Researchers have developed a printable gel that is infused with ancient cyanobacteria — a 'photosynthetic living material' which not only grows, but removes CO_2 from the air, twice over

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ANCIENT MICROBES TACKLE CO_2

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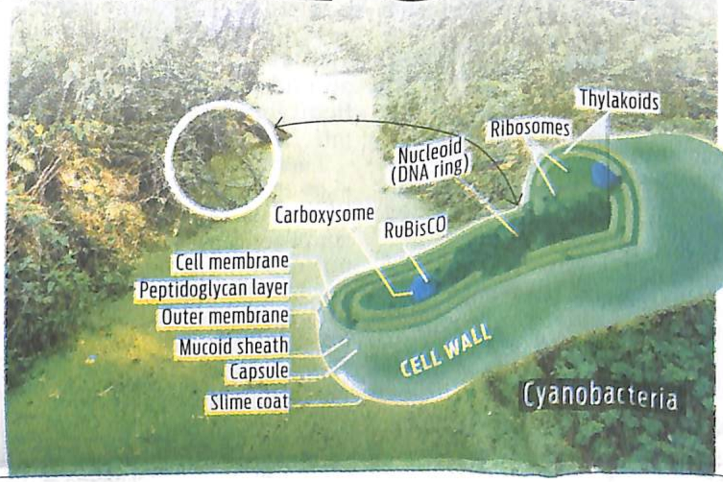
CYANOBACTERIA, often referred to as blue-green algae, are a group of photosynthetic bacteria that have existed for over 3.5 billion years. Despite their misleading name, they are not algae but prokaryotic microorganisms, lacking a nucleus and organelles, that played a foundational role in shaping life on Earth. Through oxygenic photosynthesis, cyanobacteria began producing oxygen billions of years ago, triggering the Great Oxidation Event around 2.4 billion years ago. This transformation allowed aerobic life to emerge and fundamentally altered the Earth's atmosphere and biosphere.

Today, cyanobacteria continue to be vital components of diverse ecosystems. They are found across freshwater, marine, and terrestrial environments, and some species even thrive in extreme conditions such as polar ice or geothermal springs. Cyanobacteria exist as single cells, colonies, or long filaments. Importantly, some species possess the ability to fix atmospheric nitrogen into ammonia, making them valuable in agriculture and natural ecosystems where they help sustain soil fertility.

Beyond their ecological functions, cyanobacteria have become a major focus of biotechnology and materials science. Their efficiency in capturing carbon dioxide and light makes them promising tools for carbon sequestration and biofuel production. Under the right conditions, typically involving excess nutrients and warmth, cyanobacteria can proliferate rapidly, causing harmful algal blooms that threaten ecosystems and public health. But scientists are now turning these same capabilities toward solving pressing environmental problems, particularly those related to carbon emissions and sustainable construction.



A breakthrough in this field comes from ETH Zurich, where a multidisciplinary team led by Prof Mark Tibbitt has developed a 'photosynthetic living material' by incorporating cyanobacteria into a printable hydrogel. This innovation, recently published in Nature Communications, combines biology and materials science to produce a living structure that not only grows and self-repairs, but also actively removes CO2 from the atmosphere.


Picoplanktonics shows large-format objects made of photosynthetic structures | VALENTINA MORI/ BIENNALE DI VENEZIA

At the heart of this material is a type of cyanobacteria that excels at photosynthesis, even under low light conditions. As the bacteria metabolise CO2 and water, they produce biomass, converting inorganic carbon into organic compounds. But the unique feature of these specific cyanobacteria is their ability to alter their chemical surroundings during photosynthesis. This causes minerals, such as calcium carbonate (lime), to precipitate out of the surrounding environment, storing CO2 in a highly stable, solid form. This process, known as biomineralisation, enables the material to serve as a dual carbon sink: storing carbon both in living biomass and as mineral deposits.

Sustainable architecture

The implications for sustainable architecture and environmental technology are significant. Unlike traditional construction materials, which contribute heavily to carbon emissions, these living materials act as carbon absorbers. In lab conditions, the material absorbed around 26 mg of CO2 per gram over a period of 400 days — substantially more than many biological alternatives and on par with certain chemically engineered materials, such as recycled concrete.

The carrier for the cyanobacteria is a specially designed hydrogel — a water-rich network of cross-linked polymers. This hydrogel allows light, nutrients, CO2, and water to reach the embedded cells, while providing a stable scaffold in which they can live and reproduce. The researchers used 3D-printing techniques to shape the material into structures that maximise surface area, light penetration, and nutrient diffusion. This careful design ensures that the cyanobacteria remain active and productive for long periods, over a year in some tests.

Dalia Dranseike, a co-author of the study, notes that geometry and passive nutrient distribution are key: "We created structures that enable light penetration and passively distribute nutrient fluid throughout the body by capillary forces." As a result, the photosynthetic activity is sustained without the need for complex external systems.

Beyond the lab, the material has already been used in full-scale experimental installations. At the Venice Architecture Biennale, ETH doctoral student Andrea Shin Ling scaled the production of the living material from lab to architectural dimensions. "The installation is an experiment," says Ling, adding, "We've adapted the Canada Pavilion to provide enough light, humidity, and warmth for the cyanobacteria to thrive, and now we watch how they behave." The installation is monitored and maintained daily, showcasing the balance between design, biology, and environmental stewardship. Another experimental project, Dafne's Skin, was unveiled at the 24th Triennale di Milano. Created in collaboration with MAEID Studio and Dalia Dranseike, the installation explores how living materials change the aesthetics and functionality of building facades. In this piece, wooden shingles are overgrown by microorganisms, creating a deep green patina that symbolises both decay and renewal. As these microbial colonies grow, they bind atmospheric CO2, making the structure both beautiful and environmentally beneficial.

These applications suggest that cyanobacteria-based materials could one day supplement, or even replace, traditional building materials, offering carbon-negative alternatives to cement, plaster, and insulation.