Amazing Earth-changing microbial activities: planet oxygenation

Photosynthetic microorganisms: the invisible forest

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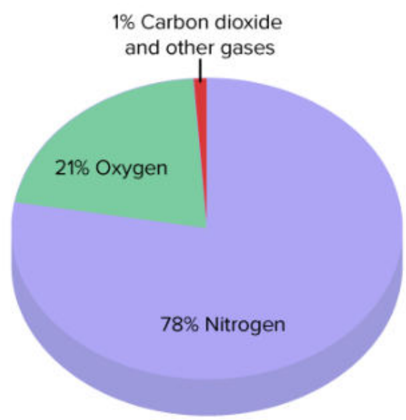
Image on the left, taken by André Karwath aka Aka, shows banded iron formation with its characteristic red color. On the right side, stromatolites can be seen. Image taken by Paul Harrison.

We need to breathe

Let's breathe together. Breathe in – breathe out. Let's do it again. Inhale – exhale. It's estimated that, on average, we take 12 to 20 breaths per minute. Each breath moves about half a liter of fresh air into our lungs and stale air out of them.



That half liter of air we just breathed in contains a mix of gases. The most abundant is nitrogen, making up about 78%. Next comes oxygen, at about 20.9%. There are also small traces of other gases like argon and carbon dioxide. Of all these, the gas that's essential for our bodies is oxygen. You've probably heard that before — but have you ever wondered why we need to breathe and why is oxygen so important?

Why do we need oxygen?

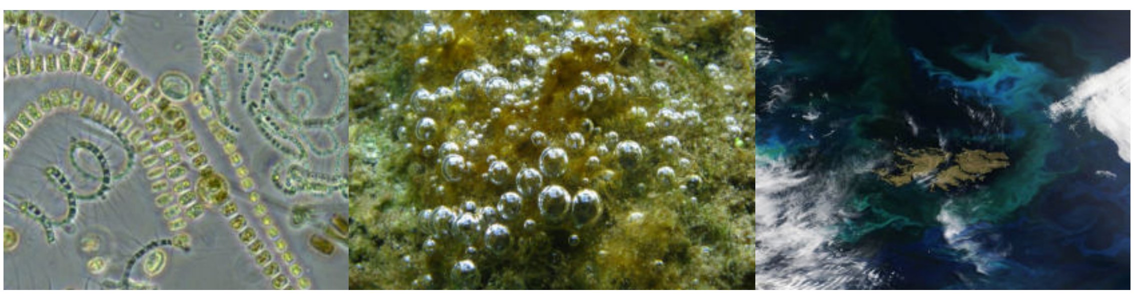
Have you ever thought about why we call the phones we carry around cellphones? It's because early mobile networks were divided into small areas called "cells." But let's take that idea further: our body is also made of cells — millions and millions of them. And just like a cellphone needs a battery to work, our body's cells need energy to function and enable you to think, move, grow… and yes, even scroll through TikTok.

Unlike cell phones, our cells don't use electricity. They make their own energy using two key ingredients: food (like glucose from what you eat) and oxygen (from the air we breathe). So, every time we take a breath, we're giving our cells the oxygen they need to 'charge up' and keep us going.

And just like any machine, our cells produce waste — in this case, carbon dioxide (CO_2). Thus: our lungs take oxygen from the air into our blood streams which deliver it to our tissues and organs. Blood also picks up waste CO_2 from our tissues and organs and delivers it to the lungs. Breathing out is how our body gets rid of it. In effect, inhaling is taking oxygen in, exhaling is pushing CO_2 out.

But where does this very important molecule — oxygen — come from?
Most of the oxygen on our planet is produced by a process called oxygenic photosynthesis. This is how plants, algae, and some microorganisms use sunlight, carbon dioxide, and water to create their own food — glucose. As a byproduct of this process, they release oxygen into the air. Yes — the very oxygen that keeps us alive!

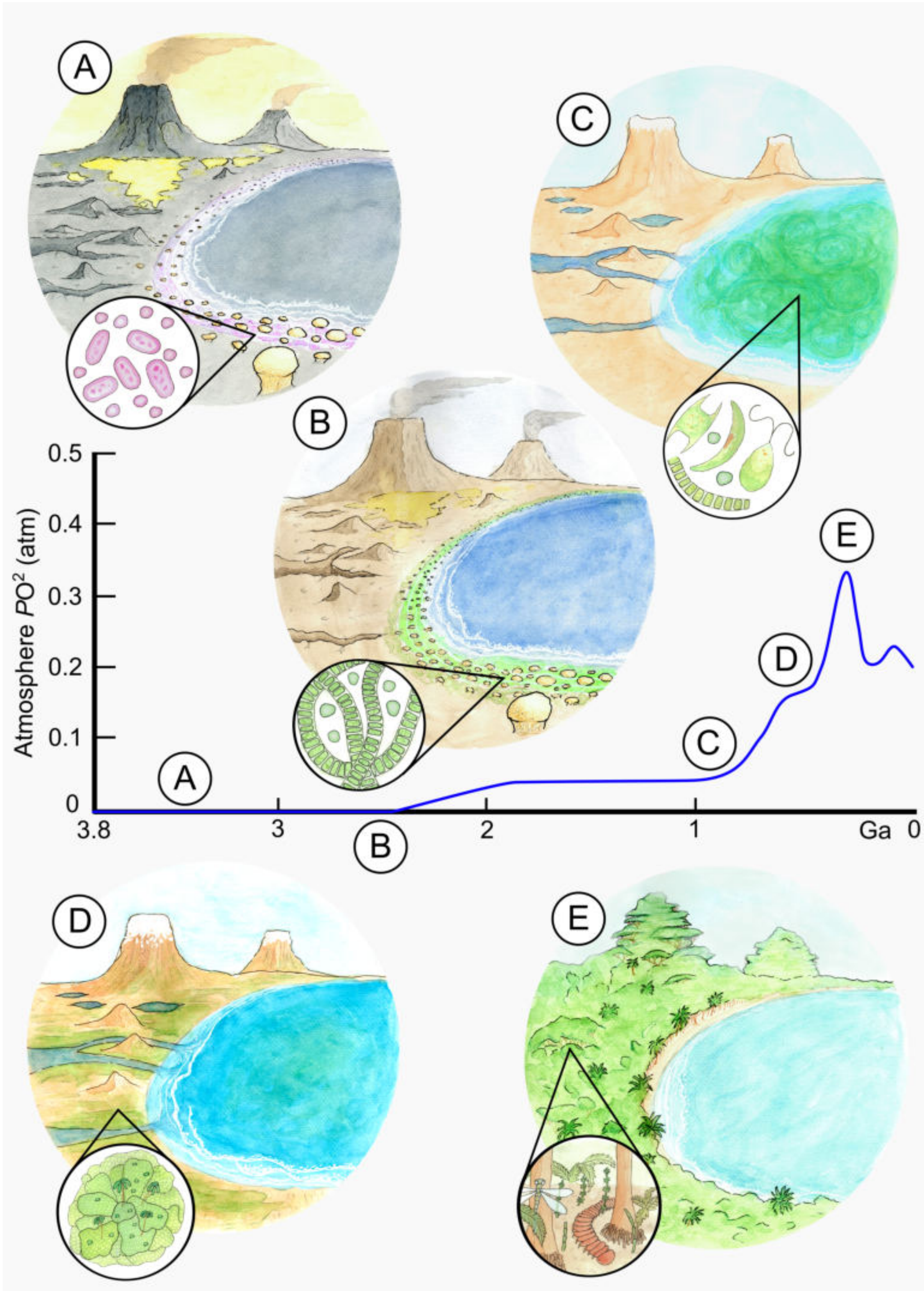
A large portion of Earth's oxygen is produced by microorganisms in the ocean.
We need to thank photosynthetic organisms for producing this oxygen — and they do it for free! Among them are the plants and trees we see on our way to school or home, but also algae and microorganisms in the ocean. Around 50% of the oxygen we breathe — that is, one out of every two breaths — comes from the ocean. These microorganisms are tiny; we can't see them with the naked eye. But when we look at our oceans from space, we can see them. Crazy, right? Something so small being visible from so far away — but they're so abundant that together, they become visible. And that's why they earn the title of one of the largest oxygen producers on our planet.



On the left, cyanobacteria and diatoms under the microscope. In the middle shows diatoms in sediments producing visible oxygen bubbles. On the right, is a NASA Earth Observatory image showing a massive diatom bloom in the Atlantic Ocean, larger than the Falkland Islands.

Per square meter, estuaries produce the most oxygen, followed by swamps and marshes, tropical rainforests, and temperate forests. When it comes to oxygen production per square meter, the open ocean ranks 13th! But since nearly 70% of our planet is covered by open ocean, it ends up being the most important contributor to the Earth's average net primary productivity.

Oxygen was not always present on our planet.
This important gas we breathe wasn't always abundant. When Earth formed about 4.5 billion years ago, there was no oxygen in the atmosphere. And it stayed that way for nearly 2 billion years Around 2.4 to 2.1 billion years ago, oxygen began to accumulate in the atmosphere. This drastically changed our planet and allowed complex life — like us — to evolve.



This picture tells the story of how life and oxygen on Earth changed over billions of years. At first (**A**), the planet had no oxygen and only tiny bacteria lived in the oceans. Later (**B**), special bacteria called cyanobacteria learned to make oxygen using sunlight. Slowly, the air started to have more oxygen. In (**C**), more tiny life filled the oceans. Then (**D**), more complex life forms appeared, like algae with many cells. Finally (**E**), plants grew on land, filling the air with oxygen and making it possible for animals—and eventually humans—to evolve and thrive.

The Great Oxidation Event

This period of rising oxygen in the atmosphere is known as the Great Oxidation Event, or GOE. It's called 'oxidation' because oxygen is a very reactive element. It's even one of the reasons why we age — our bodies slowly oxidize over time! This event also triggered the first mass extinction, wiping out many anaerobic microbes that couldn't survive in oxygen-rich environments. But it also gave aerobic microbes the chance to thrive and spread across the planet. Back then, there were no plants or trees — so who was producing the oxygen?

Cyanobacteria

It was cyanobacteria — tiny, ancient microbes living in the ocean (**see B, figure** above) Even though they were super small, they had a special power: they could use sunlight, water, and carbon dioxide to make their own food by oxygenic photosynthesis, just like plants do today. And every time they did that, they released oxygen into the water and, eventually, into the air. But cyanobacteria didn't start this story. Before oxygenic photosynthesis evolved, there were already other microbes using sunlight in clever ways — just without making oxygen (**A, in figure**). These early bacteria performed what's called anoxygenic photosynthesis. Instead of water, they used substances like hydrogen, sulfur, iron, and even toxic arsenic to capture energy from sunlight using pigments other than chlorophyll, such as bacteriochlorophylls and carotenoids. These pigments gave these microbes distinct purple and orange colorations.

How do we know?

At first, all that oxygen produced by oxygenic photosynthesis didn't go far — it reacted with minerals in the ocean. One of the most striking results of this reaction can still be found today: huge layers of ancient rock called "banded iron formations" (introductory image). These rocks formed when the oxygen produced by cyanobacteria combined with iron dissolved in the oceans, creating layers that sank to the seafloor and that we can see today.

And even before the atmosphere had oxygen, life still left marks we can see! Some of the oldest signs of life on Earth are stromatolites — layered rocky structures built by communities of microbes growing over time (introductory image). Like microbial apartment buildings, each layer tells a story. In fact, many stromatolites were made by early cyanobacteria, capturing sunlight day after day and leaving behind a stone record we can read.

The Invisible Heroes

So, the next time you take a deep breath, remember that you're not just filling your lungs with air — you're connecting with a story that began billions of years ago. A story written by tiny, invisible heroes that shaped our planet long before there were animals, trees, or even oxygen in the air. They didn't just survive in Earth's early oceans — they transformed them. They made the oxygen we breathe, built rocky stromatolites, and painted the oceans with banded iron. Today, their microscopic descendants are still out there, floating in the sea, catching sunlight, keeping our planet alive and powering human activities.

The cyanos were tiny but mighty transformers of Planet Earth and most of the life it houses!!