NO PREP

Cyanobacteria and the Breath of Life

Includes: Student reading, case study, differentiated questions, teacher key

Name: Period: Date:

Cyanobacteria and the Breath of Life

When we picture the sources of Earth's oxygen, we often imagine towering forests and lush meadows. But the truth is humbler and far more widespread: microscopic cyanobacteria drifting through the ocean have been quietly shaping our atmosphere for billions of years. These single-celled, photosynthetic bacteria—sometimes called blue-green bacteria—perform oxygenic photosynthesis, splitting water to release oxygen (O_2) while storing energy in sugars. Long before plants evolved, cyanobacteria were already at work, changing the chemistry of seas and sky and laying the foundation for complex life to flourish. Cyanobacteria thrive where many organisms struggle. Their cells contain adaptable pigments, streamlined metabolisms, and, in some groups, the power to perform nitrogen fixation, converting inert atmospheric nitrogen (N_2) into forms life can use. In open-ocean waters where nutrients are scarce and light conditions vary, these traits make cyanobacteria both resilient and indispensable. Today, they continue to fuel marine food webs, help regulate

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From Anoxic Skies to an Oxygenated World

Roughly 2.4 billion years ago, the planet's atmosphere held almost no free oxygen. Then came a planetary turning point: the Great Oxidation Event (GOE). Over countless generations, cyanobacteria released O_2 as a byproduct of photosynthesis. At first, that oxygen reacted with dissolved iron in the oceans, precipitating vast banded iron formations we still mine today. Eventually, oxygen accumulated in the atmosphere, transforming Earth's red, oxygen-poor world into the blue planet we recognize. This oxygenation didn't simply make breathing possible. It enabled aerobic respiration, a far more efficient way to harvest energy from food, and it set the stage for the evolution of eukaryotes and, much later, plants and animals. The

GOE also strengthened the ozone layer, shielding surface life from harmful ultraviolet radiation. In short, cyanobacteria didn't just "add oxygen": they rewired Earth's biogeochemistry, opening evolutionary pathways that led, ultimately, to us.

How Cyanobacteria Power Today's Oceans

Although their ancient legacy is dramatic, cyanobacteria remain vital in modern seas. Marine genera such as Prochlorococcus and Synechococcus dominate the sunlit photic zone across enormous swaths of the open ocean. Tiny Prochlorococcus cells, among the smallest known photosynthetic organisms, are astonishingly abundant; their collective photosynthesis supports a significant share of global oxygen production and primary productivity in nutrient-poor, oligotrophic waters. Trichodesmium, a filamentous cyanobacterium often called "sea sawdust," performs nitrogen fixation in warm, clear seas. It injects new, bioavailable nitrogen into surface waters and jump-starts productivity where nitrate is scarce. These microbes don't act in isolation. As cyanobacteria fix carbon through photosynthesis, they feed zooplankton and support higher trophic levels, while their dissolved organic carbon fuels the microbial loop, where bacteria and protists recycle nutrients. Some cyanobacteria form harmful blooms under nutrient-rich, warm conditions, producing toxins or fueling oxygen-depleting decay. Managing runoff and warming is therefore essential to keep the balance, maximizing cyanobacteria's benefits while minimizing risks.

Inside Oxygenic Photosynthesis

Cyanobacteria harvest light with chlorophyll a and accessory pigments (including phycobilins) arranged in efficient light-collecting structures. In the light reactions, photons energize electrons, water is split (releasing O_2), and energy is stored as ATP and NADPH. The Calvin cycle then fixes CO_2 into sugars, which power growth or flow into the food web when cyanobacteria are grazed. Accessory pigments widen the usable light spectrum—crucial in deeper or bluer waters where red wavelengths are rapidly absorbed. Equally impressive is the cellular specialization seen in some lineages. Filamentous cyanobacteria may form heterocysts—thick-walled cells that create low-oxygen microenvironments so nitrogen fixation can proceed (oxygen inactivates the nitrogenase enzyme). These innovations, along with ultra-small cell sizes and streamlined genomes in open-ocean species, help cyanobacteria succeed

from bright surface layers to dim boundary waters, sustaining primary production across vast marine regions.

Cyanobacteria, Ecosystems, and People

Cyanobacteria are lynchpins of marine ecosystem services. By fixing carbon and, in some cases, nitrogen, they support fisheries, buffer climate by drawing down CO_2, and contribute to the oxygen we breathe. Yet warming seas, altered stratification, and nutrient enrichment threaten to shift communities toward more frequent harmful blooms—some producing toxins that affect wildlife and human health. Coastal stewardship (reducing nutrient runoff), climate mitigation, and continued monitoring help keep these ancient partners working for us and the ocean.

Key Information: Table: Cyanobacterial Genera, Traits, and Ecosystem Roles

Genus	Key Trait	Primary Role in Oceans
Prochlorococcus	Ultra-small, efficient light harvesting	Dominates oligotrophic photic zone; major oxygen producer
Synechococcus	Broad thermal tolerance	Widespread primary production across coasts and gyres
Trichodesmium	Nitrogen fixation in warm waters	Adds new nitrogen; can form visible "sea sawdust" blooms
Nodularia	Filamentous, occasional toxins	Episodic blooms; nutrient cycling and potential health risks
Microcystis	Fresh to estuarine; toxin producer	Illustrates bloom risks where land and sea meet

Case Study: "Sea Sawdust" at Work—A Trichodesmium Bloom in the Subtropical Atlantic

On a calm August morning, oceanographers lower bottles into sapphire-blue water two hundred miles off the Bahamas. The water looks clear and nutrient-poor, but their instruments tell a different story: filaments of Trichodesmium are blooming. Under the microscope, the filaments clump into golden-brown "puffs" and "tufts," nicknamed sea sawdust by sailors. Despite the low nitrate levels typical of the subtropical gyres, Trichodesmium thrives by tapping directly into the atmosphere—using the enzyme nitrogenase to fix N_2 into ammonia. This biochemical trick bypasses one of the ocean's hardest limits on growth: the scarcity of usable nitrogen. Over the next week, the research team measures a cascading response. With additional fixed nitrogen entering the surface layer, phytoplankton growth nudges upward, small zooplankton graze more actively, and microbial recyclers accelerate the turnover of nutrients. Even subtle shifts like these matter in vast ocean provinces; a modest enhancement in nitrogen can translate into meaningful carbon fixation, drawing CO_2 into biomass and, eventually, into the biological pump that transports some carbon to depth. Yet the team also watches for warning signs—surface warming and excessive nutrients can push systems toward harmful algal blooms or oxygen loss. In this delicate balance, Trichodesmium's bloom is both a boon and a bellwether, revealing how finely tuned ocean productivity is to temperature, light, and nutrient supply.

1. In nutrient-poor subtropical waters, how does Trichodesmium boost productivity across the food web?

2. Why can a nitrogen-fixing bloom subtly influence the biological pump and climate?

Multiple Choice

1. Which statement best captures the Great Oxidation Event?

    a) A sudden cooling of the oceans that formed the polar ice sheets

    b) The first appearance of multicellular animals

    c) A shift from freshwater to marine ecosystems

    d) Atmospheric oxygen rose due to cyanobacterial photosynthesis

2. Why are Prochlorococcus populations so important in the open ocean?

    a) They are the largest photosynthetic cells in the sea

    b) They form calcium carbonate shells that sink rapidly to the seafloor

    c) They account for a major share of marine oxygen production

    d) They feed directly on microscopic zooplankton

3. Which pigment family helps cyanobacteria capture light in deeper, bluer waters?

    a) Phycobilins

    b) Xanthophylls

    c) Hemoglobins

    d) Carotenoids only

Matching

Write the letter of the correct definition on the line next to each term.

Term	Definition
1. ___ Great Oxidation Event	A) Rock layers formed when early oxygen reacted with dissolved iron
2. ___ Prochlorococcus	B) Accessory pigments that extend light-capture spectrum
3. ___ Trichodesmium	C) Rise of atmospheric O_2 driven by cyanobacterial photosynthesis
4. ___ Banded iron formations	D) Filamentous, N_2-fixing bloom-former in warm seas
5. ___ Phycobilins	E) Tiny marine cyanobacterium abundant in oligotrophic waters

Fill-in-the-Blank

1. Some cyanobacteria perform _____ fixation, supplying new biologically available nitrogen to surface waters.

2. Thick-walled cells that let some filamentous cyanobacteria fix nitrogen are called _____.

3. The sunlit layer of the ocean where photosynthesis occurs is the _____ zone.

Short Answer

Answer each question in 2-4 complete sentences.

1. Explain why nitrogen fixation can boost productivity in otherwise nutrient-poor regions.

_____

_____

_____

2. Describe one adaptation that helps cyanobacteria thrive under low-light conditions.

3. Identify one risk associated with harmful cyanobacterial blooms and a practical mitigation step.