5

HOW DO EARTH & LIFE INTERACT?

In this four-part lecture, David Christian will explain what the **biosphere** is and discuss the interplay between life and the Earth. David will explain how astronomy, geology, and biology are **interdependent**, and how all affect the biosphere. Then he will describe how geological, astronomical, and biological changes radically impacted life on Earth — in some cases causing **mass extinction events**. On the flip side, David will describe how living organisms radically changed the Earth's atmosphere, permanently altering the biosphere as well. After watching the lecture and reading this discussion guide, you should be able to describe why life is so abundant in the **comfort zone** of the biosphere and tell the story of various **temperature cycles** that have occurred throughout the past 4 billion years. You should also be able to explain what caused the extinction of the dinosaurs and to identify other factors that might cause other mass extinctions.

Key questions

1 Why is the biosphere, and especially its "comfort zone," so well suited for life?

2 How do Earth and life interact, and what factors contribute to changes in each?

3 What types of events have caused mass extinctions?

Transcript: Part 1

0:11-0:38

HUMAN SURVIVAL REQUIRES A DELICATELY BALANCED ENVIRONMENT

We humans are creatures of the surface. We'd drown if you leave us in water too long. We freeze or asphyxiate if you shoot us 10 kilometers into the atmosphere. To survive in those environments, we need specially constructed containers a bit like this cable car that I'm riding up to Seoul Tower, but much fancier. More like submarines or planes or even space suits.

0:38-1:59

DIFFERENT LIVING ORGANISMS ARE SUITED TO DIFFERENT ENVIRONMENTAL SURROUNDINGS

Many organisms are much hardier than us. Some microorganisms and migratory birds can live, at least temporarily, in the thin and icy air in which international jets cruise. The **oceans** have been home to life since **life first appeared**. Today, sperm whales can dive up to two kilometers below the surface, but 10 kilometers below the surface you can find much stranger organisms — some of them feasting off of the carcasses of dead whales, some of them using the chemicals and the boiling water that comes out of deep-sea oceanic vents.

MOST LIFE THRIVES IN THE COMFORT ZONE

The soil beneath our feet is full of organisms, and we now know that some of them may live up to six or seven kilometers below the surface. Still, most of life can be found in a thin envelope near the surface that we call the **biosphere**. This is life's **comfort zone**. It's a very thin and fragile layer and it's had an exciting and sometimes dangerous history. Life, it turns out, has been very vulnerable, in fact, the entire biosphere, to sudden changes. Sometimes these have generated mass extinction events when up to 50 percent of all species have died.

1:59-3:08

THE OXYGEN HOLOCAUST WAS 2 TO 3 BILLION YEARS AGO

Between 2 and 3 billion years ago, **photosynthesizers** began to **raise** the amount of oxygen in the oceans and the atmosphere. For most organisms at the time, oxygen was poisonous. So they perished in huge numbers in what today we call the **Oxygen Holocaust**. The fossil record shows that in just the last 600 million years, there may have been five **mass-extinction events**. By far, the worst was the Permian event, about 250 million years ago, in which up to 96 percent of all species on Earth may have perished in two separate catastrophes about 10 million years apart. That was a pretty close shave for life on Earth.

FIVE MASS-EXTINCTION EVENTS IN THE PAST 600 MILLION YEARS

ASTRONOMICAL, GEOLOGICAL, AND BIOLOGICAL FACTORS IMPACT THE BIOSPHERE

So here's the question. What are the main factors that have shaped the history of the biosphere? It turns out that **astronomical, geological, and biological forces** have all played a role in the history of the biosphere.

Transcript: Part 2

3:12-4:06

What astronomical factors affected the history of the biosphere? Perhaps the most important was the relationship between the **Earth and the Sun**, which is the main source of energy and light for all organisms on Earth. To avoid sharp temperature fluctuations, a habitable planet needs to have a fairly stable orbit. Now, in fact, the **Earth's orbit is constantly changing**, partly as a result of changes in the shape of the orbit, and partly as a result of changes in its axis of rotation.

TEMPERATURE FLUCTUATIONS ON EARTH ARE MODERATE

These changes are known as **Milankovitch cycles,** after the scientist who first analyzed them. What they mean is that the **temperature** at the surface of the Earth is **constantly changing**, but fortunately for us, those changes are not sufficient to make the planet uninhabitable or to affect the biosphere.

MILANKOVITCH CYCLES RESULT FROM CHANGES IN THE AXIS OF ROTATION AND VARIATIONS IN THE EARTH'S ORBIT

4:06-4:51

The **speed of rotation** of a planet also matters. If it rotates too slowly, one side gets barbecued and the other is frozen. Its size also matters. If a planet is too small, it can't hold a large enough atmosphere because there is not enough gravitational pull. If it's too large, it may hold such a large atmosphere that sunlight can't penetrate to the surface. And what's more, all of these conditions must remain **stable over many billions of years**; otherwise, what you might get is a planet that has a sort of flourishing of prokaryotes that then go extinct before any complex life forms appear. In fact, that might have been the fate of Mars.

LIFE REQUIRES BALANCED SUN EXPOSURE OVER LONG TIME PERIODS

4:51-6:00

ASTRONOMICAL FACTORS ALSO IMPACT THE BIOSPHERE

AN ASTEROID CAUSED THE EXTINCTION OF THE DINOSAURS

Asteroids can also have a huge impact on the biosphere. Walter Alvarez showed that the mass extinction that **wiped out the dinosaurs** about **65 million years ago** was probably caused by the arrival of an asteroid about 12 kilometers wide that landed off the coast of modern Mexico. The result would have been like a nuclear war. It would have kicked up a huge dust cloud that would have blocked off sunlight and prevented photosynthesis and food production for perhaps several years. The dinosaurs were particularly vulnerable because they were large, so they needed lots of food, and they reproduce slowly.

So it was very bad news for them, but it was great news for our **mammal ancestors**, who **flourished** in a world free of dinosaurs. Now, as a mammal, think about this. If that asteroid had been on a trajectory half an hour earlier or half an hour later, it would have missed the Earth, the dinosaurs would still be here, and you and I wouldn't be here. And if that asteroid had been bigger, it might have wiped out all life on Earth.

Transcript: Part 3

6:04-6:38

VOLCANIC ACTIVITY IMPACTS THE ATMOSPHERE BY RELEASING GREENHOUSE GASES

How did geological factors affect the history of the biosphere? Periodically, it seems that large movements of tectonic plates may have caused **massive volcanic eruptions** that released huge amounts of the greenhouse gases **methane** and **carbon dioxide** into the atmosphere, and **reduced** the amount of atmospheric **oxygen**. Now, the result of this would have been a sudden and perhaps **catastrophic global warming**. It's possible that the Permian extinction event 250 million years ago was caused by a change like this.

6:38-7:59

THE PLACEMENT OF CONTINENTS IMPACTS THE ATMOSPHERE

The exact **configuration of the continents** can also make a huge difference to global climates and to the history of life on Earth. For example, today the fact that a large continent, Antarctica, sits over the South Pole explains the existence of huge southern ice sheets, while the arrangement of the northern continents blocks off the flow of warm, tropical currents to the north pole. Taken together, these arrangements explain why today we live in an era of ice ages.

SNOWBALL EARTHS HAVE FORMED SEVERAL TIMES IN OUR PLANET'S HISTORY

But occasionally it seems that global temperatures have plummeted much lower than this; during so-called **Snowball Earth** events. During these events, kilometer-thick glaciers may have covered much of the Earth and threatened the very existence of the biosphere. It seems likely that one possible cause of these was an arrangement of the continents that caused massive rainfall which sucked huge amounts of carbon dioxide out of the atmosphere and led to sudden sharp falls of in global temperatures. The end of the last of these Snowball Earth events, perhaps a little over **500 million years ago**, may explain the sudden **proliferation and diversification** of life on Earth that we call the **Cambrian explosion**.

Transcript: Part 4

8:03-9:16

How is life itself affecting the biosphere? Well, one way is by changing atmospheres. We've already seen how early photosynthesizers pumped oxygen into the atmosphere and pulled out huge amounts of carbon dioxide. By doing so, they caused the Oxygen Holocaust, which wiped out many early species, but it also made possible the evolution of eukaryotes — our ancestors.

INCREASED OXYGEN CHANGED THE BALANCE OF LIFE ON EARTH

Some species take **carbon** out of the atmosphere to **make shells**, and when they die they sink to the bottom of the ocean and over millions of years, they **bury** that **carbon** in huge sheets of sedimentary rocks such as **limestones** or **chalk**. In fact, if you look at a piece of natural chalk through a magnifying glass, you may see some of those organisms. In this way, tiny creatures could transform geology by creating entire new **geological strata**.

THE CARBON IN SHELLS IS BURIED IN SEDIMENTARY ROCK

Other organisms also bury carbon and today we humans are uncovering their remains in the form of coal, oil, and natural gas — the so-called **fossil fuels**. By **burning** them, we're **returning** that **carbon dioxide** into the **atmosphere** at an incredible rate.

BURIED CARBON BECOMES FOSSIL FUELS: COAL, OIL, NATURAL GAS

9:16-9:50

HUMAN IMPACT ON THE BIOSPHERE HAS YET TO BE MEASURED

We know that the **biosphere** is **fragile** and small, and we also know that it's constantly under siege from a whole range of astronomical, geological, and biological factors. Yet, so far, knock on wood, though many species have gone extinct, life as a whole has survived for almost 4 billion years. What we don't know is how the biosphere **will change** in the future. In particular, we don't know the role that our species, ***Homo sapiens***, will play in that story.