STARS AND EXOPLANETS | LESSON 6

The Life of a Star

The life story of a star, from a glowing nebula to a white dwarf, neutron star or black hole.

Grades 6-12 | About 15 minutes of narrated flight, plus discussion stops | 10 stops | Start: learn.allseeing.space/life-of-a-star

What students will see and do

Students visit a stellar nursery, the Pillars of Creation, a young cluster, the Sun, a blue supergiant, a red giant, a white dwarf, a dying supergiant and a supernova remnant, then learn that their own atoms were made in stars.

Learning objectives

- Put the stages of a star's life in order
- Explain how a star's mass determines its lifetime and its fate
- Use star color as a clue to temperature
- Explain where the elements in the human body came from

NGSS connections

HS-ESS1-1	Nuclear fusion in the Sun's core releases energy that reaches Earth as sunlight; the Sun's life span depends on its fuel.
HS-ESS1-3	Stars produce elements through fusion; supernovas and neutron star mergers scatter heavier elements.
HS-PS1-8	Fusion of hydrogen into helium is a nuclear process that releases energy.
DCI ESS1.A / PS1.C	The Universe and Its Stars; Nuclear Processes.

40-minute class plan

1. 5 min: pre-lesson prompt. Before we fly: do you think stars live forever? If not, what do you think happens when a star dies?
2. 18-20 min: run the lesson. Keep discussion stops short (1-2 minutes each) or turn them off in the Lessons menu.
3. 8 min: whole-class discussion using two of the questions below.
4. 5 min: Exit ticket: Draw a quick flow chart of a Sun-like star's life and a massive star's life. Where do they split?

Full exploration (about 60 minutes)

1. 5 min: pre-lesson prompt, recorded so students can revisit it.
2. 25-30 min: run the lesson with every discussion stop at full length.
3. 15 min: follow-up activity. Star life-cycle card sort: shuffle stage cards and have teams order them for a small star and a massive star.
4. 10 min: revisit the pre-lesson ideas, then the exit ticket.

Before the lesson

Before we fly: do you think stars live forever? If not, what do you think happens when a star dies?

Discussion stops: timing and key points

At A star in the prime of life (4-6 min): Big stars have much more fuel than small stars, but they die much sooner. How can that be? Think about how fast each one uses its fuel.

- More massive stars have stronger gravity, which makes their cores much hotter and denser.
- That makes fusion run far faster, so they burn through their larger fuel supply sooner.
- Analogy: a big truck with a huge tank can still run out of gas before a small car if it burns fuel much faster.

At A dying giant (3-5 min): If Betelgeuse exploded tonight, when would we see it? Use what you know about light-years to explain.

- Betelgeuse is roughly 550 to 700 light-years away.
- If it exploded tonight, we would not see it for roughly 550 to 700 years.
- It could already have exploded, and the light simply has not reached us yet.

More questions for after the lesson

1. What happens to the Sun in about five billion years?
2. Why can't Earth-sized white dwarfs make new energy?
3. Gold is made in neutron star collisions. What does that say about the gold in jewelry?

Vocabulary

nebula, nuclear fusion, main sequence, red giant, white dwarf, supernova, neutron star, pulsar

Exit ticket

Exit ticket: Draw a quick flow chart of a Sun-like star's life and a massive star's life. Where do they split?

Follow-up activities

- Star life-cycle card sort: shuffle stage cards and have teams order them for a small star and a massive star.
- Color and temperature: look at a candle flame or heating element and connect color to temperature.
- Element hunt: list five elements in the human body and where in a star's life each was made.

Full transcript

Introduction

Welcome to The Life of a Star. Stars seem permanent, but they are not. They are born, they shine for millions or billions of years, and they die. A single star's life is far too long to watch. So instead, we will visit many different stars, each at a different stage, and put the story together.

Listen for one key idea as we travel: a star's mass, how much material it is made of, decides almost everything about its life, including how long it lives and how it ends.

1. A stellar nursery

This is the Orion Nebula, about thirteen hundred and fifty light-years away. On a dark night you can see it without a telescope, as a fuzzy patch in the sword of the constellation Orion. It is a giant cloud of gas and dust, mostly hydrogen, about twenty four light-years across.

Nebulas like this are where stars are born. Inside the cloud, gravity pulls some regions together into denser clumps. As a clump collapses, it spins faster and heats up. When the center reaches about ten million degrees Celsius, hydrogen begins to fuse into helium. At that moment, a star switches on.

The glow you see comes from a small group of very young, very hot stars at the heart of the nebula called the Trapezium. Their ultraviolet light makes the surrounding gas shine. The Hubble Space Telescope has photographed flattened disks of dust around many young stars here. Those disks are the raw material for new planets.

Your own Sun was born in a cloud like this about four and a half billion years ago, probably alongside hundreds or thousands of sibling stars that have since drifted apart.

Orion is a wonderful constellation for this lesson. In one small patch of sky it holds a stellar nursery, hot young stars, and an old red supergiant near the end of its life. We will come back to Orion later.

2. The Pillars of Creation

This is the Eagle Nebula, about five thousand seven hundred light-years away. It holds one of the most famous images in astronomy, the Pillars of Creation, towering columns of cold gas and dust. The tallest pillar is about four light-years long, almost the distance from the Sun to the nearest star.

The Hubble Space Telescope first photographed the pillars in nineteen ninety five. In twenty twenty two, the James Webb Space Telescope looked again in infrared light, which shines through dust, and revealed many newborn stars hidden inside the pillars.

The pillars are being sculpted by the stars they helped create. Nearby young stars blast out ultraviolet light and fast winds that slowly erode the clouds, the same way wind and water carve rock on Earth. Over time, the pillars will be worn away.

3. A young star cluster

This is the Pleiades, also called the Seven Sisters, about four hundred and forty four light-years away. Most people can see six or seven stars here with their eyes alone, but the cluster contains more than a thousand.

These stars were all born together from the same cloud, only about one hundred million years ago. That is young for stars. Dinosaurs were alive on Earth when the Pleiades formed. The brightest members are hot, blue, massive stars.

The wispy blue haze around them is a cloud of dust that the cluster happens to be passing through. The dust reflects the stars' blue light, like headlights shining through fog. Over the next few hundred million years, the cluster's stars will slowly drift apart, just as the Sun's siblings did.

The Pleiades appear in stories from cultures all around the world, from ancient Greece to Japan, where they are called Subaru, to many Indigenous peoples of the Americas and Australia.

4. A star in the prime of life

Now we visit a star in the long, steady middle of its life: your Sun. It is about four and a half billion years old. In its core it fuses about six hundred million tonnes of hydrogen every second. The outward push of that energy balances the inward pull of gravity, and that balance keeps the Sun stable.

Astronomers call this stage the main sequence. Most stars spend about ninety percent of their lives here. The Sun has enough hydrogen to stay on the main sequence for about another five billion years.

Here is the surprising rule of stellar lives. Massive stars have much more fuel, but they burn it fantastically faster. A star ten times the mass of the Sun lives only around twenty million years. A small red dwarf, burning slowly, can last for trillions of years. The bigger the star, the shorter its life.

A star's color is a thermometer. Red stars are the coolest, around three thousand degrees Celsius at the surface. Yellow stars like the Sun are around five and a half thousand degrees. Blue-white stars can be ten thousand to more than thirty thousand degrees. When astronomers plot stars by color and brightness on a chart called the Hertzsprung-Russell diagram, main sequence stars fall along one long band, with hot, massive stars at one end and cool, small stars at the other.

Discussion stop: Big stars have much more fuel than small stars, but they die much sooner. How can that be? Think about how fast each one uses its fuel.

5. A blue supergiant

Before we see how stars grow old, look at the other extreme. This is Rigel, the bright blue-white foot of Orion, roughly eight hundred and sixty light-years away. Rigel is a supergiant around twenty times the mass of the Sun, and it shines with the light of more than a hundred thousand Suns.

Stars like Rigel live fast. Rigel is only about eight million years old, a tiny fraction of the Sun's age, and it is already using up its fuel. One day it too will probably end in a supernova.

6. A red giant

This is Aldebaran, the bright orange eye of Taurus the bull, about sixty five light-years away. Aldebaran has run out of hydrogen in its core. When that happens, the core shrinks and heats up, and the star's outer layers swell enormously. It has become a red giant, about forty four times wider than the Sun.

Aldebaran is showing you the Sun's future. In about five billion years, the Sun will also swell into a red giant. It will grow so large that it will swallow Mercury and Venus, and possibly Earth. Even if Earth survives, its oceans will have boiled away long before.

In the red giant stage, the core gets hot enough to fuse helium into carbon and oxygen. Those are two of the elements your body is made of. Stars are factories for the elements.

7. A white dwarf

What happens at the end for a star like the Sun? Look here at Sirius, the brightest star in Earth's night sky. Circling it is a tiny companion, Sirius B. Sirius B is a white dwarf, the exposed core of a star that has already died.

When a Sun-like red giant runs out of fuel, it gently puffs its outer layers into space, making a glowing shell of gas called a planetary nebula. The name is misleading, because it has nothing to do with planets. What is left behind is the hot core, a white dwarf.

A white dwarf is incredibly dense. Sirius B holds about the mass of the Sun in a ball roughly the size of Earth. It no longer makes energy. It simply glows from leftover heat and will slowly cool over billions of years. This is how your Sun will end.

8. A dying giant

Now we look at a much bigger star. This is Betelgeuse, the red shoulder of Orion, roughly five hundred to seven hundred light-years away. It is a red supergiant, perhaps fifteen to twenty times the mass of the Sun. If it took the Sun's place, its surface would reach beyond the orbit of Mars.

Betelgeuse is only about ten million years old, but because it is so massive, it is already near the end of its life. Inside, it is fusing heavier and heavier elements, carbon, neon, oxygen, silicon, building up layers like an onion.

In late twenty nineteen and early twenty twenty, Betelgeuse suddenly dimmed so much that people noticed it with their own eyes. Some wondered if it was about to explode. Astronomers found it had puffed out a cloud of dust that blocked part of its light. It has since brightened again.

Betelgeuse will explode as a supernova, probably sometime in the next hundred thousand years. When it does, it may shine as brightly as a half Moon for weeks, visible even in daytime. It is far enough away that it will not harm Earth.

Discussion stop: If Betelgeuse exploded tonight, when would we see it? Use what you know about light-years to explain.

9. A supernova remnant

This is what a supernova leaves behind. The Crab Nebula, about six thousand five hundred light-years away, is the expanding wreck of a massive star that exploded. Astronomers in China recorded its light in the year ten fifty four. It was bright enough to see in daylight for about three weeks.

When a massive star's core is full of iron, fusion stops making energy. The core collapses in less than a second, and the rest of the star explodes outward. The explosion can outshine a whole galaxy of billions of stars.

At the center of the Crab sits a neutron star, the crushed core. It is only about twenty kilometers across, but it holds more mass than the Sun. A teaspoon of it would weigh billions of tonnes. It spins about thirty times every second, sweeping beams of radiation across space like a lighthouse. Objects like this are called pulsars.

Supernovas also forge and scatter elements heavier than iron. Some of the heaviest elements, like gold, are also made when two neutron stars collide. Cores even heavier than the Crab's may collapse all the way into black holes.

10. You are made of star stuff

We end at home, because this story is about you. The hydrogen in your body was made in the Big Bang. But the carbon in your cells, the oxygen you breathe, the calcium in your bones, and the iron in your blood were all made inside stars that lived and died before the Sun was born.

Those stars scattered their elements into clouds like the Orion Nebula. New stars and planets formed from that enriched material, including the Sun, Earth, and eventually, you. In a very real sense, you are made of star stuff.

Wrap-up

So here is the life story of a star. Born in a nebula, shining steadily for most of its life, then swelling into a giant. Smaller stars like the Sun end as white dwarfs. Massive stars end in supernova explosions, leaving neutron stars or black holes, and seeding space with the elements for new worlds.

Remember the key idea: mass decides a star's fate. Press L to choose another lesson, or try Into the Dark to see what happens to the very biggest stars.

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