Name: ______________________________ Form: ______

GCSE

Astronomy

Club

3.4 Stars

Evolution of Stars

a) Associate the stages of evolution of a star: i with a solar mass ii with a much greater mass, with the components of the HR diagram

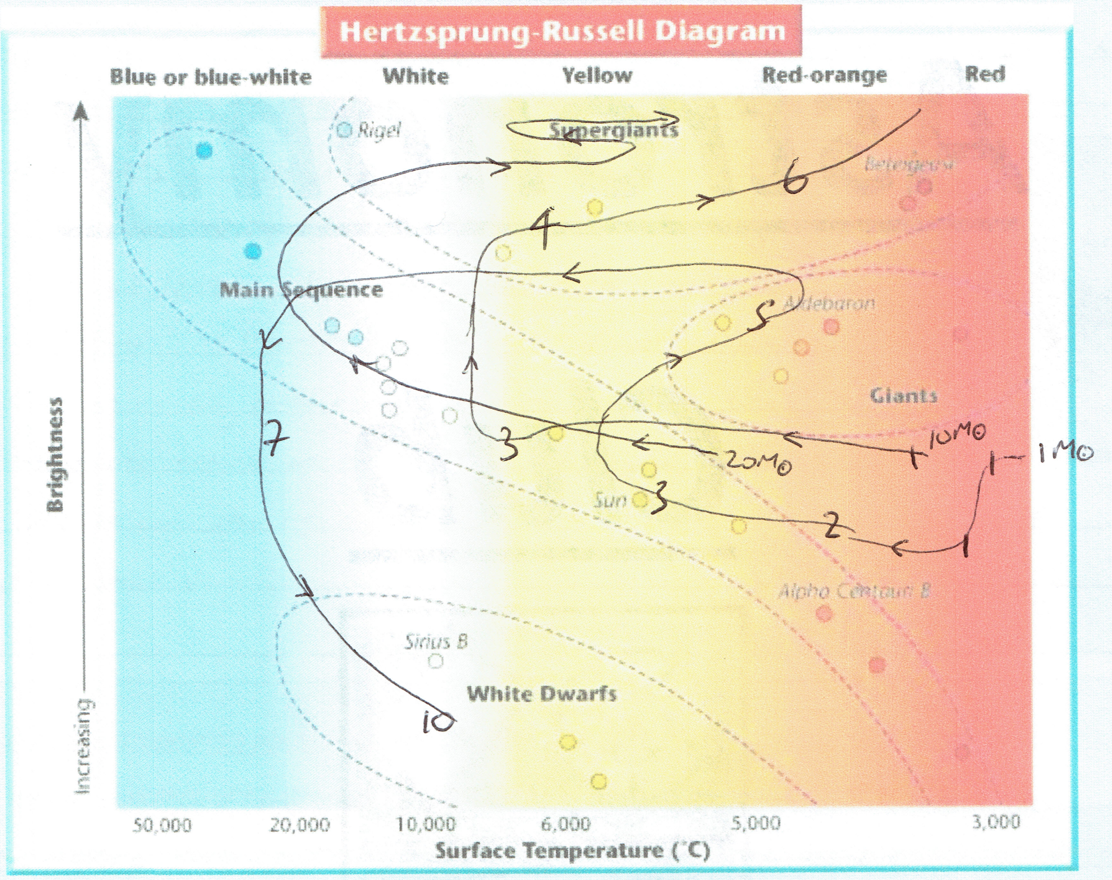
Complete the diagram below to show the evolution of stars,.

1 ~~Nebula~~ Molecular Cloud → 2 Protostar → 3 Main Sequence → 4 Red Supergiant / 5 Red Giant

4 Red Supergiant → 6 Supernova → 8 Black Hole (Star of 20x solar mass) / 9 Neutron Star (Star of 10x solar mass)

5 Red Giant → 7 Planetary Nebula → 10 White Dwarf (Star of 1x solar mass)

Label the HR diagram with the numbers 1 to 10 to show where each stage of the evolution of a star is located in the HR diagram.



Draw a line on the HR diagram to show the path through the diagram of a star of one solar mass as it evolves.

Draw a line on the HR diagram to show the path through the diagram of a star of ten solar masses as it evolves.

Draw a line on the HR diagram to show the path through the diagram of a star of twenty solar masses as it evolves.

Explain, for each stage, what causes the star to move to the next stage:

The process starts with the gravitational collapse of a giant molecular cloud. The collapsing gas releases GPE as heat. As the temperature and pressure increase, a protostar is formed. The protostar continues to grow by accretion, until conditions are right for fusion to begin. This balances the force of gravity ~~and~~ (radiation pressure) and the star enters a stable state – the main sequence phase. How long it stays in this phase depends on the mass. Bigger, hotter stars evolve more quickly. Small stars and big stars take different paths after the main sequence, which happens when the star's 'fuel' begins to run out.

Smaller stars (like our Sun) become red giants. Hydrogen burning nearer the surface causes the star to expand and thus cool, thus becoming more red. Total energy generation gradually ~~rises~~ decreases and the star contracts, getting hotter in the process. The outer layers are expelled to form a planetary nebula. The star that is left is very compact and very hot – a white dwarf – and gradually cools as it radiates its remaining heat into space.

Bigger stars go through a similar process initially, becoming red supergiants. The core grows hotter and denser and heavier elements are formed. Past iron, this process would consume instead of generate energy. The result is sudden, catastrophic gravitational collapse, into either a neutron star or black hole. Some of the GPE released is converted into a supernova.

b) Demonstrate an understanding that emission nebulae, absorption nebulae and open clusters are associated with the birth of stars

Complete the table:

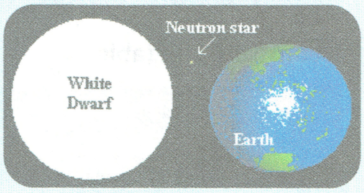
Object	What they are	Association with the birth of stars
Emission nebulae	A nebula (cloud of dust and gas) that is ionised and emits light of various colours (especially red). Usually ionised by high energy photons from a nearby hot star	Often (eg. H II regions) the source of the ionising radiation are young, massive stars. Often these are clusters of stars.
Absorption nebulae (or dark nebula)	A type of interstellar cloud so dense it obscures light from objects behind it. Dust grains in cold molecular clouds (frozen) extinguish the light (visible light).	These clouds are the spawning grounds of stars (+ planets).
Open clusters (or galactic cluster)	A group of up to a few thousand stars that were formed from the same giant molecular cloud and have roughly the same age. Loosely bound by gravity. (+ tend to disperse)	Tend to be dominated by young hot blue stars. Formed by collapse of part of the cloud. (triggered by eg. a supernova). (tend to go on to form H II regions)

C) Demonstrate an understanding that planetary nebulae and supernovae are associated with the death of stars

Complete the table:

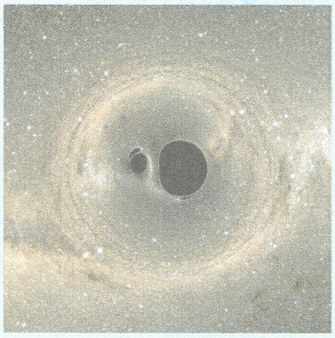
Object	What they are	Association with the birth of stars
Planetary nebulae	An expanding glowing shell of ionised gas ejected from old red giant stars late in their lives. Stellar winds expel the star's outer layers. The exposed core ionises this with UV radiation	As stars get old, they create heavier elements. The winds recycle these into the interstellar medium. This enrichment can help the formation of new stars from other nebulae.
Supernovae	One of the last stages in the life of a massive star. Most likely occur due to the sudden gravitational collapse of the core, overcoming the pressure outwards from fusion. The outer layers of the star are violently expelled.	The expanding and fast moving shockwave spreads out into the interstellar medium (again taking heavy elements with it). The shockwave can trigger the compression of molecular clouds, and star formation. (It can also disrupt it).

d) Describe the nature of neutron stars and black holes



A neutron star is: a type of compact star that is the densest and smallest stars known to exist in the Universe. They can have a mass of about twice that of the Sun with a radius of about only 7 miles. They are made almost entirely of neutrons.

It is caused by: the gravitational collapse of a massive star after a supernova. Large, old stars eventually run out of (nuclear) fuel and the outward pressure is defeated. This causes the temperature to rise and electrons + protons to combine to form neutrons. Eventually the density stops further collapse + the atmosphere bounces off in a supernova.



A black hole is: a region of spacetime with such strong gravity that nothing can escape (including light) from inside it. The boundary is called the event horizon. Supermassive black holes - with masses of millions of Suns - are thought to be at the centre of most galaxies.

It is caused by: an incredibly compact mass deforming spacetime. When very massive stars collapse at the end of their life cycle, not even neutron pressure can stop the implosion down to a singularity, where the laws of physics break down.

e) Describe how astronomers obtain evidence for the existence of neutron stars and black holes.

Evidence for the existence of neutron stars: Theorised since at least the 1930s, but thought too small to be detected. Jocelyn Bell used a rudimentary radio telescope at Cambridge University and (in 1967) found ~~a~~ rapid, regular pulsing signals (maybe aliens?!). The only possible object that is small and dense enough to rotate so quickly is a neutron star. If these 'pulsars' are linked with a supernova remnant, then it is more than likely a neutron star. The ~~[illegible]~~ pulses we 'see' are from radiation emitted from a neutron star's magnetic poles - like a lighthouse.

Evidence for the existence of black holes: ~~Theorised since at least the~~ Space is black and black holes are black so how can you find one? You can see it indirectly. A black hole is very massive (dense) so it influences objects near it. A binary system that is bright in X-rays would be a good place to look. A black hole pulls in material and it is accelerated and heated up, giving off X-rays. To be sure it is a black hole and not a neutron star, use Kepler's law to check the masses. If it is very big it is likely a black hole. Supermassive black holes are suspected at the centre of most galaxies by looking carefully at the speed of rotation. Also, sometimes the light from distant galaxies appears to have been bent by a very dense object - gravitational lensing could be evidence for black holes.