasekhar) is the theoretical mass limit of a white dwarf and is equal to 1.4 solar masses. Simply put, if the *core* of a star were to exceed this limit, then it would become a supernova rather than produce a White Dwarf.

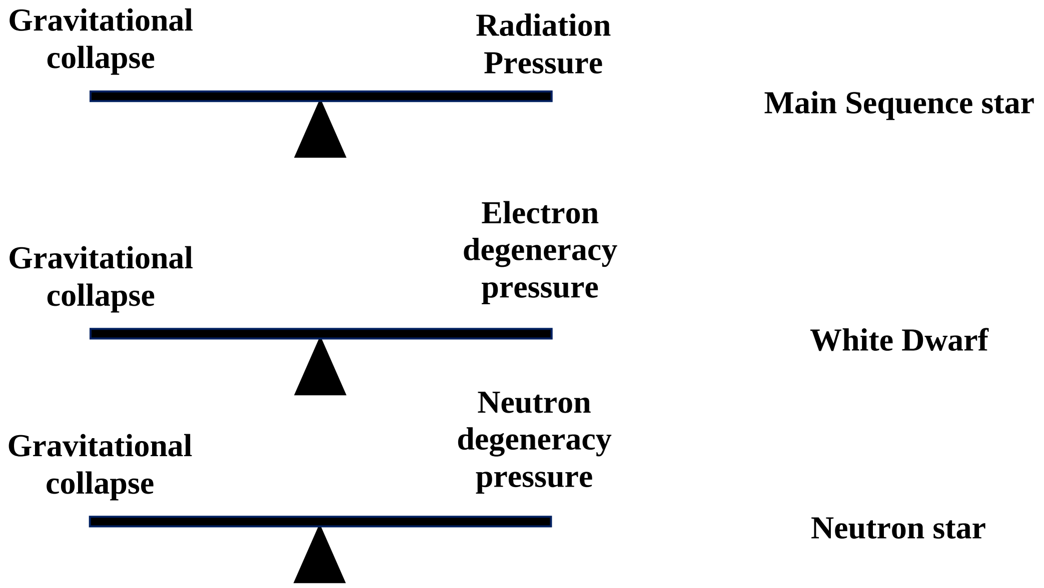
**White Dwarf** stars are in equilibrium due to gravitational collapse on one hand, and electron degeneracy pressure on the other. This is due to the Pauli exclusion principle, whereby no two electrons can exist in the same state (thus they cannot all exist in the same energy level at the same time).

**Neutron Stars** are formed if a high mass star (greater than approximately 8 solar masses) has a sufficiently rapid gravitational collapse to force the electrons into the nuclei. Electron capture $(e^- + p \rightarrow n + \nu_e)$ will result in just neutrons (and neutrinos) being produced. It is this production of neutrinos which triggers the infalling material to explode outwards in a supernova. At the centre, a neutron star is formed where gravitational collapse is now balanced by neutron degeneracy pressure.

**Black holes** form if the neutron star is more than 3 solar masses, in which case the neutron degeneracy pressure is insufficient to halt the collapse further.

# Further support

A 'see-saw' diagram can be used to illustrate the balance between gravitational collapse and radiation pressure or electron pressure or neutron degeneracy pressure.




Youtube – The Life Cycle of Stars (Institute of Physics)
https://www.youtube.com/watch?v=PM9CQDlQI0A

Youtube - Astronomically Correct Twinkle Twinkle (minutephysics)
https://www.youtube.com/watch?v=hhn-RzMELhY

COSMOS, The SAO Encyclopaedia of Astronomy - Stellar Evolution
http://astronomy.swin.edu.au/cosmos/S/Stellar+Evolution

Caltech.edu – Stellar Evolution handout
http://www.astro.caltech.edu/~dperley/astro10/starevolhandout.pdf

## Topic test questions

1. Complete the following sentences:
   a) In a White Dwarf, gravitational collapse is balanced by _________________ pressure.
   b) In a Main Sequence star, ________________________ is balanced by radiation pressure.
   c) In a neutron star, gravitational collapse is balanced by _________________ pressure.

2. What triggers the formation of a red giant?

3. Why do low mass stars produce planetary nebula?