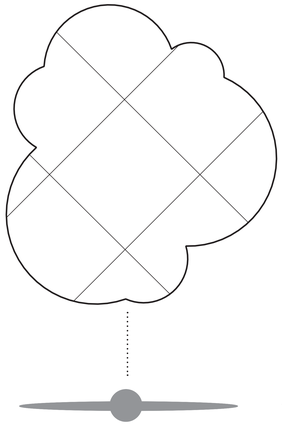
STELLAR EVOLUTION
THE BIRTH & DEATH OF STARS

The life cycle of every star is determined entirely by its formation mass

BIRTH STAGE

All stars form from huge (100 light years), cold (5 – 10 K or -268°C to -263°C) molecular clouds comprising mainly Hydrogen through gravitational collapse. The cloud may even collapse into separate, smaller clouds that eventually become multiple stars or even open clusters of stars.



Each cloud collapses into a protostar with most of the cloud's mass at its core with a protoplanetary disk around it from which planets can form.

BROWN DWARF (mass < 0.1 MΘ)
The protostar's mass is too low for gravitational contraction to trigger thermonuclear fusion and the gathering of mass from the parental cloud simply peters out.

RED DWARF (mass ≈ 0.5 MΘ)
The protostar's mass is sufficient for gravitational contraction to trigger the slow thermonuclear fusion of Hydrogen into Helium, and the star's lifetime is very long, measuring trillions of years. Proxima Centauri is the closest (2.4 light-years) Red Dwarf to Earth.

SUN-LIKE STAR (mass < 1.4 MΘ; the 'Chandrasekar Limit')
These stars fuse Hydrogen into Helium for ≈ 10 billion years. When their supply of Hydrogen is depleted, they expand into a Red Giant which fuses Helium into Carbon and Nitrogen. Their mass is too low to cause the 1 billion K temperature required for Carbon fusion.

There is then insufficient radiation pressure to counteract gravity and the star explodes as a Type Ia Supernova, shedding its outer layers as Planetary Nebulae, with the core contracting into an Earth-sized White Dwarf.

The resistance of electrons to occupying the same atomic orbitals ('electron degeneracy') can withstand the gravitational force caused by a mass of ≈ 1.4 * MΘ. This is therefore the upper mass limit for Sun-like stars that end their live as White Dwarfs. Sirius 'B' is the closest (7.8 light years) White Dwarf to Earth.

MASSIVE STARS (mass < 10 * MΘ)
The star fuses Hydrogen, Helium, Carbon, Neon, Oxygen and Silicon into Iron in a 'fusion onion' (see 'Origin of the Elements' tablet). When the core fusion ceases, the star expands into a Supergiant.

RED GIANT PHASE (lasts around 1 billion years)

A PLANETARY NEBULA centred around a WHITE DWARF lasts for only 10,000 years

SUPERGIANT PHASE (short lifespans of 100's of thousands to 30 millions years)

If the remnant core after the Supernova explosion has a mass of < ≈ 8 * MΘ it will collapse into a NEUTRON STAR of about 1.5 * MΘ with a diameter of ≈ 10 km which can rotate at up to several hundred revolutions per second. This is because the resistance of neutrons to occupying the same nuclear orbitals ('neutron degeneracy') can withstand the gravitational force arising from a mass of < ≈ 8 * MΘ.

If the core remnant has a mass > 8 * MΘ gravity prevails and the core collapses into a BLACK HOLE whose density is so high that NOTHING – not even light – can escape from it.

A Neutron Star with a magnetic field becomes a Pulsar. At the core of the Crab Nebula (M1) there is a Pulsar.

When a star comes too close to a Black Hole the intense gravity will pull it apart forming a disk around the Black Hole, which emits a portion of the star's mass as two jets of high-energy plasma from opposite poles that are observed as X-ray jets for a period of up to 6 months.

BROWN DWARF

RED DWARF

WHITE DWARF

FORMATION MASS ==>

BIRTH	MAIN SEQUENCE	OLD AGE	DEATH	REMNANT

EVOLUTIONARY PATH ==>