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Introduction

Our Fantastic and Catastrophic Relationship with the Planet We Live On

You and I are both a part of the life that once came into existence from the primordial ingredients of our planet. Our bodies are made up of atoms that were formed at the same time as the universe. As my children grow, they're being built from elements in the soil, water, rock, and air. Sometime in the future, the atoms in my body will become trees, glaciers, and granite.

But we humans are also more than just our bodies. The clothes I wear, the house I live in, the knife I use to butter my bread—they're all just as important as my fingers and toes. And without the mines and bulldozers that help make fertilizer and food, you'd probably never even have been born.

All of the objects in our lives—and the materials they're made of—play a role in the unique circumstance we've developed together: our civilization. And I like civilization. I like living in a warm house and traveling to new places, and I can hardly even imagine a life without all the knowledge of the world only a click, tap, or swipe away—even though I grew up with an encyclopedia on the bookshelf and handwritten letters in the mailbox.

Every single day, new windows, phones, and people are being made. It's incredible that this is even possible. But the question is: How do we get hold of the building blocks for all of these people, things, and food? What's it all made of? And will our planet ever run out of these building blocks—causing everything to screech to a halt?

There's a lot of talk about the environment these days, in particular about how human consumption affects water, earth, and air. We talk about species dying out at the same rates as when a meteorite put a hasty end to the dinosaurs sixty-six million years ago. We discuss how the ocean is filled with so much garbage that pretty soon there will be more plastic than fish in the sea. And last but not least, we consider the fact that the oil and coal we're burning in power plants and cars is actually changing the climate—so much so that many places on Earth will become uninhabitable in the near future.

The conversation about environmental degradation can quite easily make me feel completely powerless. Who am I in the big picture, really? Is it my fault that species are dying out? What kind of world am I leaving behind for my children? Is there anything I can do that will not only ease my own conscience but also actually lead to the world evolving in a more positive direction? I wrote this book because I want us to be able to talk about how our steady production of things, food, and, ultimately, ourselves has consequences that are both fantastic and catastrophic at the same time. It’s only when we really understand what we’re talking about that we can start finding solutions that will actually make a difference for those who come after us.

1 | The History of the World and the Elements in Seven Days

THE HISTORY OF THE ELEMENTS stretches back to the birth of the universe. Their story is long—in fact almost incomprehensibly long in relation to human time. To make it a bit easier, I thought I'd take the creation myth of Genesis as inspiration and tell the history of the world in seven days.

In this story, I'll turn 1 billion years into half a day, 1 million years into 45 seconds, and 1,000 years will be covered in 0.44 seconds. It's been 13.8 billion years since the universe was born, but in this account, time began when the clock struck midnight on Monday morning. By the time you reach the end of this chapter, the clock will strike midnight again, and Sunday will be over.

MONDAY: THE BIRTH OF THE UNIVERSE

At first, there was neither time nor space. How and why everything got started is complicated—but we know that it all started with a bang. The explosion we've come to know as the big bang flung the energy in the newborn universe out in all directions. After this chaotic start, the young universe started to be governed by the laws of nature we know from our world today.

Just as the dust in my house gathers into dust bunnies (it's just a matter of giving it enough time!), the energy in the universe eventually started clumping together. These clumps, or particles of energy, are what we call mass: matter, substance, that which is tangible, that which makes up everything you could potentially touch and feel in the universe.

My body, my belongings, and the planet we live on—absolutely everything we surround ourselves with is made up of atoms. Atoms are composed of three types of particles: protons, neutrons, and electrons. The protons and neutrons are firmly stuck together in the atom's nucleus, and the number of protons in the nucleus is what determines which element the atom is. If the nucleus were to get rid of some protons or receive some new ones, the atom would become a different element. Initially, an atom has the same number of protons and electrons, but the electrons are whirring around the outer edge and can be exchanged between atoms in what we call chemical reactions.

Protons, neutrons, and electrons arose in the glowing soup of energy and mass that made up the young universe. Protons and neutrons ended up sticking together and becoming atomic nuclei in the elements hydrogen, helium, and lithium. These smallest and lightest elements have one, two, and three proteins in their nuclei, respectively. Today, hydrogen is an important building block in water and in the organic molecules that make up living beings. Take the human body, for example, which is made up of almost 10 percent hydrogen. When you think of it that way, you could technically say that you come directly from the birth of the universe!

Sixteen seconds past midnight, the universe had gotten so cold that electrons could attach to atomic nuclei without being released immediately. So, for the very first time, it was possible for light to move through the universe without being stopped by hot electrons. At just past midnight, there was visible light in the universe—even though there was no one there to see it.

Over the course of the next twelve hours, the mass in the universe continued clumping together. Huge clouds of atoms were formed, and before the clock struck three in the morning, groups of these clouds had become the very first galaxies. One of these galaxies turned out to be the Milky Way—our home. Today, the Milky Way is just one of more than two thousand billion galaxies in the universe.

At 6:00 am, some of the atom clouds in the galaxies had become so big that they collapsed beneath their own weight. This is how the first stars came to be. In one of these—a clump of material that was considerably larger than our own sun is today—were the hydrogen atoms that would be transformed into the oxygen you just inhaled.

The weight of all the surrounding atoms pressed these hydrogen atoms against each other with enormous force. First, this caused the electrons to detach from the nuclei. The pressure then became so intense that it caused the hydrogen nuclei to fuse together and form new helium nuclei. This fusion released huge amounts of energy that warmed up the clump of atoms, making it a bright star. The same process is still taking place today in our own sun; the light that meets your eyes when you look outside your window comes from atomic nuclei fusing within the sun's interior.

As most of the hydrogen nuclei gradually became helium, the release of energy in the star's interior started to slow down. The center of the star no longer had enough power to withstand the pressure from the surrounding material, and it collapsed. This started a new phase of the star's life. The collapse forced the helium nuclei so close together that they fused in new reactions. Three helium nuclei with two protons each became a nucleus with six protons—which is carbon. Then, the carbon nucleus fused with yet another helium nucleus to form a nucleus of eight protons. This is oxygen, and this atomic nucleus can be found at this very moment in an oxygen atom inside a red blood cell on its way to your brain.

Inside the star, the process of fusing atomic nuclei into heavier and heavier elements continued. Eighty-six percent of your body is made up of carbon, nitrogen, and oxygen, all of which were formed during this phase. Here on Earth, the pressure is far too low to make such elements, so we can be sure that these building blocks in our bodies actually did come from stars. We are stellar beings—every single one of us! In addition, the iron in our blood, the phosphate in our skeletons and DNA, the aluminum in our mobile phones, and the salt (sodium and chloride) we sprinkle on our food were all made during this phase.

A few minutes into the weeklong story, the star's life is over, ending with an explosion so spectacular that it got the name "supernova." In the explosion, elements even heavier than iron were formed—including nickel, copper, and zinc. The power lines in your house are made of materials from a supernova.

The leftovers from the explosion—the material that was not thrown into space, that is—collapsed and became a neutron star. In a neutron star, all of the nuclei have fused together into a massive clump the size of a large city (about 10 miles/15 kilometers in diameter), and, in a way, it really is an enormous nucleus, even though we don't call it an element. There are about one billion neutron stars here in our own galaxy, but since they're so small and cold compared to the other stars, it's not easy to spot them.

When I think about how much space there is in the universe and how small neutron stars are, I feel like what happened next seems almost infinitely impossible. All the same, we know that it had to have happened. At some point during the first days of the universe, two neutron stars collided. This collision created gold, silver, platinum, uranium, and a host of other elements so heavy that they can only be formed in such extreme events. The newborn elements were cast out into space and mixed with clouds of dust and atoms in the galaxy.

And that's how elements came about on the first of seven days. Elements are still being created out in the universe as stars are being born and dying, exploding, and colliding all the time. Here on Earth, however, the elements are fairly constant. It's only through radioactive processes in which unstable nuclei of uranium and other heavy elements sometimes start splitting up that elements are created and destroyed on our planet. Even in laboratories, it's almost impossible to recreate the processes that take place inside stars. We have almost endless opportunities to create materials by varying how we assemble elements, but when it comes to the elements themselves—what we've got is what we've got.

FROM TUESDAY TO THURSDAY: STARS ARE BORN AND DIE

The universe continued on the same track for the next three days. Stars were born, and stars died. Supernovae sent pressure waves and clouds of matter out into space. Since hydrogen and helium were constantly being fused into new elements inside the stars, the total amount of hydrogen and helium in the universe steadily decreased while the amount of heavier elements increased.

FRIDAY: OUR SOLAR SYSTEM IS FORMED

At four o’clock on Friday afternoon, a star died in our neighborhood. The pressure wave from the supernova squeezed dust and gas into a cloud that contained the oxygen you just inhaled. This triggered a chain reaction where clumps of matter became heavy enough to absorb the dust and gas in the surrounding area, and the bigger and heavier they became, the more of their surroundings they sucked up. Just forty-five minutes later, the cloud had become a star with several planets in its orbit. This star is our sun—the center of our solar system.

All planets orbit around a star. The closer to the star the planet is, the more the planet is heated by the radiation from the nuclear reactions in the star’s interior. In our solar system, the closest planets became extremely hot. Today, they have surface temperatures of over 750°F (400°C). The outer planets, on the other hand, are quite cold; the sun’s rays can’t get them any warmer than 32°F (0°C). The planets farthest away are frozen worlds below –300° F (–185°C).

But for one planet, the distance from the sun was just right. In the habitable zone around the sun, the temperature of the planet could be low enough that water doesn’t boil and at the same time high enough that not all water freezes. It was this planet that would become our home, Earth.

In the beginning, however, Earth was glowing hot—fully liquid, actually. It was also constantly being hit by large and small meteorites. One or more of these stones hit Earth with such force that the matter thrown off after the collision clumped together in orbit around Earth, becoming the moon.

As Earth gradually cooled off in the cold of outer space, heavy elements such as iron, gold, and uranium sank into the center of the liquid sphere. The lighter elements—including silicon and the main components of our bodies, carbon, oxygen, hydrogen, and nitrogen—were left at the outermost edge, eventually forming a solid crust of siliceous rock around the planet with a gaseous atmosphere surrounding it.

In this first atmosphere, molecules were formed—groups of atoms in which two hydrogen atoms were linked to one oxygen atom—this is water. At 6:30 in the evening, the temperature had become cool enough for water molecules to clump into droplets. When the droplets had become large and heavy enough, they rained down on the surface, creating the first, warm sea.

Deep down in this sea, something almost magical happened: Carbon, hydrogen, and oxygen attached themselves to large molecules along with smaller amounts of sulfur, nitrogen, and phosphorus. At some point, some of these molecules developed a structure that caused them to make copies of themselves by getting nearby elements to attach in the very same way. This is the basis of life. When did these molecules go from being a complex chemical system to becoming something living? Did life arise in one place, at one time, or did life first spread across the planet after a long series of attempts? Researchers do not yet have a clear answer for this, but we ourselves are proof that life succeeded.

We humans will never benefit from the metals that sank into the middle of the planet; they're simply much too far into the center of the earth. Fortunately, something happened around ten o'clock on Friday night that would be decisive in how we've been able to develop our society: For the rest of the evening, Earth was bombarded by meteorites. Scientists don't quite understand why. One theory is that the larger planets were adjusting their orbits and disrupting how other matter was moving in the solar system. In any case, the metal in these meteorites was cast out across Earth's crust without sinking into the center because the crust had become firmer. These are the metals we use to make cars and forks today.

About half an hour before midnight, Earth's crust started to crack open and move. The crust on our planet still consists of plates floating around the mantle, a viscous sea of rock. Up here on the surface, it's so cold that when molten rock appears through cracks between the plates, it solidifies and becomes new crust. The plates are therefore constantly changing shape as they move in relation to one another. When the continents on two different plates collide, large mountain ranges are formed—just as the Himalayas are being formed right now as India squeezes into Asia from the south. In many places, a plate with a thin seabed slides under the thicker continental crust of another plate. This is happening today along the Pacific coast of South America. Elsewhere, the plates scrape against one another, shoulder to shoulder. If they get stuck, huge earthquakes can be triggered when they finally slip again, crushing bedrock and leaving large systems of cracks throughout the bedrock.

The dance of Earth's plates with one another is known as plate tectonics. In our solar system, Earth is the only planet with such an active surface. It isn't clear why only Earth's crust is dancing, but without this dance, it would've been a dead planet. Plate tectonics is Earth's conveyor belt and the driving force behind everything that makes our planet such an exciting place. The movement recycles Earth's materials by allowing what has been carried out to sea by water and wind and then buried in the seafloor for millions of years to be lifted back up to the surface. It creates cracks through the crust where flowing water can transport elements up from the depths. Today, the remnants of these cracks are where we excavate gold and other metals.

SATURDAY: LIFE BEGINS

The bombardment of Earth's crust lasted until about a quarter to one early Saturday morning. Then, conditions on the planet became a lot calmer. By 5:30 in the morning, Earth had developed its own magnetic field—an invisible shield that prevents most of the sun's energy-rich and harmful particles from reaching the planet. Without this protection, we would have to live in subterranean caves in order to survive.

Around the same time as the formation of the magnetic field, the first single-celled organisms appeared.

In reality, living organisms aren't anything but small machines that use energy from their surroundings to make copies of themselves. The organisms can, of course, have several other functions as well, such as registering what's going on around them, moving, or communicating with one another. While our bodies get energy from the food we eat, researchers believe the very first living creatures harvested the energy they needed from chemical compounds deep in the oceans. There are still entire ecosystems that live in complete darkness in areas where the tectonic plates are sliding apart. Here, mineral-rich water flows up through chimneylike structures in the seabed, and the chemical bonds in these minerals contain energy that living beings can benefit from.

Today, almost all life on Earth gets its energy from the sun, either directly through photosynthesis or by eating molecules that contain stored solar energy. During photosynthesis, the energy coming from sunlight is used to split carbon dioxide and water into carbon, hydrogen, and oxygen. The atoms are then put together in new combinations to form the energy-rich molecules we know as carbohydrates, proteins, and fats. Photosynthesis was most likely developed by bacteria in the ocean around three o'clock on Saturday afternoon. Today, it's still being utilized in all green plants, trees, and blue-green algae (cyanobacteria). All matter in these organisms contains a small amount of solar energy.

When carbon dioxide and water become plant material, there is an excess of oxygen atoms. Organisms involved in photosynthesis release these oxygen atoms in the form of oxygen molecules, where two oxygen atoms are bonded to each other. Oxygen molecules have a tendency to react with other compounds. We're familiar with this from fire, which is nothing more than oxygen reacting with carbon or other combustible substances and releasing energy in the form of heat. We therefore wouldn't be able to find oxygen molecules in either the ocean or the atmosphere, if they weren't being produced by some source at any given time. The oxygen gas that is so vital to us is constantly being produced through photosynthesis—but in the very first atmosphere on Earth, there were no oxygen molecules, and none of the first organisms needed oxygen to survive, either.

Before photosynthesis began, the oceans contained large amounts of dissolved iron, which they no longer do. In our day and age, iron that comes into contact with water very quickly develops a rough, red surface that breaks down easily. This red material—rust—is a chemical link between iron and oxygen. As long as there is oxygen in the air and water, unprotected iron will always rust.

On Saturday afternoon between around 3:00 and 6:45, the seas started to rust. All of the oxygen that was produced in the first photosynthesis reacted with iron, and the resulting rust sank to the bottom. Eventually, this rust became thick layers of reddish, banded rock. Today, we dig up this red rock, remove the oxygen from the iron in large furnaces, and use the resulting iron metal to make knives and train tracks.

When most of the iron had rusted away, oxygen molecules started to accumulate in the oceans. Oxygen was a deadly poison for most of the planet's first creatures—and photosynthesis thus led to one of the largest mass extinctions of species our planet has ever undergone. However, there were some creatures that had learned to use oxygen to their advantage, for example by utilizing the oxygen from their surroundings to release solar energy that was stored in organisms they'd eaten. By doing so, they got the energy to run their own life processes without having to perform photosynthesis on their own.

While myriad life-forms were lost to the toxic oxygen, the organisms that did use oxygen gained a tremendous advantage. We are the descendants of these organisms. The energy you're using to read this—to move your eyes and transform the text into information in your brain—comes from a chemical reaction in which oxygen and carbohydrates turn into carbon dioxide and water inside your body's cells.

As seawater became saturated with oxygen, oxygen gas started to flow from the oceans into the atmosphere. This change led to tremendous upheavals here on Earth. Our planet is constantly radiating heat into outer space, and the temperature of its surface is heavily influenced by how much of this thermal radiation is trapped by gases in the atmosphere. This is what we call the greenhouse effect. The early atmosphere was rich in methane, which absorbs a great deal of thermal radiation, keeping Earth's surface warm. As oxygen gas in the atmosphere started to break down the methane, the greenhouse effect became weaker, and the planet was propelled into a global ice age. Up until a quarter past nine on Saturday evening, much of the biodiversity that had developed in the seas had been lost to the cold.

High up in the atmosphere, oxygen molecules were being struck by the most energy-rich light from the sun, causing the two atoms in the oxygen molecules to break apart. When the single oxygen atoms collided with the other oxygen molecules that were flying past, ozone (molecules with three oxygen atoms) was formed. The ozone layer effectively acts as a trap for the most energy-rich part of the sun's rays, which can torch vulnerable organic molecules if they reach Earth's surface. Today, the ozone layer is what makes it possible for us to walk around beneath the open sky without experiencing severe damage to our eyes and skin.

Once the ozone layer was in place, it was then possible for organisms to survive near the surface of the water, and even on dry land. Here, there was even more sunlight to utilize in photosynthesis, and the production of organic matter and oxygen gas saw a sharp increase. The first forms of life on dry land were mats of algae and bacteria that covered a flat, barren landscape and laid the foundation for what would become a layer of fertile soil on our planet.

The organisms with cell nuclei (which are what we originate from) arose at about 3:20 am on Sunday. By five o'clock that morning, single-celled organisms had developed such close cooperation that they were no longer considered to be isolated individuals but rather living beings consisting of multiple cells. Nevertheless, it still took a long time before life as we know it really started to flourish. It wasn't until 5:25 pm, after Earth had undergone a new global ice age between 3:15 and 4:15, that specialized species of plants and animals emerged to form complex ecosystems in the oceans. When geologists study petrified seabeds from the subsequent time period, they find fossils from a variety of species, such as cephalopods and woodlouse-like trilobites.

At five past six on Sunday evening, the first animals crawled ashore, where they started working on converting algae-matter and stone into a layer of fertile soil. This is where the first land plants could take root, which they did at about 6:31 pm. With plant roots holding on to soil, water, and later also tree trunks, preventing the wind from blowing away loose materials from the ground, dry land went from being smooth and barren to becoming more diverse—with rivers, valleys, marshes, and lakes.

Life on Earth suffered a few hard blows as well—volcanic eruptions, meteor showers, and changes in solar activity led to major changes in temperature, sea level, and oxygen levels in the atmosphere and in the ocean. Eighty-five percent of the species that had developed after the first flourishing of complex life was lost in a global ice age by 6:36 pm. Life picked up again thereafter, but at 7:28 pm, the trilobites were suffocated by a lack of oxygen on the seabed and disappeared along with 80 percent of all species found in the oceans at that time.

The largest mass extinction to date occurred at 8:56 pm on Sunday evening, when enormous volcanic eruptions in Siberia sent considerable amounts of carbon dioxide into the atmosphere, something that ultimately led to a global temperature increase and acidification of the world's seas—issues we are well aware of today. The fossils from just after the extinction testify to a disaster that left desolate landscapes with neither forests on land nor coral reefs in the seas.

A few minutes later, however, the forests and seas flourished once again, and more and more species came into existence. Both mammals and dinosaurs made their appearance before 9:30 that evening. The good times didn't last long, however, coming to an end at 9:34, when a new global warming wiped out at least three-quarters of all species on Earth. Mammals and dinosaurs were among those who endured, and it was perhaps precisely this extermination of competitors that gave dinosaurs the chance to become the next rulers of Earth. When the dinosaurs also had to give in around 11:12 pm, Earth's climate had likely been so punishing for such a long time that when the tremendous meteorite hit in what is present-day Mexico, it was simply the last nail in the coffin for many of Earth's species.

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