In the past 40 wonderful weeks together, we've explored all of the fundamentals of biology, from the tiny little machines that make us work to the systems that power the most awe-inspiring and most complex organisms on earth.

Now, I want to take our learning to the next level, simply by broadening our perspective. With a solid understanding of biology at the small scale under our belts, it's time for the long view. For the next 12 weeks we'll be learning how the living things that we've study interact with and influence each other and their environments. It's the science of ecology.

The idea of an organism interacting with its environment may sound simple, but it is actually pretty marvellously complicated. Nothing escapes the long arm of ecology, life influences the chemical make-up of the atmosphere, the geology of the planet, the climate. And nothing impacts life on earth today more than humanity does. And so we're going to be exploring that relationship, between mankind and our environment in a lot of detail in the coming weeks.
Life is powerful, and in order to understand how living systems work, you first have to understand how they originated, and developed and diversified over the past 4.5 billion years of Earth's history. The principles that you hear about here today will form the framework of our next 12 weeks together. Get ready for the epic drama that is the history of life on Earth.

(Intro)

Earth is like a cheap rental house in a college town, there's always somebody living there, but tenants are always moving in and out, and new tenants moving into old one's rooms and sometimes the electricity gets turned off because nobody paid the power bill. It's pretty much just chaos. And like a rental house the Earth isn't invincible; I mean, a good semester of back-to-back frat parties could tear a house up pretty fast, and then you know then everybody gets evicted and some new tenants move in. Which gives you a little bit of perspective on humanity's position as the current dominant species on the planet. There have been others before us and there'll probably be others when we are gone. It's just how the planet rolls.

But it's taken eons for the Earth to get the way that it is today. The Earth formed about 4.6 billion years ago and for a while it was just a junk of rock circling the Sun suffering collisions with other junks of rock, generating unreal amounts of heat. Eventually the constant smashing slowed down a little bit and the outer layer of the Earth cooled, but the core of the planet remained hot. Like really hot, as hot as the surface of the sun. It gives you some idea of how much energy and radiation contributed to the Earth's formation when you consider that 4.5 billion years later there's still molten stuff in the middle of our planet.

And it's that inner heat that makes the Earth's surface so dynamic. The planet's insides that continually bubbling up, destroying what's there (renovating and rearranging furniture). It's this constant renewal, that's part of what makes life here possible. And in the scheme of things it didn't actually take life very long to show up on that hot rock.
About 4.4 billion years ago the planet was still getting pelted with giant chunks of rock and ice left over from the formation of the solar system. There was no oxygen in the atmosphere and volcanoes were firing off all over the place, but it was finally cool enough for some of the water in the atmosphere to turn from vapour into liquid. The first seas formed and in them and in the atmosphere, a soup of chemicals: nitrogen, nitrogen oxides, carbon dioxide, methane, ammonia, hydrogen, hydrogen sulfide. All those things that with the help of heat and lightning and who knows what else, eventually created small organic molecules. In some way, some how, life happened. We don't know how it happened. I wish we did, but we don't.

The first life on earth probably wasn't even life as we think of it, it was just a collection of chemicals surrounded by a membrane, because phospholipids, as you may remember, spontaneously form bi-layer membranes in water. Over time, some of the chemicals inside these membranes developed into amino acids, and eventually RNA, the nucleic acid that was probably the first genetic material. These collections of chemicals trapped within membranes, called protobionts, most likely began to grow and split and replicate themselves until some crazy copying error gave way to DNA nucleotides - which is a way more stable repository for genetic information because it's double-stranded, not single-stranded like RNA. And once these little guys had DNA, they were on their way. They might have only been one cell, and they were probably living in the equivalent of a hydrothermal vent, but they were making the most of it.

So the first living things were prokaryotes, single-celled organisms with no nuclei that were probably pretty similar to the archaea that we find living today in hydrothermal vents, sulfur hot-springs, and oil wells - and I apologize for pronouncing archaea wrong for the entire biology series. My bad.

These prokaryotes probably made their grand entrance between 3.9 and 3.5 billion years ago during what is known as the Archean Eon. This is the first of what scientists would identify as three eons in Earth history: the Archean, the Proterozoic, and the Phanerozoic, the Phanerozoic being what we've been experiencing for the last half billion years or so. An eon, as you might expect, takes freaking forever. The first one went on for 2.5 billion years. So we break up the eons into eras, periods, and epochs which are organized by the big deal events that we can see in the fossil record.

So from 3.5 billion years ago until about 2.1 billion years ago, these prokaryotes were all alone on Earth. But then, something weird happened; the amount of oxygen in the atmosphere suddenly shot up, basically from none to 10%, in a very short period of time, geologically speaking. This oxygen was most likely produced by a brand new prokaryote, called cyanobacteria, which had figured out how to make its own food through photosynthesis - the more cyanobacteria were out there, the higher the atmospheric concentration of oxygen became. This "oxygen revolution," as it's called, probably spelled D-double-O-M for a lot of prokaryotes out there that had evolved without oxygen.

And this was also one of the first real game changers for life on Earth, because it was the first major instance of living things bringing massive change to their own environment. In fact, it may be the earliest example of ecology at work. Cyanobacteria changed the atmosphere, judo-chopped the competition, and made way for the evolution of living things to take a new, specific direction. Then, about 2.1 billion years ago, a new kind of organism made its big debut: eukaryotes. These, as you know, are a big deal because they include all plants and animals.

Eukaryotes probably evolved by a process called endosymbiosis, where one prokaryote parasitized another prokaryote, or maybe just ate it but forgot to digest it. And the result was actually really awesome for both the host and the parasite/undigested prey. It formed a single-celled organism with organelles, specifically mitochondria and plastids, which probably evolved from those eaten or parasitic prokaryotes. This allowed for much more complexity and by 1.5 billion years ago we start seeing multi-cellular eukaryotic organisms in the fossil record, the very first of them probably being algae, but it wasn't until around 535 million years ago that the eukaryotes went berserk. And that's known as the Cambrian Explosion, a super-major biological golden age when the diversity of all animal life on Earth exploded.

Nobody's entirely sure what started it, but suddenly life created innovations that the planet had never seen. Creatures used minerals and seawater to build skeletons and shells, some acquired weapons like claws while others developed defensive plates - the evolutionary arms race between predators and prey was underway. This heralded the dawn of the Phanerozoic Eon, the one that we're in right now.

That's right, the Earth spent the better part of two eons under the rule of a bunch of archaea and bacteria and some, like, soft-bodied worms, until the Cambrian exploded and we started to see a lot of animal phyla that we actually are hanging out with today.

After the Cambrian, the party got so hot in the oceans that by the Ordovician Period, about 500 million years ago, plants, animals, and fungi started colonizing land, probably as a strategy for escaping predation. Now there were whole new ecosystems to explore and adapt to and create!

During the Devonian Period, about 365 million years ago, tetrapods, four-legged vertebrates that probably evolved from lobe-finned fishes, showed up on land, and so did arthropods like insects and spiders. From here we begin to see ecological systems that we recognize today, because organisms were changing their environments by consuming oxygen in the atmosphere and releasing carbon dioxide. And you know who likes carbon dioxide!: the plants.

The Carboniferous Period that extended from 359 to 299 million years ago was when the plants entirely went nuts. The forests were so dense and so widespread that they made all our fossil fuels - all the coal and oil that we now use to power all the things with were made over the course of about 60 million years. This time, it was the plants that had changed both the climate and the geology of Earth. These forests cranked out so much oxygen that the atmosphere contained around 35% oxygen rather than today's, like, 21%. All this oxygen started cooling the planet, because there wasn't enough carbon dioxide to maintain the balmy temperatures that the vast carboniferous jungles needed to survive. So, the whole system crashed, and all the carbon from these forests sunk into swamps and eventually got locked into rocks. Of course, now we're releasing all that carbon by burning fossil fuels, which is certainly helping to keep the planet toasty now. That right there, some good ecology!

In the Permian Period, 299 to 251 million years ago, all the land masses of the world joined to form one giant continent that we call Pangaea, altering global climate and ocean currents, and animals and plants evolved in response. We started seeing gymnosperms, the first plants with seeds like modern pines and spruces and firs, and archosaurs, the grand-daddys of dinosaurs and modern birds showed up.

But you probably picked up enough of the pattern here to predict that this party didn't last forever. About 252 million years ago, something happened, or maybe a lot of things happened in quick succession. But whatever they were - movie executives, take note - the Permian-Triassic Extinction Event would make the most awesome disaster film of all time, because up to 96% of all marine species and 76% of terrestrial vertebrate species bought the farm. And it's the only known mass extinction of insects; about 57% of all taxonomic families and 83% of all genera became extinct. It was the most significant extinction event on the planet, ever.

It's been hard to pinpoint the reason for this extinction event because most of the evidence has been wiped out, of course. It may have been kicked off by an asteroid that released the energy-equivalent of the detonation of a few million nuclear weapons all at once. And then insult added to injury, when a whole bunch of volcanoes erupted, methane was released from the sea floor, there were probably some gas explosions in what's now Siberia, and then a whole bunch of climate changes, sea level changes, and changes in ocean salinity probably occurred. Nobody's sure exactly what happened, but we do know it took a long time for life on Earth to make a comeback.

But look on the bright side, as a result of the Permian-Triassic event we got dinosaurs! They were able to evolve during the Triassic because there wasn't much competition for resources. So they evolved to fill an available niche, that is, a combination of living and non-living resources that they could use to survive. Remember that word, because a lot of ecology comes down to who's exploiting or leaving or getting kicked out of or altering their niches.

And during the Triassic period, there were tons of niches, the sky was the limit, because hey! there weren't very many animals or plants to compete with. So by the Jurassic Period, about 199 to 145 million years ago, huge herbivorous dinosaurs were roaming the Earth, smaller, mean-as-crap carnivorous dinos were stalking the herbivores, the oceans were full of giant squid and ichthyosaurs and long-necked plesiosaurs, the air was full of pterosaurs and the first birds, and there were mammals! Small ones, but they were all over the place, it just wasn't our time to shine. The Jurassic was dino time, and the dinos lived it up.

They partied down until about 65 million years ago when they all went extinct, as I'm sure you're aware, except for their surviving descendants, the birds. It was probably an asteroid that hit the Yucatan peninsula in Mexico that did them in, but other theories suggest it could've been climate change due to increased volcanic activity and they just couldn't adapt to changes in other living things around them. For instance, about 100 million years ago, angiosperms, or flowering plants, first appeared, and they did really well. Especially since flying insects evolved with them, providing a great vehicle for reproduction - this is a great example of another ecological principle, co-evolution.

But dinosaurs liked to eat the old-fashioned gymnosperms, so we know that from studying their fossilized poop, so maybe their pickiness made them go extinct, who knows? And with the dinos out of the picture, mammals and birds were free to take over. And this is where the flora and fauna on Planet Earth start looking a lot more like they do today. Since then, there have been climate fluctuations and extinction events and the evolution of many animals and plants, including humans. And on a geological scale, oddly enough, that kind of brings us up to today.

Ecology is all about action and reaction: an asteroid hits and a bunch of stuff happens because of it, plants take over and different stuff happens because of that. Humans start releasing all the carbon dioxide locked in 300 million year old rocks and the planet heats up and, you know, we don't know what happens. But ecology is providing us our best guesses. Over the next three months, we're going to explore these relationships in more and more detail, as well as, like, how humans relate to the whole thing and how we're affecting all of this.

Thank you for watching this very first episode of Crash Course: Ecology. Thanks to everyone who helped put this episode together, and if you want to review anything that we went over this episode, there's a table of contents over there. If you have any questions, or comments, or ideas for us please leave those down in the comments or on Facebook or Twitter, and we'll see you next time.