The life cycle of a star

4.8.1.2 · Space physics · revision notes

How a star changes during its life, why the path it follows depends on its size, and how fusion in stars and supernovae produces the chemical elements. Expect flow charts with missing stages, 'describe' and 'explain' questions, and 6-mark comparisons of two life cycles. GCSE Physics only, not in Combined Science.

Key facts

- Every star: nebula → protostar → main sequence star
- Much bigger than the Sun: → red super giant → supernova → neutron star or black hole
- Main sequence: hydrogen fuses into helium
- Elements heavier than iron are produced in a supernova
- About the size of the Sun: → red giant → white dwarf → black dwarf
- The size (mass) of a star decides its life cycle
- Fusion in red giants and red super giants makes heavier elements (up to iron in the biggest stars)
- A supernova distributes the elements throughout the universe

Notes

The start of every star

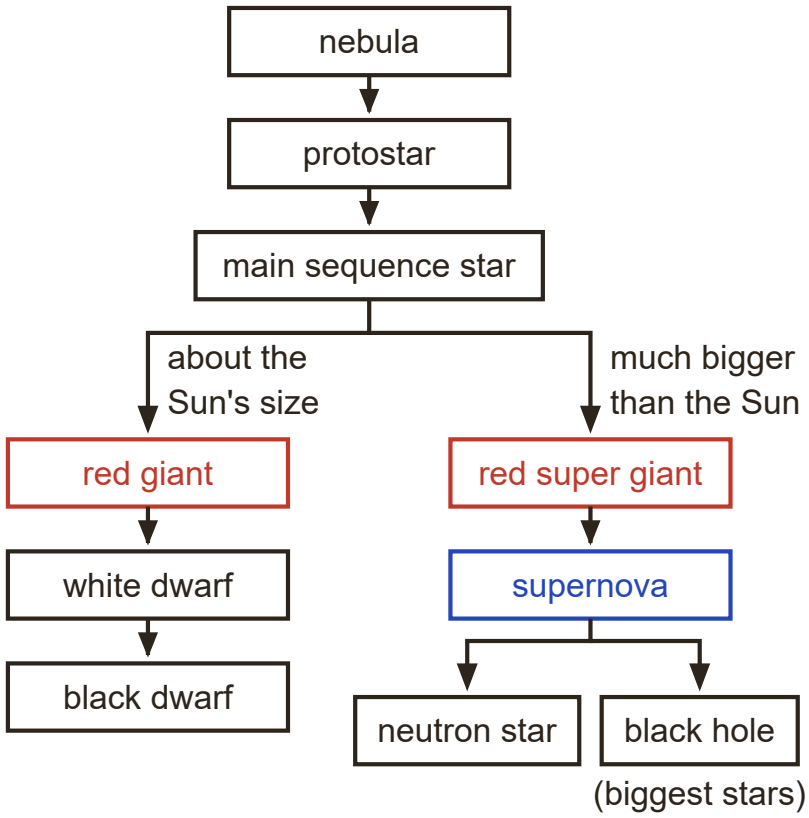
- A **nebula** (cloud of dust and gas) is pulled together by gravity to form a **protostar**.
- When hydrogen starts to fuse into helium in its core, it becomes a **main sequence star**.
- It stays stable while the inward pull of gravity is balanced by the outward pressure from fusion energy. For a star like the Sun, this lasts billions of years.
- What happens next depends on the **size (mass)** of the star.

Stars about the same size as the Sun

- When the hydrogen in the core runs out, the star swells to become a **red giant**. Helium nuclei fuse to form heavier elements, such as carbon.
- The outer layers drift away, leaving a **white dwarf**: a small, very hot, dense core in which fusion has stopped.
- The white dwarf cools and fades until it no longer gives out significant light. It is then a **black dwarf**.

Stars much bigger than the Sun

- When the hydrogen in the core runs out, the star swells to become a **red super giant**. Fusion forms heavier and heavier elements, up to iron.
- The star then explodes as a **supernova**.
- The core that is left becomes a **neutron star** (extremely dense) or, for the very biggest stars, a **black hole** (so dense that not even light can escape its gravity).



The path after the main sequence depends on the mass of the star.

How stars make the elements

- Fusion processes in stars produce the naturally occurring elements, building them up from hydrogen.
- Main sequence stars: hydrogen nuclei fuse to form helium.
- Red giants and red super giants: helium and other light nuclei fuse to form heavier elements, such as carbon and oxygen. In the biggest stars this goes as far as iron.
- Elements heavier than iron are produced in a **supernova**.
- The explosion of a supernova spreads the elements throughout the universe. New stars and planets, like the Sun and the Earth, form from clouds of dust and gas containing these elements.

How to answer each type of question

Name the missing stages in a life cycle

1 mark each | Grade 3

1. Decide first which path it is: a star about the size of the Sun, or one much bigger.
2. Write out the whole sequence for that path from memory, then match it to the chart.
3. Use the full names, e.g. 'main sequence star', 'red super giant'.

Example. A star much bigger than the Sun goes through these stages:
nebula → protostar → main sequence star → **A** → **B** → neutron star
Name stages **A** and **B**.

Model answer.

A: red super giant (1)

B: supernova (1)

Describe the life cycle of a star like the Sun

3 to 4 marks | Grade 5

1. Start from the point the question asks about, e.g. 'after the main sequence'.
2. Give each stage in order, and say what triggers the change (the hydrogen in the core running out).
3. End with the final stage: the black dwarf.

Example. The Sun is a main sequence star.
Describe what will happen to the Sun after its main sequence stage.

Model answer. When the hydrogen in its core runs out, the Sun will swell to become a red giant (1). It will then become a white dwarf, a small, hot, dense core in which there is no fusion (1). The white dwarf will cool and fade until it gives out no significant light, becoming a black dwarf (1).

Explain how fusion forms new elements

3 to 4 marks | Grade 5

1. Main sequence stars: hydrogen fuses into helium.
2. Later stages: heavier elements form by fusion, up to iron.
3. Elements heavier than iron: formed in a supernova.
4. If asked about the Earth, say that the supernova scatters the elements, which end up in new stars and planets.

Example. The Earth contains many elements that were made inside stars.
Explain how these elements were formed and how they became part of the Earth.

Model answer. In main sequence stars, hydrogen nuclei fuse to form helium (1). In red giants and red super giants, helium and other nuclei fuse to form heavier elements, up to iron in the biggest stars (1). Elements heavier than iron are formed in a supernova (1). The supernova distributes the elements through space, and the Earth formed from a cloud of dust and gas that contained them (1).

6-mark: compare the life cycles of two stars 6 marks (level of response) **Grade 7**

1. Plan both paths first: the shared start (nebula → protostar → main sequence), then the two different endings.
2. Write the stages in order and compare as you go, using 'whereas' or 'but'.
3. Add the processes: gravity, hydrogen fusing into helium, equilibrium, heavier elements forming, the supernova explosion.
4. Finish with the final stage of each star.

Example. Compare the life cycle of a star about the same size as the Sun with the life cycle of a star much bigger than the Sun.

Model answer.

Model answer: Both stars form from a nebula, a cloud of dust and gas pulled together by gravity, which becomes a protostar. Both become main sequence stars when hydrogen starts to fuse into helium in the core, and both stay stable while the outward pressure from fusion energy balances gravity. When the hydrogen in the core runs out, the Sun-sized star swells into a red giant, whereas the much bigger star becomes a red super giant, in which heavier elements up to iron are formed. The Sun-sized star then becomes a white dwarf, which cools to become a black dwarf. The much bigger star instead explodes as a supernova, forming elements heavier than iron, and leaves behind a neutron star or, for the very biggest stars, a black hole.
Level 3 (5 to 6 marks): both life cycles complete and in the correct order, clearly compared, with the processes explained.
Level 2 (3 to 4 marks): most stages of both life cycles in order, with some processes or comparison.
Level 1 (1 to 2 marks): some correct stages named, with little order or comparison.

Don’t lose marks

- Saying the Sun will become a supernova or a black hole. It is not big enough: it will become a white dwarf, then a black dwarf.
- Writing 'red giant' for a star much bigger than the Sun. Massive stars become red super giants.
- Putting the dwarfs in the wrong order. A white dwarf cools to become a black dwarf, not the other way round.
- Saying all elements heavier than helium are made in supernovae. Elements up to iron are made by fusion inside stars; it is the elements heavier than iron that are produced in a supernova.
- Leaving out the nebula, protostar or main sequence stage when asked for the whole life cycle.

More tips

Memory tricks

- The big star's path has 'super' twice: red **super** giant, then **super**nova. The Sun's path has no 'super'.
- Sun-sized stars go out quietly, cooling from white dwarf to black dwarf. Massive stars go out with a bang (a supernova).
- Iron is the cut-off: elements up to iron are made by fusion inside stars; elements heavier than iron are made in supernovae.
- A massive star ends as 'N or B': a neutron star, or a black hole for the very biggest stars.

Exam technique

- Use the stage names exactly as the specification does: 'main sequence star', 'red giant', 'red super giant', 'white dwarf', 'black dwarf', 'supernova', 'neutron star', 'black hole'.
- In 6-mark answers, stages alone will not reach the top level. Add what happens at each stage: what is being fused, what is balanced, what forms or is scattered.
- When asked to compare, write both stars into the same sentence, e.g. 'The Sun becomes a red giant, whereas a much bigger star becomes a red super giant.'
- In flow chart questions, look for a stage you already know (e.g. 'supernova' or 'white dwarf') to tell which path it is.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Order the first stages of a star's life**
Every star starts as a nebula, then becomes a protostar, then a main sequence star.

Grade 4 — **State what decides a star's life cycle**
The size (mass) of the star decides which path it follows after the main sequence.

Grade 4 — **Describe the life cycle of a Sun-sized star**
Main sequence star, then red giant, then white dwarf, then black dwarf.

Grade 5 — **Describe the life cycle of a massive star**
Main sequence star, then red super giant, then supernova, then neutron star or black hole.

Grade 5 — **Explain how stars make new elements**
Hydrogen fuses into helium, then heavier elements up to iron form, and elements heavier than iron form in supernovae.

Grade 7 — **Explain how elements from stars reach planets**
A supernova scatters elements through the universe, and new stars and planets form from clouds containing them.

Grade 7 — **Compare two life cycles in a 6-mark answer**
Give both paths in order, compare them stage by stage and include the processes at each stage.

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