E.5

Stellar Evolution

IB PHYSICS | ASTROPHYSICS

Measuring the Age of the Stars

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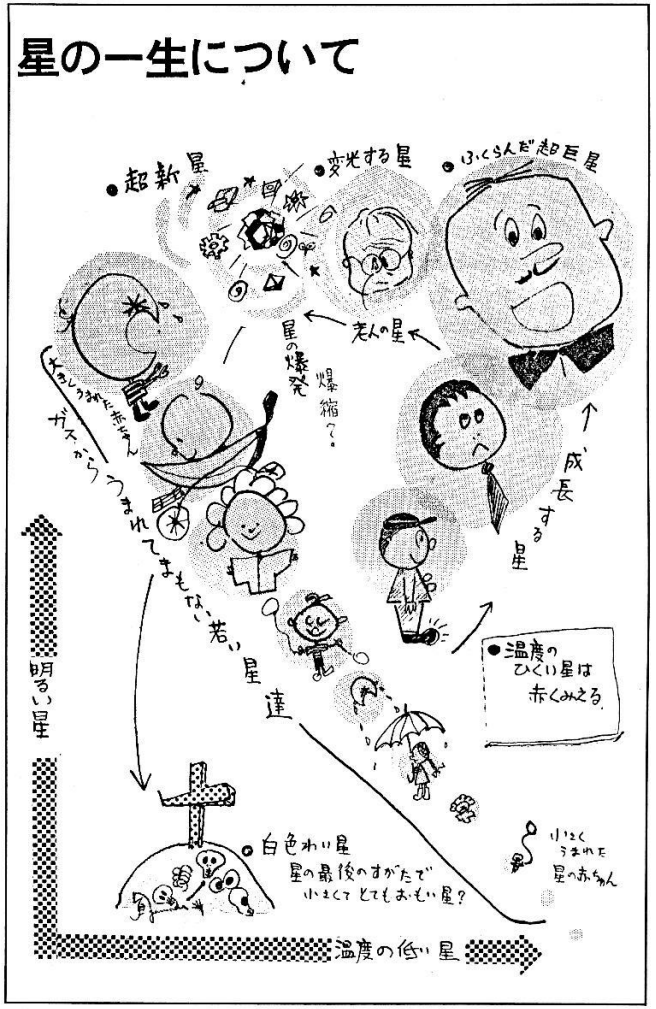

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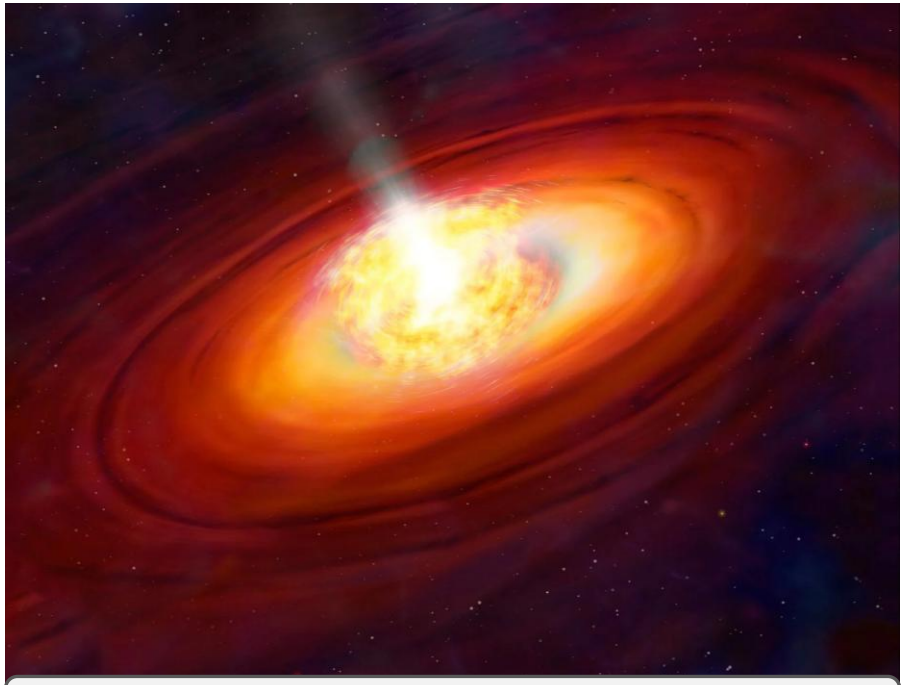
The Birth of a Star

Cloud of “dust” where gravity begins to pull hydrogen together



Beginning stage of a star where accumulated matter starts to heat up

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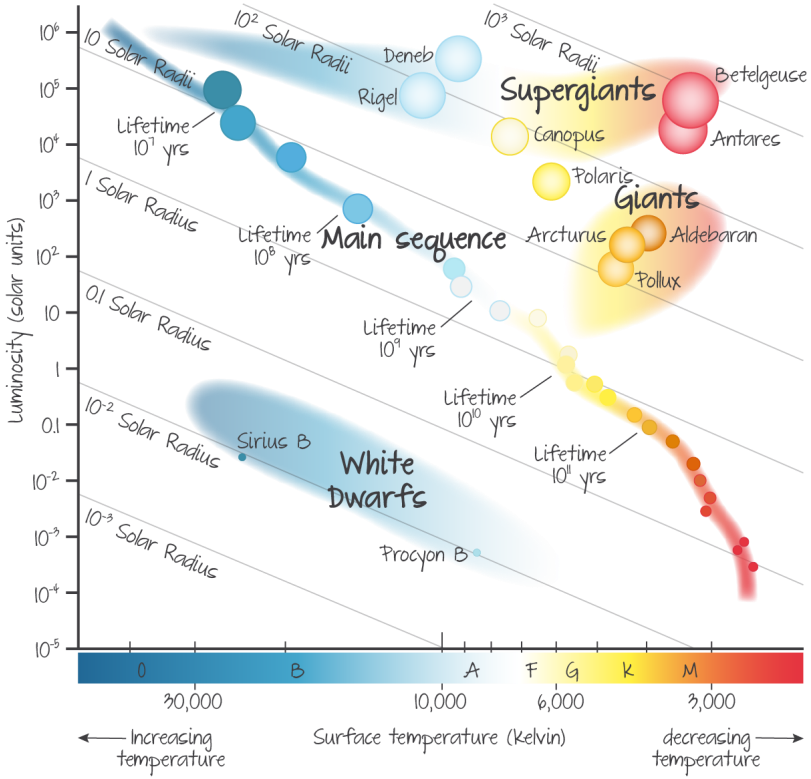
All stars start on main sequence

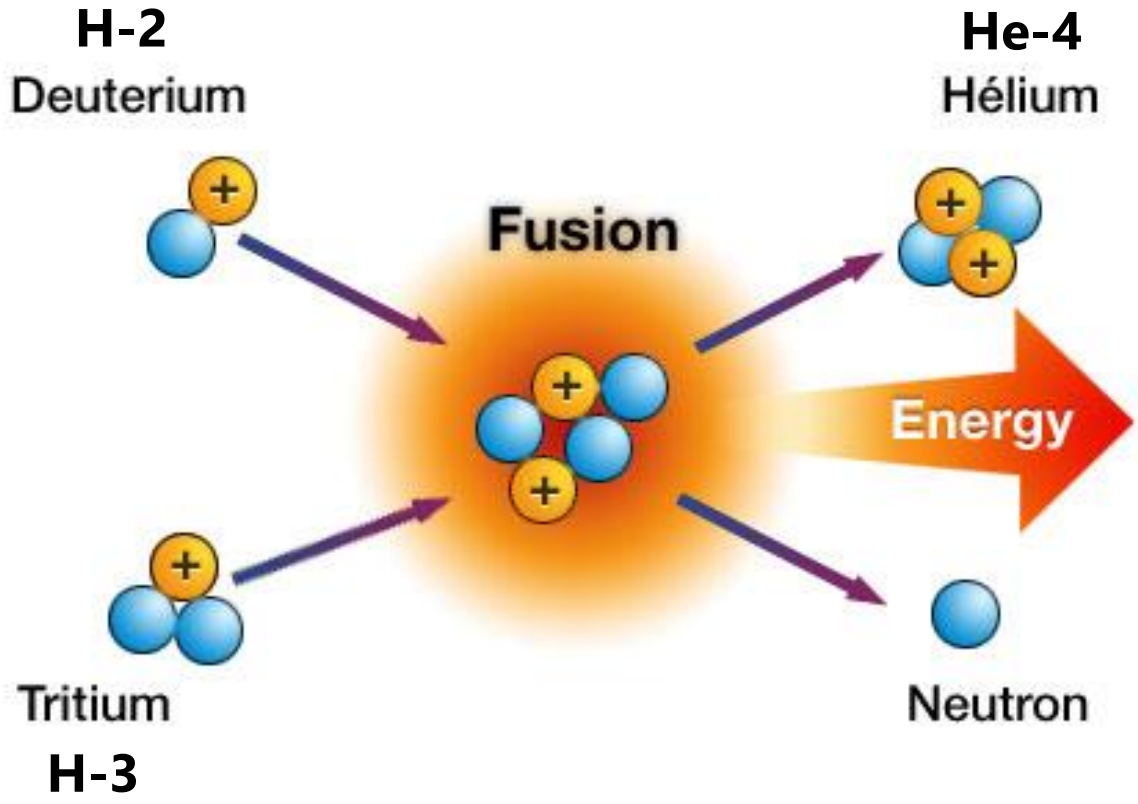
A star's position on the main sequence depends on how much matter was pulled together

This also sets into motion a series of stages that determine the star's evolution and death



Fusion

All stars begin by fusing hydrogen into helium



Fusion

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Hydrogen-2	2.0141 u
Helium-3	3.0161 u
Neutron	1.0087 u

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + energy$$

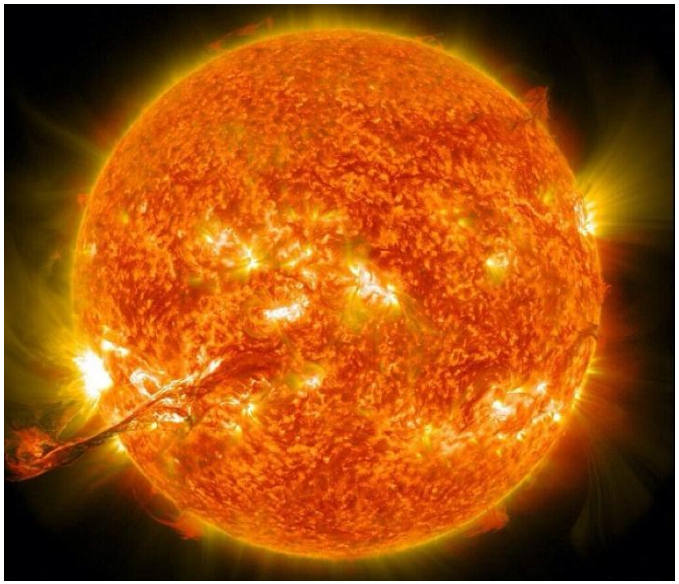
(2.0141 u + 2.0141 u) – (3.0161 u + 1.0087 u)

4.0282 u 4.0248 u

Mass Defect		Energy Released	

Conditions for Fusion

It's significantly more difficult to create fusion reactions here on earth



Fusion vs. Fission

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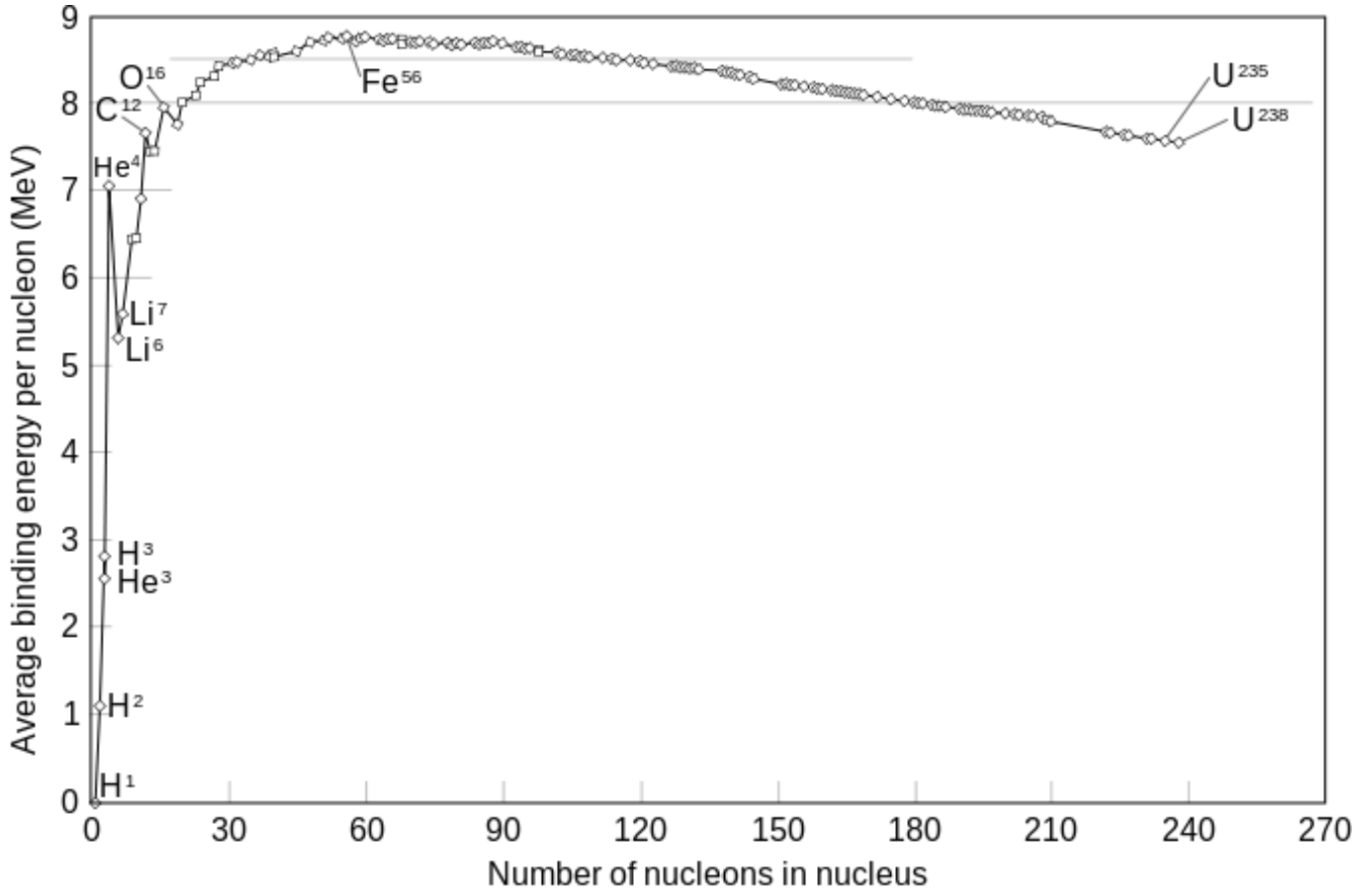
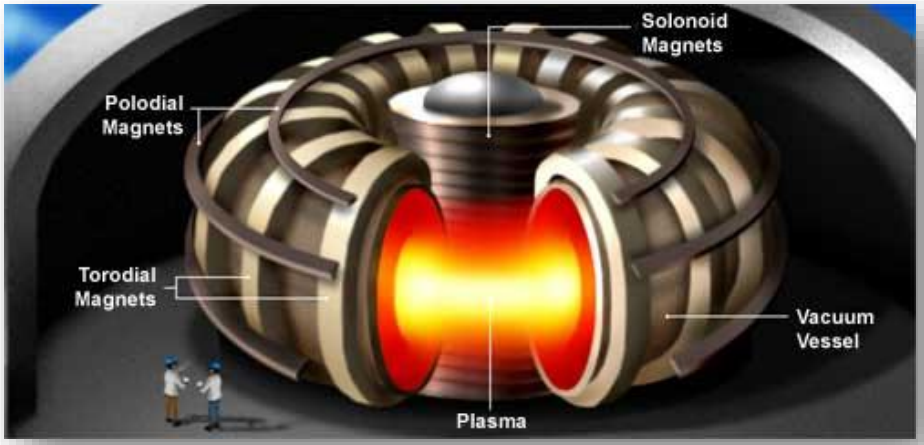
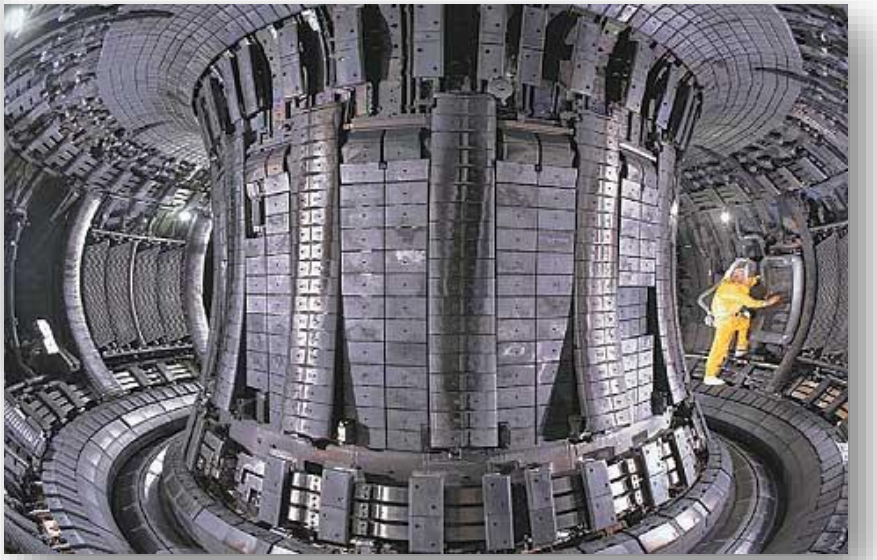


Fusion as a Power Source

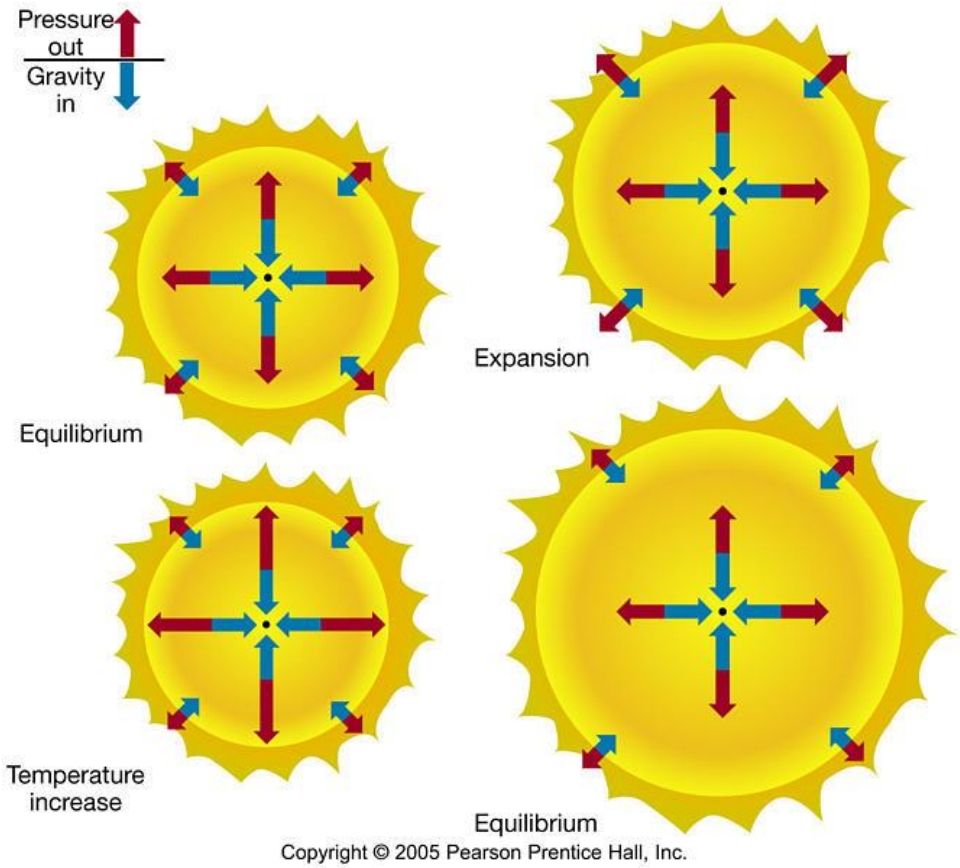
Fusion reactions have been successfully controlled using strong magnetic fields but the energy used to run the magnets exceeds the energy released in the reaction…

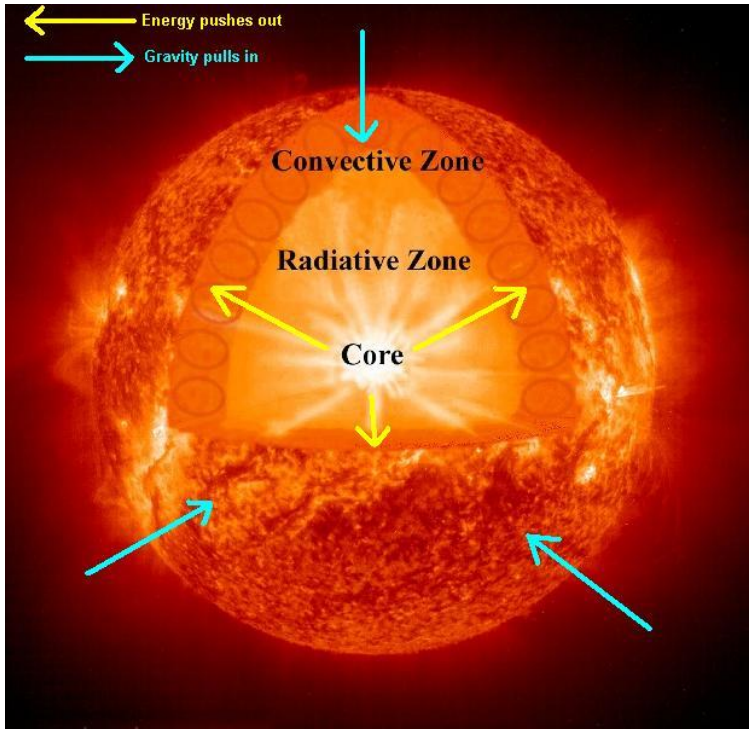




Stellar Equilibrium

Increasing temperature increases pressure and causes expansion





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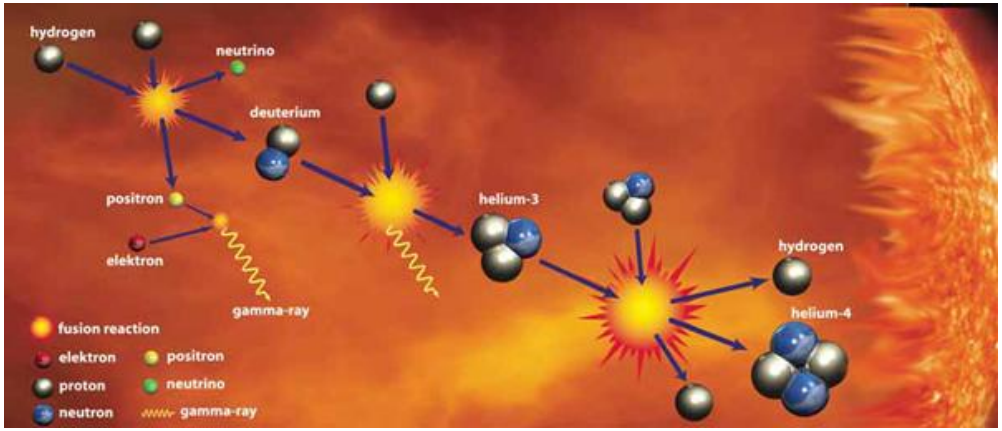
What happens as Stars Age??



Fusion in the core

1. Core runs out of _____
2. Hydrogen fusion outside of core and heats up star
3. More outward pressure / Star Expands [_____]
4. Star runs out of Hydrogen and star _____
5. High pressure/temp allow fusion of _____ → _____

What happens as Stars Age??

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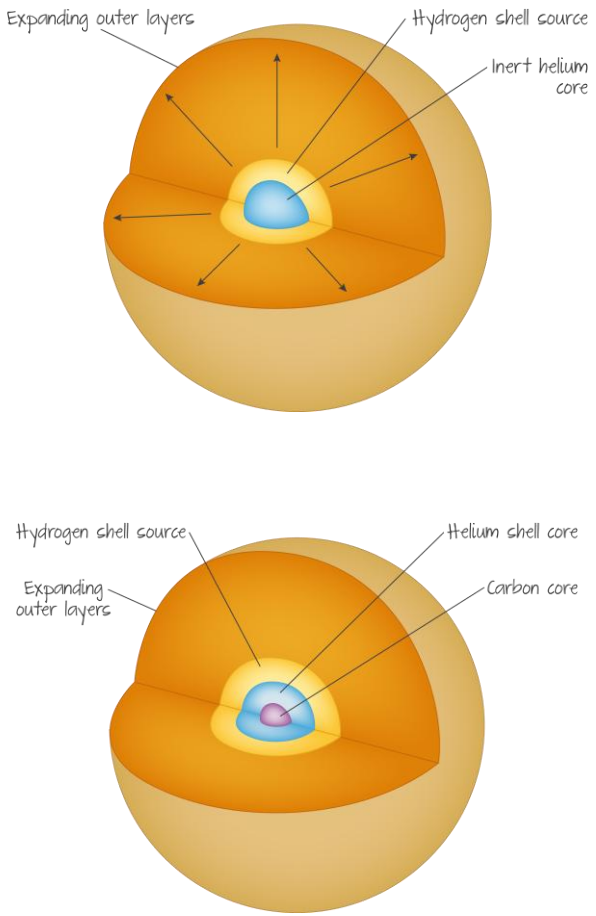
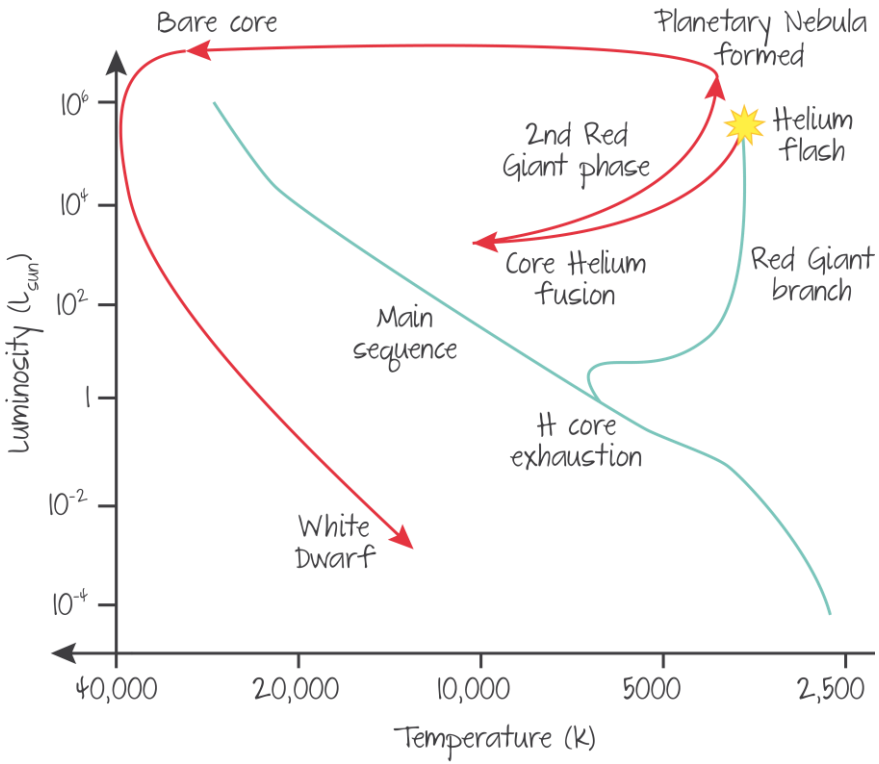


An average star can only fuse up to carbon before it dies



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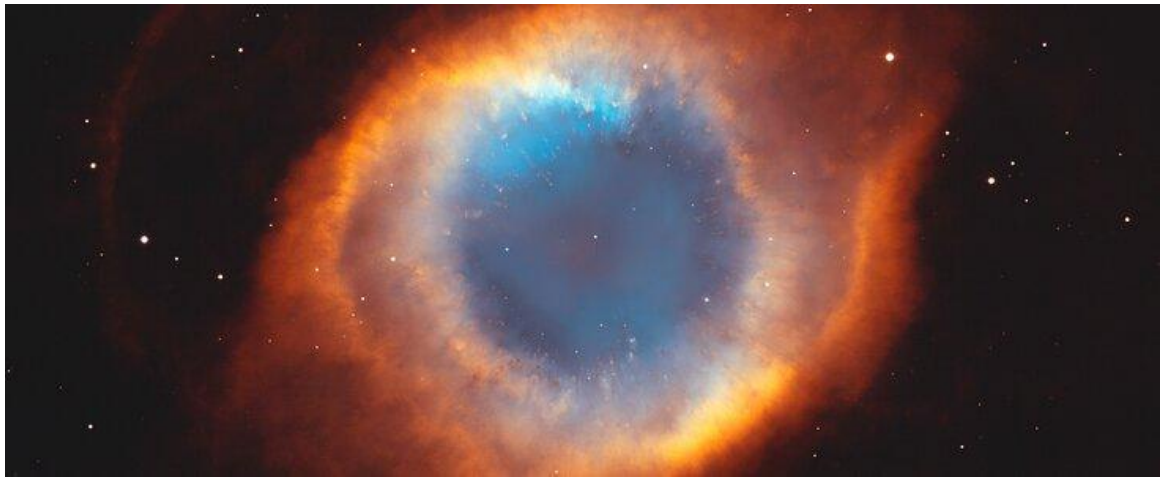
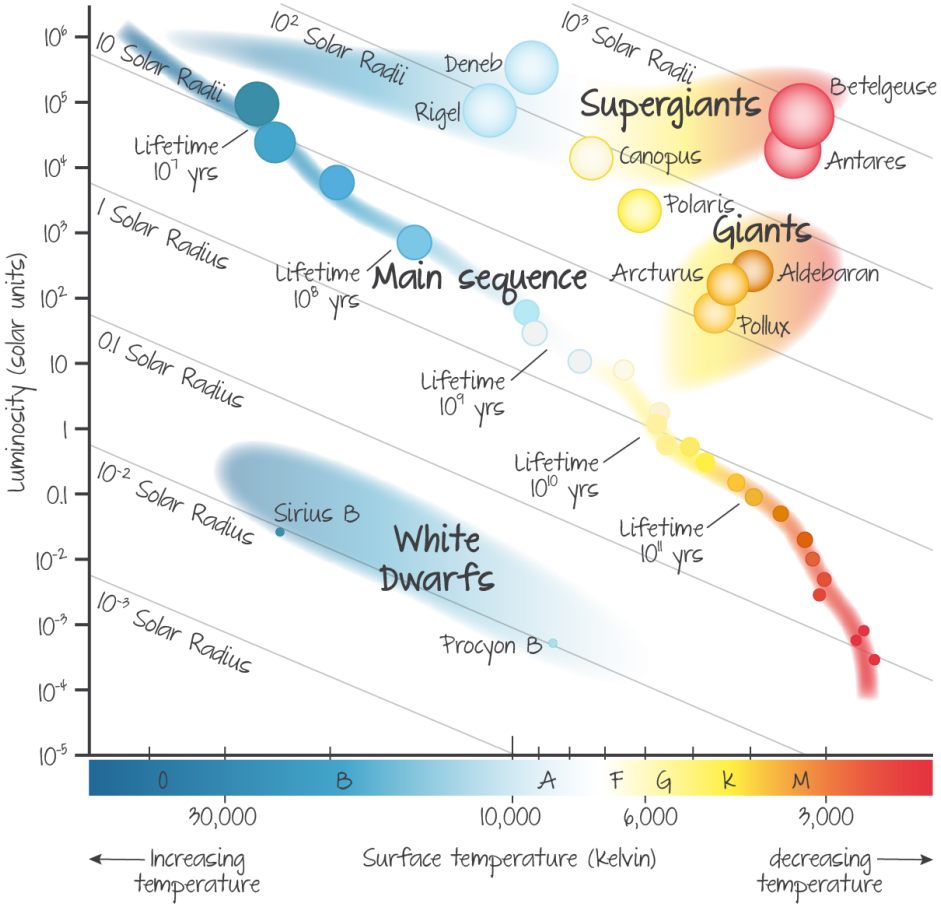
Planetary Nebula

After the average star fuses its helium, the outer layers are ejected to form a planetary nebula

The hot dense core left behind is called a _____



White Dwarf Stars



Life Cycle of Sun-Sized Star

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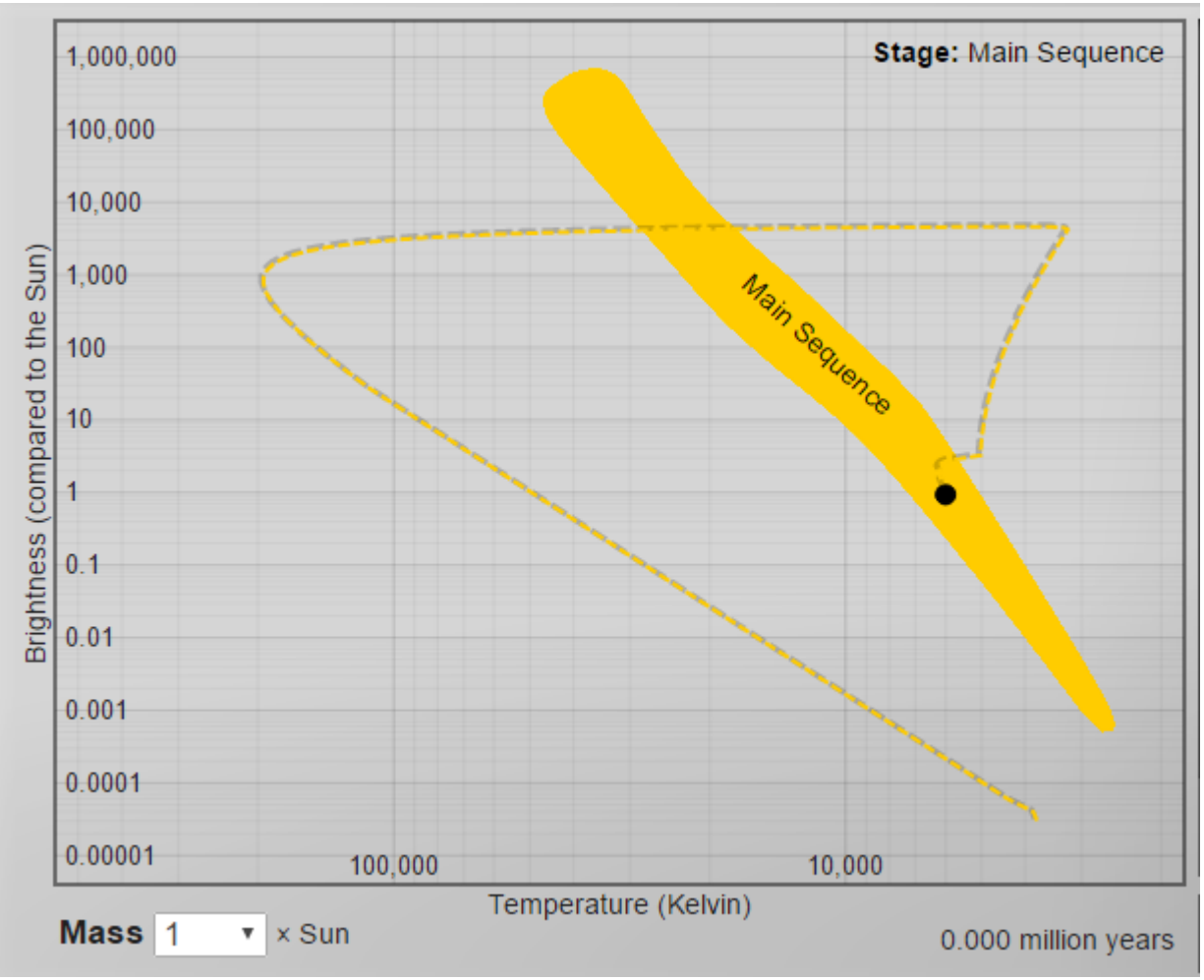

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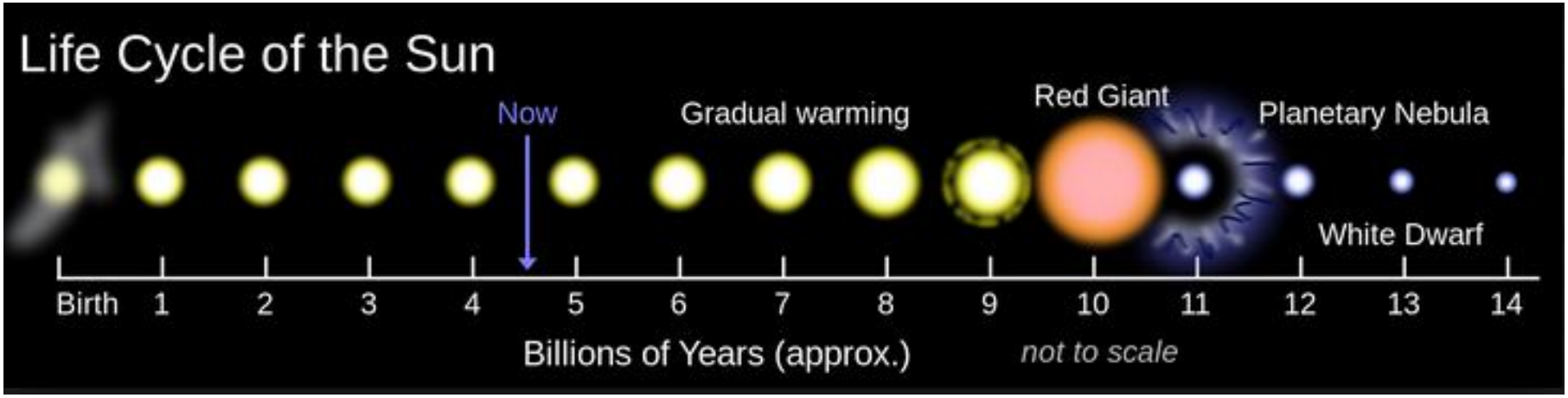
Life Cycle of our Sun



White Dwarf Stars

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There is a maximum mass of a core that can become a white dwarf

Chandrasekhar Limit = 1.4 $M_\odot$

The core only makes up about 1/3 of the stars mass so a star with a total mass greater than about 4 $M_\odot$ will not form white dwarfs

If Star's Total Mass $< 4M_\odot$ It will become a White Dwarf

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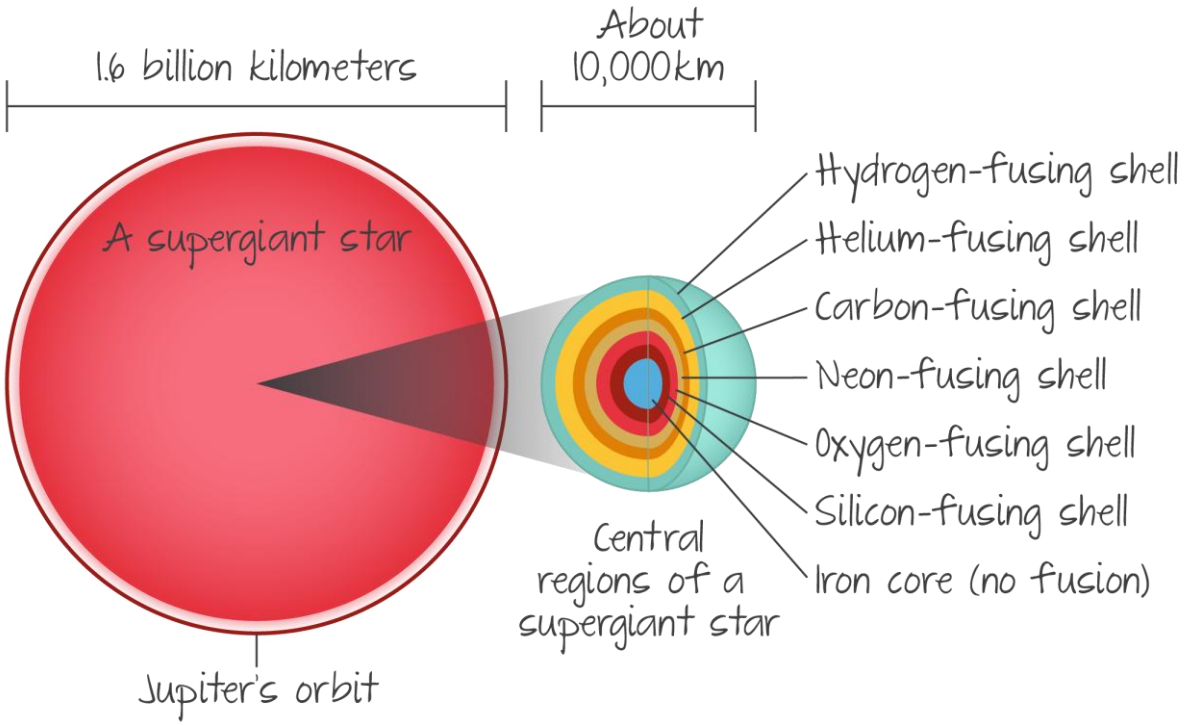
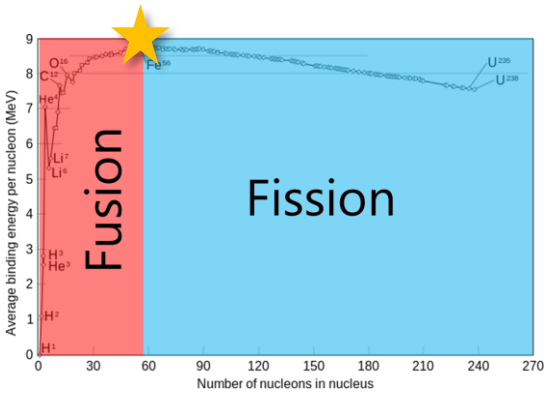
Life Cycle of Massive Star

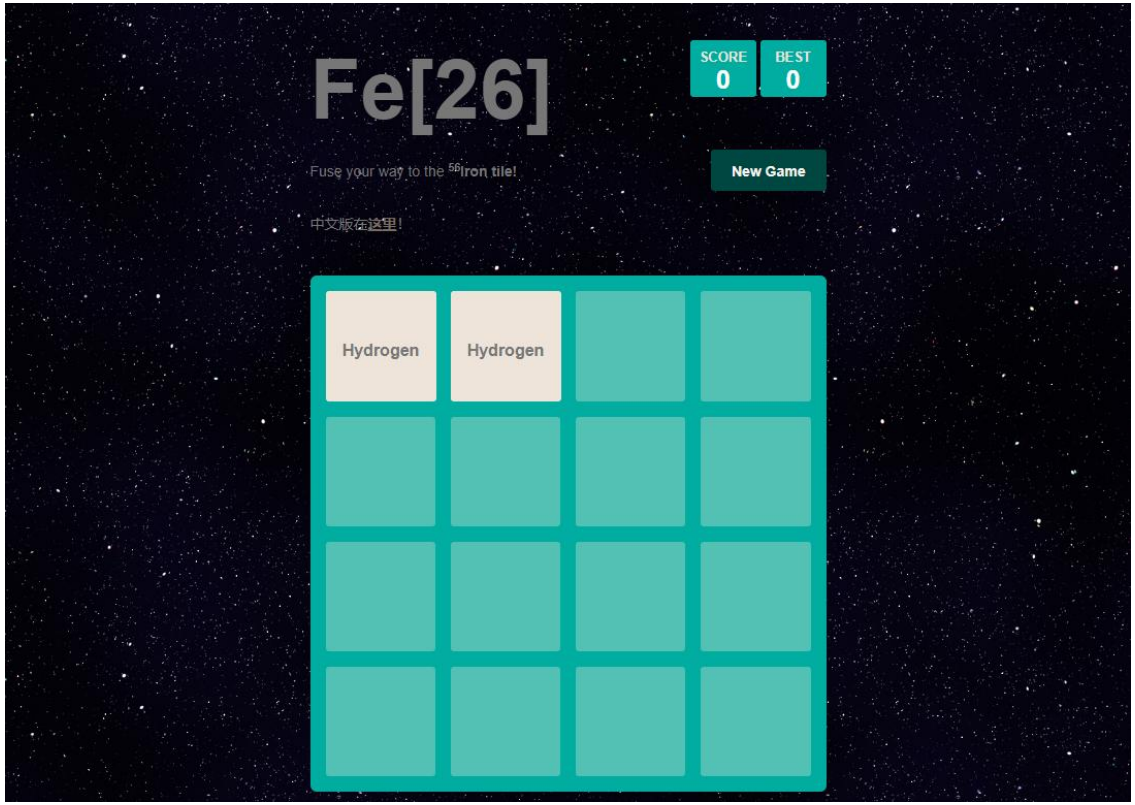
Massive stars have enough gravity to keep fusing elements beyond carbon into shells of increasingly larger elements

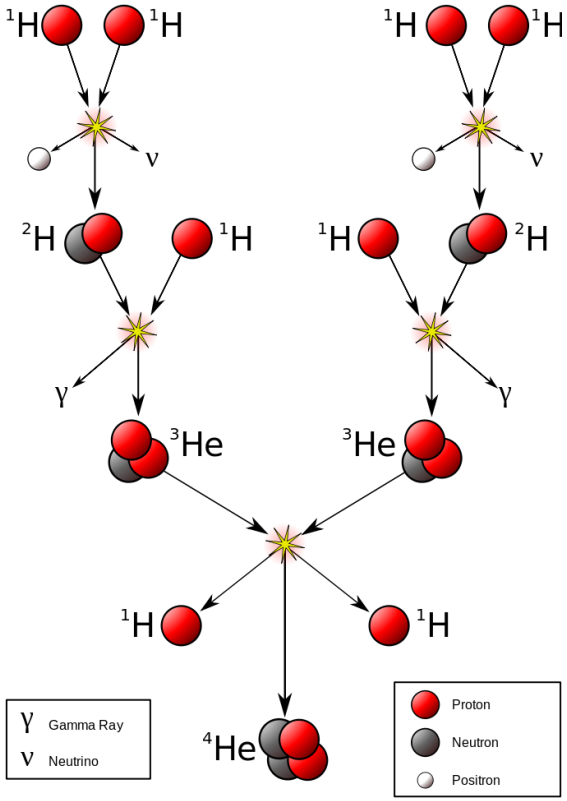




Remember the largest element in this "Fusion block"?

The Process Continues…





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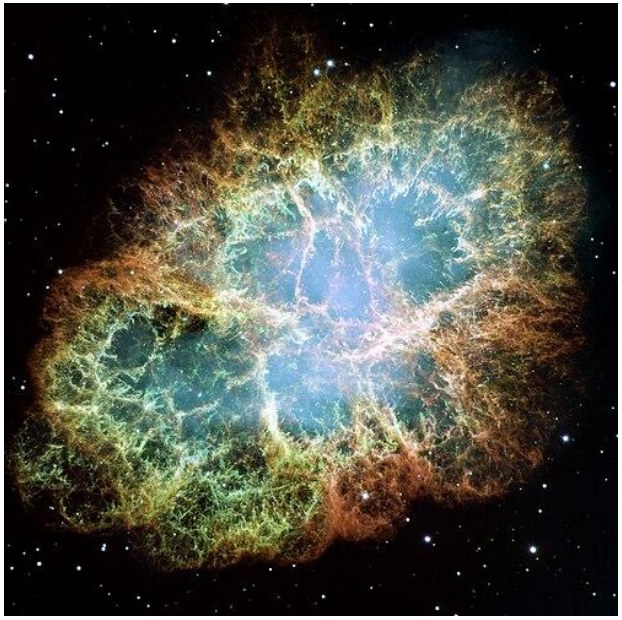
The Star Collapses

Once iron builds up, fusion can no longer produce energy, and the gravity overcomes the outward push causing the star to collapse in a violent event called a _____



Life Cycle of Massive Star

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The ultimate fate of a massive star depends on the mass of the final core after the outer layers are ejected

Oppenheimer-Volkhoff Limit = 3 $M_\odot$

A Neutron star above the Oppenheimer-Volkhoff Limit will collapse and form a Black Hole.

$< 3M_\odot \rightarrow$

$> 3M_\odot \rightarrow$

Life Cycle of Massive Star

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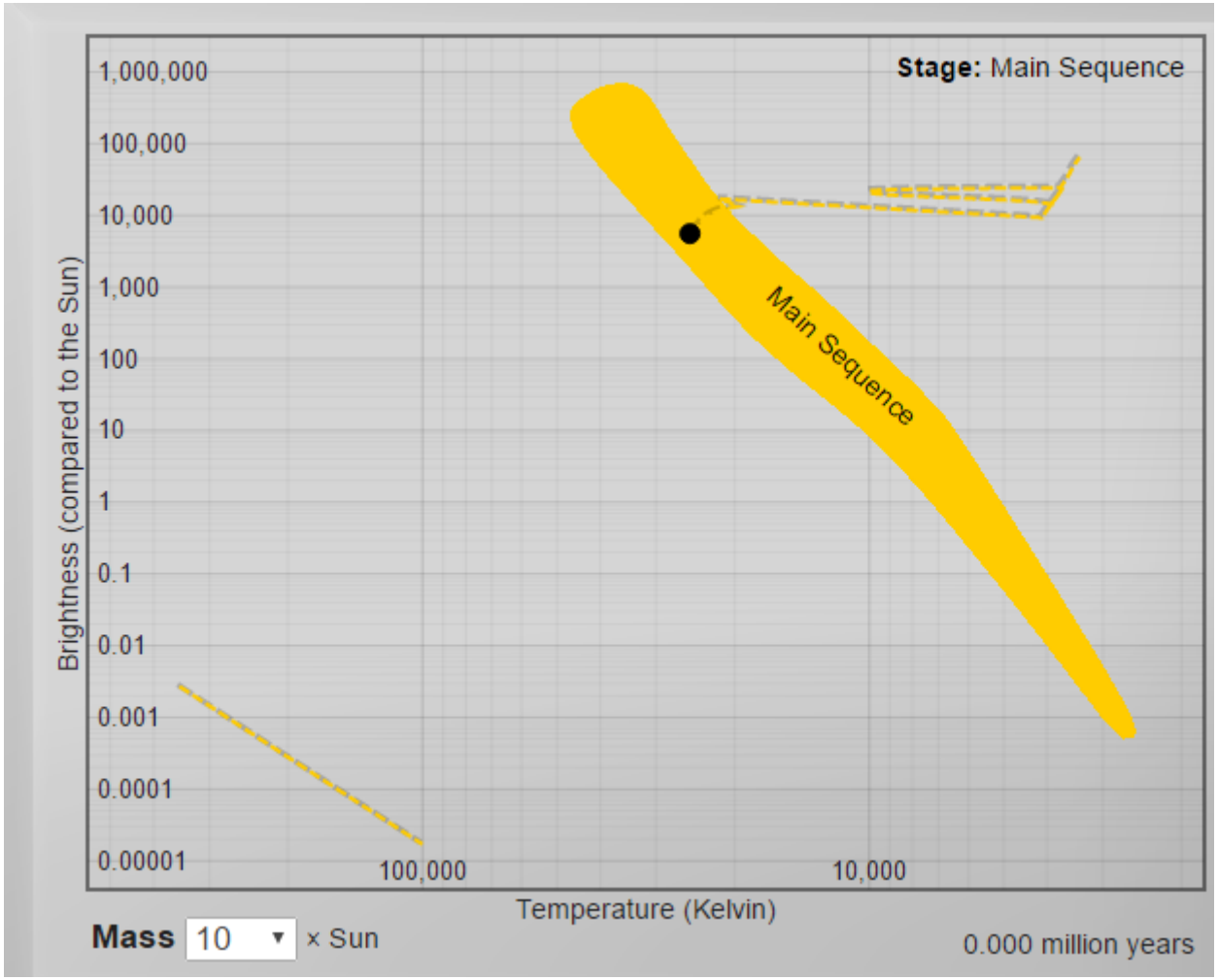

Black Holes?

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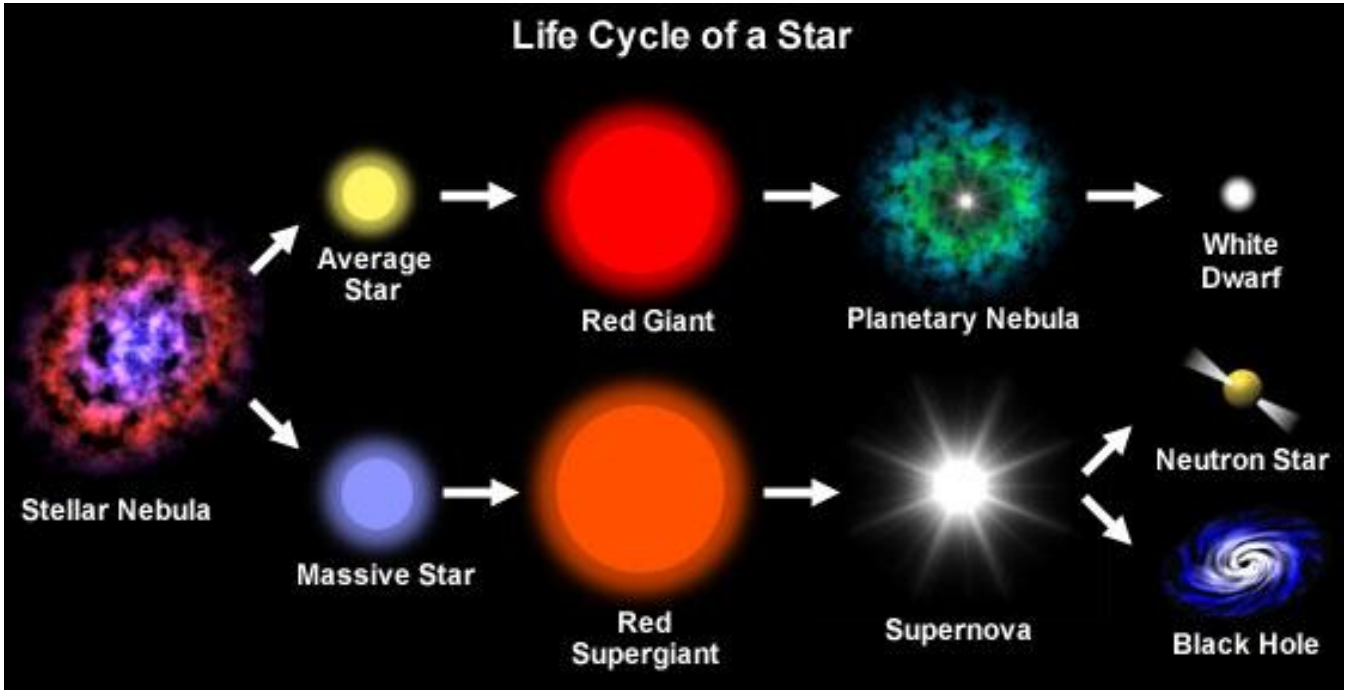
Life Cycle of a Star



Lesson Takeaways

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- ❑ I can describe the process of fusion and conditions required for it to happen
- ❑ I can calculate the energy released in a fusion reaction
- ❑ I can discuss the forces involved in stellar equilibrium
- ❑ I can describe the life cycle of a star
- ❑ I can describe the differences in fusion for an average and massive star
- ❑ I can predict the death outcome of a star based on the mass of its core at the end of life