The Earth: Crash Course Astronomy #11

Crash Course: Astronomy
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The Earth is a planet. That's a profound statement, and one that's not really all that obvious. For thousands of years, planets were just bright lights in the sky, one-dimensional points that wandered among the fixed stars. How could the Earth be one of them? With the invention of the telescope those dots became worlds, and with spacecraft they became places. The Earth went from being our unique home in the Universe to one of many such… well, planets. The Earth is the largest of the terrestrial planets, the four smaller, denser, rocky worlds orbiting close in to the Sun. It's about 13,000 kilometers across, and has a single, large Moon which we'll learn a lot more about next week. Unlike the other three terrestrial planets, Earth has something very important: Water. Or, more specifically, liquid water on its surface, where it can flow around, evaporate, become clouds, rain down, and then mix up chemicals so they can do interesting, complex things—like support life. Earth's ability to sustain life depends on that water. It also depends on Earth's atmosphere, of course—breathing has its advantages—and both, weirdly enough, depend on Earth's magnetic field to exist. And that, in turn, depends on what's going on deep inside our planet. So, let's take a look. Like the Sun, the Earth is a many-layered thing. At its very center is the core, which actually has two layers, the inner core and the outer core. The inner core is solid, and made mostly of iron and nickel. These are heavy elements, and sank to the center of the planet when it was forming, leaving lighter elements like oxygen, silicon, and nitrogen to rise to the surface. The solid inner core is about 1200 kilometers in radius, or about 10% the radius of the Earth. The outer core is also mostly iron and nickel, but it's liquid. The material in it can flow. It's about 2200 kilometers thick. The temperature in the Earth's core is tremendously high, reaching 5500° C. The pressure is huge as well, as you might expect with the weight of an entire planet sitting on top of it. You might think at such a high temperature, iron would be a liquid, but iron can stay solid if the pressure is high enough. In the inner core, the pressure is extremely high, and even though it's hot, iron is solid. In the outer core, where it's still hot, but the pressure is a little bit lower, iron is a liquid. Above the core is the mantle.It's about 2900 kilometers thick. The consistency of the mantle is weird; most people think it's like lava, but really it's like very thick hot plastic. It behaves more or less like a solid, but over long periods of time, geologic periods of time, it can flow. We'll get back to that in a sec. On top of the mantle is the crust, a solid layer of rock. The overall density of the rock in the crust is less than in the mantle, so in a sense it floats on the mantle. There are two types of crust on Earth: Oceanic crust, which is about 5 kilometers thick, and continental crust, which is a much beefier 30-50 kilometers thick. Still, the crust is very thin compared to the other layers. The crust isn't a solid piece, though; it's broken up into huge plates, and these can move. What drives the movement of these plates is the flow of the rock in the mantle, and that, in turn, is powered by heat. The core of the Earth heats the bottom of the mantle. This causes convection; the warmer material rises. It's not exactly a speed demon, though: The rate of flow is only a couple of centimeters per year, so it takes about 50 or 60 thousand years for a blob to move a single kilometer. The hot material rises toward the surface, but it's blocked by the crust. The magmatic rock pushes on the plates, causing them to slide around very slowly. Your fingernails grow at about the same rate the continents move. Over millions of years, though, this adds up, changing the surface geography of the Earth—where you see continents now is not at all where they were millions of years ago. In some places, generally where the plates come together, the crust is weaker. Magma can push its way through, erupting onto the surface, forming volcanoes. Other volcanoes, like Hawaii or the Canary Islands, are thought to be from a plume of hotter material punching its way right through the middle of a continental plate. As the plate moves, the hot spot forms a linear chain of volcanoes over millions of years. Volcanoes create new land as material wells out, but they also pump gas out of the Earth too. A large part of Earth's atmosphere was supplied from volcanoes! The interior of the Earth is hot; in the core, it's about as hot as the surface of the Sun! Where did that heat come from? Most of it is leftover from the Earth's formation, more than 4.5 billion years ago. As rock and other junk accumulated to form the proto-Earth, their collisions heated them up. As the Earth grew that heat built up, and it's still toasty inside even today. Also, as the Earth formed and gained mass it began to contract under its own gravity, and this squeezing added heat to the material. Another source is elements like uranium deep inside the Earth, which add heat as the atoms radioactively decay. And a fourth source of heat is from dense material like iron and nickel sinking to the center of the Earth, which warms things up due to friction. All of these things add up to a lot of heat, which is why, after all these billions of years, the Earth still has a fiery heart. The outer core of the Earth is liquid metal, which conducts electricity. The liquid convects, and this motion generates magnetic fields, similar to the way plasma in the Sun generates magnetic fields. The Earth's rotation helps organize this motion into huge cylindrical rolls that align with the Earth's axis. The overall effect generates a magnetic field similar to a bar magnet, with a magnetic north pole and south pole, which lie close to the physical spin axis poles of the Earth. The loops of magnetism surround the Earth, and play a very important role: They deflect most of the charged particles from the solar wind, and they trap some, too. Without the geomagnetic field, that solar wind would hit the Earth's atmosphere directly. Over billions of years, that would erode the Earth's air away, like a sand blaster stripping paint off a wall. Mars, for example, doesn't have a strong magnetic field, and we think that's why its atmosphere is mostly gone today. But we do have an atmosphere, and it's more than just air blowing around. Earth's atmosphere is the layer of gas above the crust. Because it's not solid, it doesn't just stop, it just sort of fades away with height. By accepted definition—and by that I mean it's not really science, it's more of a "Eh, let's just do it this way" kind of thing—the line between Earth's atmosphere and space is set at 100 kilometers up. This is what's called the Kármán line, and if you get above it, congratulations! You're an astronaut. The atmosphere is, by volume, about 78% nitrogen, 21% oxygen, 1% argon of all things, and then an assortment of trace gases. There's water vapor, too, almost all of it below a height of about 8-15 kilometers. This part of the atmosphere is warmest at the bottom, which means we get convection in the air, creating currents of rising air, which carry water with them, forming clouds, which in turn is why we have weather. At a height of about 25 kilometers on average is a layer of ozone, a molecule of oxygen that's good at absorbing solar ultraviolet light. That kind of light can break apart biological molecules, so the ozone layer is critical for our protection. Incidentally, the Earth's magnetic field does more than trap solar wind particles; it also channels some of them down into the atmosphere, where they slam into air molecules about 150 kilometers up. This energizes the molecules, which respond by emitting light in different colors: Nitrogen glows red and blue, oxygen red and green. We call this glow the aurora, and it happens near the geomagnetic poles—far north and south. The lights can form amazing ribbons and sheets, depending on the shape of the magnetic field. I've never seen an aurora. Some day. You may not be aware of the atmosphere unless the wind is blowing, but it's there. It exerts a pressure on the surface of the Earth of about a kilogram per square centimeter, or nearly ten tons per cubic meter! There's roughly ton of air pushing down on you right now! You don't feel it because it's actually pushing in all directions—down, to the sides, even up—and our bodies have an internal pressure that balances that out. The Earth also has liquid water on its surface, unique among the planets. The continental crust is higher than oceanic crust, so water flows down to fill those huge basins. The Earth's surface is about 70% covered in water. Most likely, some of this water formed when the Earth itself formed, and some may have come from comet and asteroid impacts billions of years ago. The exact proportion of locally sourced versus extraterrestrial water is still a topic of argument among scientists. Earlier, I mentioned trace molecules of gas in the atmosphere. One of these is carbon

dioxide, which only constitutes about 0.04% of the lower atmosphere. But it's critical. Sunlight heats the ground, which emits infrared light. If this infrared light were allowed to radiate into space, the Earth would cool. But carbon dioxide traps that kind of light, and the Earth doesn't cool as efficiently. This so-called greenhouse effect warms the Earth. Without it, the average temperature on Earth would be below the freezing point of water! We'd be an ice ball. This is why climate scientists are concerned about carbon dioxide. A little is a good thing, but too much can be very dangerous. Since the Industrial Revolution, we've added a lot of the gas to our atmosphere, trapping more heat. By every measure available, the heat content of the Earth is increasing, upsetting the balance. It's melting glaciers in Antarctica and Greenland, as well as sea ice at the north pole. Sea levels are going up, and some of the extra CO2 in the air is absorbed by the oceans, acidifying them. There's an old concept in science fiction called terraforming: Going to uninhabitable alien planet and engineering it to be more Earth-like. I don't know what the opposite process would be called, but it's what we're doing to Earth right now. The Earth is the only habitable planet in the solar system. And you know what? We should keep it that way. Today you learned that the Earth is a planet, with a hot core, a thick layer of molten rock called the mantle, and a thin crust. The outer core generates a strong magnetic field, which protects the Earth's atmosphere from the onslaught of the solar wind. Motion in the mantle creates volcanoes, and the surface is mostly covered in water. The Earth's atmosphere is mostly nitrogen, and it's getting warmer due to human influence. Crash Course is produced in association with PBS Digital Studios. This episode was written by me, Phil Plait. The script was edited by Blake de Pastino, and our consultant is Dr. Michelle Thaller. It was co-directed by Nicholas Jenkins and Michael Aranda, and the graphics team is Thought Café.