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

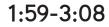
We humans are creatures of the surface. We'd drown if you leave us in water too long. We freeze or asphyxiate if you shoot us 10 kilometers into the HUMAN SURVIVAL atmosphere. To survive in those environments, we REQUIRES need specially constructed containers a bit like A DELICATELY this cable car that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

0:11-0:38

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 DIFFERENT LIVING international jets cruise. The oceans have been ORGANISMS ARE home to life since life first appeared. Today, sperm SUITED TO DIFFERENT whales can dive up to two kilometers below the ENVIRONMENTAL surface, but 10 kilometers below the surface you SURROUNDINGS 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.

0:38-1:59

The soil beneath our feet is full of organisms, and MOST LIFE we now know that some of them may live up to six THRIVES IN THE or seven kilometers below the surface. Still, most COMFORT ZONE 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.



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

ASTRONOMICAL. So here's the guestion. What are the main factors GEOLOGICAL, that have shaped the history of the biosphere? It AND BIOLOGICAL turns out that astronomical, geological, and bio-FACTORS IMPACT logical forces have all played a role in the history of THE BIOSPHERE the biosphere.

Transcript: Part 2

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 tempera- TEMPERATURE ture fluctuations, a habitable planet needs to have a FLUCTUATIONS ON fairly stable orbit. Now, in fact, the Earth's orbit is EARTH ARE constantly changing, partly as a result of changes MODERATE in the shape of the orbit, and partly as a result of changes in its axis of rotation.

3:12-4:06

These changes are known as Milankovitch cycles, MILANKOVITCH after the scientist who first analyzed them. What CYCLES RESULT FROM they mean is that the temperature at the surface CHANGES IN THE AXIS of the Earth is constantly changing, but fortunately OF ROTATION AND for us, those changes are not sufficient to make the VARIATIONS IN planet uninhabitable or to affect the biosphere.

THE EARTH'S ORBIT

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 LIFE REQUIRES too small, it can't hold a large enough atmosphere BALANCED SUN because there is not enough gravitational pull. If it's EXPOSURE OVER 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.

4:06-4:51

LONG TIME PERIODS

4:51-6:00

Asteroids can also have a huge impact on the biosphere. Walter Alvarez showed that the mass ASTRONOMICAL extinction that wiped out the dinosaurs about FACTORS ALSO 65 million years ago was probably caused by the IMPACT THE arrival of an asteroid about 12 kilometers wide BIOSPHERE that landed off the coast of modern Mexico. The result would have been like a nuclear war. It would AN ASTEROID have kicked up a huge dust cloud that would have CAUSED THE blocked off sunlight and prevented photosynthesis EXTINCTION OF and food production for perhaps several years. The THE DINOSAURS 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

How did geological factors affect the history of the biosphere? Periodically, it seems that large movements of tectonic plates may have caused massive VOLCANIC ACTIVITY volcanic eruptions that released huge amounts of IMPACTS THE the greenhouse gases methane and carbon dioxide ATMOSPHERE BY into the atmosphere, and reduced the amount of RELEASING atmospheric oxygen. Now, the result of this would GREENHOUSE GASES 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.

6:04-6:38

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 THE PLACEMENT OF fact that a large continent. Antarctica, sits over the CONTINENTS IMPACTS South Pole explains the existence of huge southern THE ATMOSPHERE 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.

6:38-7:59

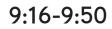
SNOWBALL EARTHS But occasionally it seems that global temperatures HAVE FORMED have plummeted much lower than this; during so-SEVERAL TIMES IN called Snowball Earth events. During these events, OUR PLANET'S kilometer-thick glaciers may have covered much of HISTORY the Earth and threatened the very existence 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

How is life itself affecting the biosphere? Well, one 8:03-9:16 way is by changing atmospheres. We've already seen how early photosynthesizers pumped oxygen INCREASED OXYGEN into the atmosphere and pulled out huge amounts CHANGED THE of carbon dioxide. By doing so, they caused the BALANCE OF LIFE Oxygen Holocaust, which wiped out many early ON EARTH species, but it also made possible the evolution of eukaryotes - our ancestors.

Some species take carbon out of the atmosphere to THE CARBON make shells, and when they die they sink to the bot- IN SHELLS tom of the ocean and over millions of years, they IS BURIED IN bury that carbon in huge sheets of sedimentary SEDIMENTARY rocks such as limestones or chalk. In fact, if you ROCK 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.

Other organisms also bury carbon and today we BURIED CARBON humans are uncovering their remains in the form BECOMES FOSSIL of coal, oil, and natural gas - the so-called fossil FUELS: COAL, fuels. By burning them, we're returning that carbon OIL, NATURAL GAS dioxide into the atmosphere at an incredible rate.



9:16-9:50 We know that the biosphere is fragile and small, and we also know that it's constantly under siege HUMAN IMPACT ON from a whole range of astronomical, geological, THE BIOSPHERE and biological factors. Yet, so far, knock on wood, HAS YET TO though many species have gone extinct, life as a BE MEASURED 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.