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WHY STAR STUFF MATTERS

0:01–0:56

STARS

Hi, I'm Emily Graslie and welcome to Crash Course Big History. Today we'll talk about why something as distant as cosmology and stellar chemistry is deeply intertwined with humanity: our past, present, and future.

When we start the grand narrative of thirteen point eight billion years, our minds are blown by the incomprehensible mysteries of the Big Bang and the vast size of our Universe. We then spend some time looking at the birth of the chemical elements in stars. It is very tempting, sometimes, to look at this stellar chemistry and think, "alright, alright, when do we get to the dinosaurs?" Or, "when do we ditch all this science stuff and get to humanity?"

But before we get there, to illustrate just how important chemistry is to the grand narrative I'm going to pick just one of the elements from the periodic table to show you just how crucial "star stuff" is. Get ready for a "little" big history. This is the story of our intrepid hero, Carbon.

0:56–1:39

STARTS WITH A BANG

The Universe had begun with a bang. About 3 minutes later, the first protons and neutrons formed into the nuclei of hydrogen and helium, our two lightest elements, effectively Carbon's mother and father.

Then, the Universe cooled down too quickly for new elements, other than slight traces, to form. That said, the Universe was still an oppressive, murky sea of radiation from which not even light could escape. Hydrogen and helium nuclei couldn't even become fully fledged atoms.

Let's fast forward about three hundred eighty thousand years, and go to the Thought Bubble.

The universe cooled down enough for the young hydrogen and helium nuclei to capture electrons and become fully fledged atoms. Hydrogen and helium became the dominant forms of matter in the Universe. But for now they were wispy gases, airheads without much structure or complexity.

1:39–2:00

GRAVITY

Fast forward again, about 100 million years. Slight inequalities in the distribution of hydrogen and helium allowed them to clump together. Gravity sucked more in. And more, and more, until there was so much pressure that the first stars were born.

The hydrogen and helium inside them were squeezed together so tightly they fused to create lithium, then beryllium, boron, and, finally, Carbon was born.

2:00–2:41

CREATION OF ELEMENTS

More stars created Carbon, along with heavier brothers and sisters all the way up to iron. As the first stars began to run out of fuel, they exploded. Carbon and its siblings were scattered out into the void. All of the heavier elements, like gold and uranium, were created.

About six hundred million years after the Big Bang, Carbon and its siblings, along with millions of stars had grouped together into a very young Milky Way. Over the next 3 billion years, more stars joined the party in a series of galactic mergers, creating the swirling cosmic island we call home.

Then about 5 billion years ago, about a light year or so away, a giant star collapsed into yet another supernova, peppering our neighborhood with more Carbon and other elements and triggering the formation of our Sun.0

2:41–3:12

EARTH

About 99% of Carbon declared early retirement and made its home in the warm embrace of the Sun, but a sliver of Carbon wound up on the orbital track of where our Earth is. It was rolled up over the next few million years, with all the other elements, into what eventually would become our planet.

Thanks, Thought Bubble.

The Hadean era was a real mess. The Earth was bombarded by asteroids, was full of volcanoes and the sky was red. Over time, heavy elements like iron and nickel sank to the Earth's core, while lighter elements like Carbon floated upward and were belched out of early sky-scraping volcanoes as a gas.

3:12–3:49

CARBON

Some carbon combined with oxygen forming carbon dioxide, and there was so much of it in the atmosphere that it turned the skies above that volcanic landscape red. More solid forms of carbon can be found in the Earth's thin crust.

Only a small amount of the Earth's atmosphere and crust, a fraction of a percentage point, is made of Carbon, paling in comparison to the vast masses of oxygen and silicon.

But carbon is stable, and this makes it one of the most flexible of all the elements when it comes to forming molecular combinations of other elements. In a way, carbon forms the keystone of most molecular complexity. It is estimated that, without carbon, about 95% of all molecular combinations would not exist.

3:49–4:20

COMPLEXITY

Without carbon, complexity probably would never have increased much further beyond the most basic chemistry. We'd have stars, we'd have gases, and we'd have metals, we'd have a few basic minerals. And not much else. No life, no complex chemistry, no "us".

And because Carbon is so ready to bond with other elements, it became the prime candidate for self-replicating organic chemicals that would one day, approximately 3.8 to 4 billion years ago, become life.

Carbon can bond easily with oxygen, hydrogen, and nitrogen — all abundant on Earth and all crucial for life.

4:20–4:57

LIFE ARISES

Carbon tied them all together. Because it's so flexible, carbon can be used to stick together extremely long molecules, a handy thing when you consider how complex the molecules required to sustain life are.

Carbon-based life began as single celled organisms in the ocean, evolving into photosynthesizing bacteria near the surface of the sea.

This bacteria would evolve into multicellular plants, at first in the sea starting six hundred and thirty five million years ago, and later with the plant-based conquest of the land some two hundred million years later.

The plants in your garden, and those you eat for dinner are about 45% Carbon. Given that we eat so much Carbon, you could argue that without it, you would starve to death – not that you would have evolved in the first place.

4:57–5:27

LIFE DIVERSIFIES

Plants also need carbon, taking in carbon dioxide and expelling the oxygen as a waste product of photosynthesis. The process of photosynthesis led to a massive increase in oxygen in the atmosphere about 2.5 billion years ago.

The by-product was that other Carbon based bacteria began to harness oxygen's energy and evolve into more and more complex forms.

This includes fish, frogs, dinosaurs, lions, tigers, bivalves, and you. The entire evolutionary epic of nature, multi-celled organisms, predators, prey, and all the survivors, owe their existence to carbon.

5:27–6:05

18% CARBON

Your body is 65% oxygen, 10% hydrogen, 3% nitrogen, and a smattering of calcium, phosphorous, potassium, sulfur, sodium, chlorine, and magnesium.- and all of it is held together by 18% Carbon.

Carbon rich plants played a key role in human history. It was in everything from the crops we ate, to the wood houses that provided shelter, to the wood we burned to cook for energy, to the even more energy dense charcoal which we used to build our cities and grow our technology.

If carbon could not be manipulated in this way, it is likely the past 10,000 years of history would have never happened at all and we would still be a few million foragers with stone tools wandering around the Earth. Without the internet.

6:05–6:55

ANTHROPOCENE

Carbon is also responsible for one of the greatest leaps forward in 13.8 billion years: the rise of complexity in the modern era and the Anthropocene, where we have created systems more complex that harness a greater density of energy than anything else we see in the Universe.

From microscopic photosynthesizing bacteria to the giant forests that existed in the Carboniferous, all inevitably died, and some were buried by the soil, protected from rotting, and sank over millions upon millions of years as more soil fell on top of them. As these plants sank deeper and deeper into the crust, the pressure made temperatures rise. This pressure and heat converted plants into coal.

Coal was used by humans as a source for starting fires as early as 1000 BCE, but the noxious smoke it gave off made wood preferable for a long time. So, coal was the second choice. Ancient civilizations definitely knew about it, though: the Latin word used by the Romans for coal was Carbo.

6:55–7:35

COAL

Then, when the Industrial Revolution was still in its infancy in Britain, a shortage of wood for increasing fuel demands prompted the British to turn to coal. In 1709, Abraham Darby enhanced steel production by using coke derived from coal instead of Charcoal.

In 1781 James Watt produced a commercially viable steam engine that found its way into the engines of all manner of production and rail transport. From there, industrialisation spread across the world, tying all humans together more closely in a human network, exchanging and producing more ideas, accelerating change, and skyrocketing the concentration of energy.

All thanks to little Carbon, in the form of coal. Even today, approximately 43% of all energy production is the result of coal.

7:35–8:30

INDUSTRIAL REVOLUTION

With the Industrial Revolution, largely ignited by the spark of carbon, came goods that could be produced more cheaply - which was great! Luxury goods transformed into everyday staples, the carrying capacity gradually lifted, and people found more opportunities off of the farm.

The immense tapestry of ideas, advancement, and trade of today – the next rise of complexity – owes itself to carbon.

Nowadays, we also make huge use of other fossil fuels like oil and natural gas. Carbon-based marine life hundreds of millions of years ago died, sank to the bottom of the seas and oceans, and were buried deep in the silt. With such intense pressures, the carbon was transformed into either a black sludge we call oil or heated to such high temperatures that they became natural gas.

This shapes not only global production, and directly impacts our quality of life – from transport, to our everyday goods, to the myriad of plastic products we use and depend upon – it also shapes modern day politics, with the oil-rich nations and oildependent nations directly influencing the daily tide of events.

8:30–9:03

FOSSIL FUELS

Ironically, though, Carbon may also prove our downfall. One of the greatest threats to human complexity today is our dependence on these fossil fuels. The carbon dioxide they release into the atmosphere, which raises the average surface temperature of the Earth and will cause a great deal of environmental problems and human suffering.

If disaster strikes as a result, Carbon, which was so crucial to the rise of complexity in Big History, may bring complexity down to a crashing halt.

But some forms of Carbon are a little more benign-like, in the form of graphite, an extremely soft material that you might find in your pencil. Sometimes graphite is used to help conduct electricity.

9:03–9:48

DIAMONDS

And at the other end of the spectrum, the hardest known material is diamond, also a gift from Carbon. Crucial to all sorts of advanced machinery like electrical insulators and thermal conductors, diamonds are perhaps best known as a pricey rock that saw its value skyrocket in the 1930s.

This was thanks to a highly successful advertising campaign by a diamond company that convinced a lot of people to spend a month's salary on a shiny rock in order to propose marriage. This led to a tragic exploitation of the environment and people for the sake of these shiny stones. So we can think of carbon as both a gift and at times a curse,

depending on the way we look at it.

Carbon is just 1 out of 92 naturally occurring elements, a single piece of the puzzle among many others. But, Carbon was absolutely vital to the entire story of complexity in the Universe. Without it modernity and the heights of human complexity wouldn't exist.

9:48–11:03

WE ARE STAR STUFF

The Industrial Revolution wouldn't have happened - along with ancient and medieval civilizations, and the evolution of all plants and animals.

Remove Carbon from the equation and all that complexity would not have existed. Misuse carbon and the fate of human complexity in the Anthropocene may similarly be doomed.

Without Carbon, the tale of rising complexity would be a short story, involving stars, space dust, and barren planets floating in emptiness. And there would be nobody around to tell it.

In some cases, that story of rising complexity would not have happened at all. To quote the great late Carl Sagan: the cosmos is also within us. We're made of star-stuff. We are a way for the cosmos to know itself.

Thanks for watching, we'll see you next time.