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Review

About the Cyanobacteria and Stromatolites

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Abstract: Stromatolites are layered biochemical accretionary structures formed in shallow water by the trapping, binding and cementation of sedimentary grains in biofilms (specifically microbial mats), especially cyanobacteria. Stromatolites occur widely in the fossil record of the Precambrian but are rare today. Life on Earth was born at least 3.7 billion years ago, but since then the number of living things has grown exponentially. Surprisingly, some of the earliest life forms on our planet still exist and not just in fossilized form - stromatolites - a life form that has witnessed the entire evolution of our planet can still be discovered in certain areas of the globe. Stromatolites are living fossils, the oldest life forms on Earth. Their existence spans an incredible period - stromatolites have existed for 75% of the period since the formation of the Solar System. They are defined simply as rock structures built by colonies of microscopic organisms that do photosynthesis. These organisms are known as cyanobacteria. As the soil settled in shallow water, bacteria began to grow on it, joining the sedimentary particles and building additional layers until mounds formed. These constructions of microorganisms in the earth are perhaps the essential element in the emergence of more complex life on earth - through their respiration, they produced and developed oxygen on Earth until it came to form 20% of the Earth's atmosphere. Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex.

Keywords: Stromatolites, Bacteria, Cyanobacteria, Water, Microorganisms, Respiration, Energy, Life, Solar System, Biotechnology Bioengineering, Biomimetics

Introduction

Cyanobacteria are Gram-negative bacteria. Five types of cyanobacteria have been identified as producing toxins, including two strains of Anabaena flosaquae, Aphanizomenon flosaquae, Microcystis aeruginosa and Nodularia species. Cyanobacterial toxins are of three main types: Hepatotoxins, neurotoxins and Lipopolysaccharide ndotoxins (LPS). Acute drinking water disease contaminated with cyanobacteria is a more common gastroenteritis. Cyanobacteria do not depend on a fixed carbon source and, as such, are widely distributed in aquatic environments. These include freshwater and marine environments and in some soils. Direct microscopic examination of the flowering material will allow the identification of the cyanobacterial species present. Preventing the formation of blooms in spring water is the best way to ensure that your drinking water is free of cyanobacteria and membrane filtration technology has the potential to remove virtually any cyanobacteria or toxins from their drinking water. Cyanobacteria have the ability to grow as biofilms.

They are representative of aspects of its basic microbiology, natural history, metabolism and physiology, clinical features, pathogenicity and virulence, environmental survival, aquatic survival and epidemiology, evidence for biofilm growth, detection methods and risk assessment.

Cyanobacteria (also called blue-green algae) are an ancient group of photosynthetic microbes that occur in most inland waters and can have major effects on water quality and the functioning of aquatic ecosystems. These include about 2000 species of 150 genera, with a wide range of shapes and sizes.

Cyanobacteria have a variety of cell types, cellular structures and physiological strategies that contribute to their ecological success in plankton, metaphyton, or periphyton. They are of particular interest to water

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quality managers, as many produce the taste and odor compounds, several types of toxins and harmful flowers. From an ecological point of view, the three most important groups of cyanobacteria found in inland waters are the mat formators, which form crusts rich in polysaccharides, films and thicker layers over rocks, sediments and plants; Flower formers, which occur in eutrophic lakes and disrupt the food web, as well as produce toxins and surface residues and picocyanobacteria, tiny species that are often the main type of photosynthetic cells in oligotrophic (nutrient-poor) lakes and their food webs. Additional ecological groups include metaphyton which is vaguely associated with emerging macrophytes; colonial aggregates of cyanobacteria that are common in mesotrophic waters; and various symbiotic associations. Several indoor cyanobacteria species are harvested or grown as food sources, feed, fertilizers and health products (Percival *et al*., 2004; Vincent, 2009).

As with other cyanobacterial poisoning suspects, the identification of algae in water samples or in samples collected from the animal's skin or gastric contents is useful in assessing the diagnosis. Samples containing algae must be refrigerated, not frozen, preserved in 10% formalin (v/v 50:50) and presented to a physician for identification. Because cyanotoxin toxicity is strain-specific, positive identification does not predict the level of hazard.

Antoxin, homoanatoxin and anatoxin intoxication (s) do not result in specific changes in the chemical parameters of the serum. In fact, due to rapid progression and death with these neurotoxins, blood tests are rarely performed. If available, possible non-specific changes are hyperglycemia, acidosis, mild hypophosphatemia and mild respiratory alkalosis. In cases of toxoid poisoning (s), low blood cholinesterase activity along with adequate cerebral cholinesterase activity supports the diagnosis.

Toxicological tests for algae toxins in biological samples are recommended for diagnosis. Anatoxin can be analyzed by liquid chromatography and tandem mass spectrometry in algal material, water, gastrointestinal contents, urine and bile. Selected veterinary toxicology laboratories may perform analyzes of biological samples for toxoid(s) (Puschner and Moore, 2013).

Cyanobacteria are a coherent phylogenetic group of evolutionary phototrophic bacteria that are evolutionarily diverse, morphologically diverse and ecologically important. They are defined by their ability to perform photosynthesis with oxygen (oxidation of water, which develops oxygen, plant-like photosynthesis). With a few exceptions, they synthesize chlorophyll as a major photosynthetic pigment and phycobiliproteins as light-capturing pigments. All are able to grow using CO_2 as the only source of carbon, which they fix using primarily the reductive pathway of phosphate pentose. Their chemoorganotrophic potential is limited to the mobilization of reserve polymers (mainly glycogen) during dark periods, although it is known that some strains grow chemoorganotrophic in the dark to the detriment of external sugars. As a group, they show some of the most sophisticated morphological differences between bacteria and many species are truly multicellular organisms. Cyanobacteria have left fossils 2000-3500 million years old and are thought to be ultimately responsible for oxygenating the Earth's atmosphere. During their evolution, through an early symbiotic partnership, they gave birth to algae and higher plant plastids. Today, cyanobacteria make a significant contribution to the global primary production of the oceans and become locally dominant primary producers in many extreme environments, such as hot and cold deserts, hot springs and hypersaline environments. Their total biomass is estimated to exceed 1015 g of wet biomass, in particular, the unicellular marine genera Prochlorococcus and Synechococcus, the filamentous genera Trichodesmium (a circumtropical marine form) and microcoleus vaginitis terestops and sterile terrestrial croocides. Flowering cyanobacteria are important features for the ecology and management of many freshwater and eutrophic brackish bodies. The aerobic nitrogen-fixing capacity of some cyanobacteria makes them important players in the biogeochemical cycle of nitrogen in tropical oceans, terrestrial environments and some agricultural lands. Due to their sometimes-large size, metabolism and their ecological role, cyanobacteria have long been considered algae; even today it is not uncommon to refer to them as blue-green algae, especially in ecological studies.

With the possible exception of their optional capacity for anoxygenic photosynthesis, cyanobacteria in nature are all oxygenated photoautotrophs. It can be logically argued that, after the evolutionary evolution of oxygenated photosynthesis, the evolutionary history of cyanobacteria has been one aimed at optimizing and expanding this metabolic capacity to a growing number of habitats. This article provides an overview of the characteristics of their central metabolism and a limited impression of their diversity.

Generalizations could, in the face of such diversity, easily become simplifications.

Whenever they are made, the reader is reminded to keep this in mind (Abu-Lebdeh *et al*., 2019; Garcia-Pichel *et al*., 2004; Biddanda *et al*., 2015; Duda *et al*., 2016; Grotzinger and Rothman, 1996; Lepot *et al*., 2008; Monty, 1981; Allwood *et al*., 2009; McMenamin, 1982; Aversa *et al*., 2021, 2019, 2018 a-b, 2017a-b, 2016 a-n; Aljohani and Desai, 2018; Alexander and Wang, 2018; Apicella *et al*., 2018a-c; Machín *et al*., 2020, 2021a-b, 2022; Marquetti and Desai, 2018; Armah, 2018; Wilk *et al*., 2017; Babaev *et al*., 2010; Petrescu *et al*., 2020a-c, 2019, 2017, 2015; Petrescu and Petrescu, 2021, 2019a-b; Abdul-Razzak *et al*., 2012; Ajith *et al*., 2009;

Atasayar *et al*., 2009; Ahmed *et al*., 2011; Covic *et al*., 2007; Willis, 1953; Willis *et al*., 1954; Willis, 1957; Ha, 2010; El-Gendy, 2010; Enstrom, 2014; Hansen *et al*., 2014; Rath and Pauling, 1990, 2000; Ravnskov, 2009; Kunutsor *et al*., 2016; Hickey *et al*., 2007; Choudhury and Greene, 2018; Choudhury, 2018; Zeng *et al*., 2021).

Materials and Methods

Stromatolites are layered biochemical accretionary structures formed in shallow water by the trapping, binding and cementation of sedimentary grains in biofilms (specifically microbial mats), especially cyanobacteria. Stromatolites occur widely in the fossil record of the Precambrian but are rare today. Life on Earth was born at least 3.7 billion years ago, but since then the number of living things has grown exponentially. Surprisingly, some of the earliest life forms on our planet still exist and not just in fossilized form - stromatolites - a life form that has witnessed the entire evolution of our planet can still be discovered in certain areas of the globe.

Stromatolites are living fossils, the oldest life forms on Earth. Their existence spans an incredible period - stromatolites have existed for 75% of the period since the formation of the Solar System. They are defined simply as rock structures built by colonies of microscopic organisms that do photosynthesis. These organisms are known as cyanobacteria.

As the soil settled in shallow water, bacteria began to grow on it, joining the sedimentary particles and building additional layers until mounds formed.

These constructions of microorganisms in the earth are perhaps the essential element in the emergence of more complex life on earth - through their respiration, they produced and developed oxygen on Earth until it came to form 20% of the Earth's atmosphere.

Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex.

Today, live stromatolites can only be found in a few lagoons and saltwater bays. Western Australia is one of the places known for the significant number and variety of stromatolites, whether live or fossilized (Biddanda *et al*., 2015; Duda *et al*., 2016; Grotzinger and Rothman, 1996; Lepot *et al*., 2008; Monty, 1981; Allwood *et al*., 2009; McMenamin, 1982).

The oldest stromatolite fossils date back 3.5 billion years and are located 1,000 kilometers north of the Pilbara region of Western Australia. Stromatolites are basically a window into time - they are life forms that tell us what our planet looked like near its beginnings, before the formation of continents, before there were plants, other animals, or humans and even before there were dinosaurs.

Stromatolites are layered sedimentary formations that are created by photosynthetic cyanobacteria. These microorganisms produce adhesive compounds that cement sand and other rocky materials to form mineral “microbial mats”. In turn, these mats build up layer by layer, growing gradually over time. A stromatolite may grow to a meter or more. Although they are rare today, fossilized stromatolites provide records of ancient life on Earth.

If man were to follow and repeat the physicochemical processes produced by these cyanobacteria, he could produce cement directly from the sand, a high-quality cement that could be used in various construction areas with great success. Nano natural chemical processes produced in stromatolite cyanobacteria are a lesson for humans but to this day one not yet learned, not only for the transformation of sand into quality cement but also for the elimination in the air of some substances essential to life.

Cyanobacteria, also known as Cyanophyta, are a phylum of Gram-negative bacteria that obtain energy via photosynthesis. The name cyanobacteria come from their color (Greek: Κυανός, romanized: Kyanós, lit. 'blue'), giving them their other name, "blue-green algae", though modern botanists restrict the term algae to eukaryotes and do not apply it to cyanobacteria, which are prokaryotes. They appear to have originated in freshwater or a terrestrial environment.

Unlike heterotrophic prokaryotes, cyanobacteria have internal membranes. These are flattened sacs called thylakoids where photosynthesis is performed. Phototrophic eukaryotes such as green plants perform photosynthesis in plastids that are thought to have their ancestry in cyanobacteria, acquired long ago via a process called endosymbiosis. These endosymbiotic cyanobacteria in eukaryotes then evolved and differentiated into specialized organelles such as chloroplasts, etioplasts and leucoplasts.

By producing and releasing oxygen as a byproduct of photosynthesis, cyanobacteria are thought to have converted the early oxygen-poor, reducing atmosphere into an oxidizing one, causing the Great Oxygenation Event and the "rusting of the Earth", which dramatically changed the composition of the Earth's life forms and led to the near-extinction of anaerobic organisms.

Cyanobacteria produce a range of toxins known as cyanotoxins that can pose a danger to humans and animals.

Cyanobacteria Synechocystis and Cyanothece are important model organisms with potential applications in biotechnology for bioethanol production, food colorings, as a source of human and animal food, dietary supplements and raw materials.

Cyanobacteria can teach us how to produce oxygen through photosynthesis, today they have a significant role in the planet, even if they have shrunk a lot in the area. Their restriction on the planet after they formed planetary oxygen may have helped the emergence of animal and human life because they also produce toxins dangerous to humans and today the oxygen needed by the planet is donated only or mainly by plants, also through photosynthesis, but without producing and ethyl alcohol and other toxins as cyanobacteria do. If many cyanobacteria are no longer needed today to start oxygenating the planet as happened in the distant past, their main role of primary oxygenation of the planet being then and now taken over by plants of great diversity, they are still very interesting in that they can teach us to produce oxygen ethyl alcohol through photosynthesis, but also sand cement, using sand silicon to transform it into quality cement. The natural processes that take place in cyanobacteria should have been studied more closely for a long time.

On the other hand, the authors of this study proposed to produce oxygen on other planets that humanity wants to prepare for terrestrial life by nuclear methods, generally nuclear fission reactions, to obtain massive primary oxygen on nearby planets today uninhabited and uninhabitable. Then the planet will be planted with various types of trees to continue the action of normal and continuous oxygenation, but now we propose through this new work the use of stromatolites taken to a new planet, initially on Mars, as primary sources of natural oxygen, so as happened a long time ago on earth. Current methods with small electrical devices capable of synthesizing oxygen from carbon dioxide on the planet Mars could also be used, but massive oxygen could be produced faster by implanting stromatolites on the red planet and by some nuclear reactions, which do not requires raw materials such as carbon dioxide, present on Mars but not very frequent and massive and with the help of stromatolites and specific nuclear fission reactions, the planet Mars could be oxygenated very quickly, at a fast pace.

Sending people to the red planet soon for colonization will not be successful unless rapid oxygenation of Mars is considered so that it becomes habitable and then water production on the planet because water exists there. many millions of years ago and obviously the production of an ozone shield similar to the one on our blue planet. The problem of the electromagnetic shield with lines of force would remain to be discussed later and with natural, atmospheric protection against space radiation, just like on Earth, the planet Mars would become naturally habitable. Otherwise, we risk that those sent there for colonization will not die en masse with what is suspected now, but that they will all disappear quickly and the action will be compromised from the start, humanity losing from the beginning the current historical chance to start colonizing the universe, with a first failed attempt. on Mars.

We are in a historical period of humanity united and lost here on Earth, without its possibility of extension so far and we do not allow ourselves to start such an extremely important action without it being fully thought out and well developed. The oxygen-producing apparatus that has already been tested on the waters of the planet Mars is good for making directly there the oxygen needed daily by humans that will soon be deployed on the red planet for the obvious purpose of colonizing it, not just measuring its parameters. the robots sent there have been doing it for a long time) and not in order to see how long people can survive there in the current conditions. Life in burrows dug deep with permanent protective suits will not be easy but even so, man's resistance to radiation will not be final in the current conditions there and then the first settlers sent will be just people sacrificed almost in vain, on the so-called altar of science. We are forced to start just before sending people there to massively produce oxygen on Mars through various nuclear reactions and even by implanting stromatolites brought from Earth and adapted there on Mars somehow, perhaps by producing fresh water for them to it can adapt and start working and all this before we rush to send people to Mars to live there permanently.

What are stromatolites, the creatures that have witnessed the last 3.7 billion years on Earth (Fig. 1-4)?

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Stromatolites are stratified biochemical accumulation structures formed in shallow water by the trapping, binding and cementing sedimentary grains into biofilms (especially microbial mats), especially cyanobacteria. They have a variety of shapes and structures or morphologies, including conical, stratiform, branched and columnar types. Stromatolites are widely found in pre-Cambrian fossil records but are rare today. Very few ancient stromatolites contain fossilized microbes.

Fig. 1: The stromatolites, the creatures that have witnessed the last 3.7 billion years on Earth

Fig. 2: Visible structure of one cm of stromatolites. Fossilized stromatolite in Strelley Pool chert, about 3.4 billion years old, from Pilbara Craton, Western Australia.

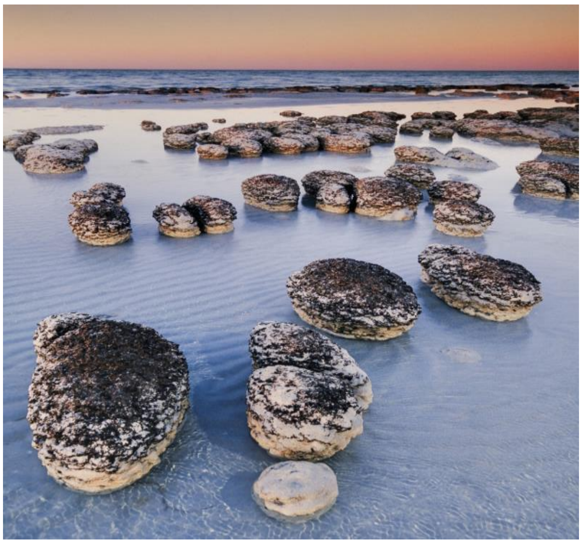

Fig. 3: The stromatolites, the creatures that have witnessed the last 3.7 billion years on Earth

Fig. 4: Modern stromatolites in Shark Bay, Western Australia

While the characteristics of some stromatolites suggest a biological activity, others possess characteristics that are more consistent with abiotic (non-biological) precipitation. Finding reliable ways to distinguish between biologically formed and abiotic stromatolites is an active area of research in geology.

Most stromatolites have a spongiostromate texture, no recognized microstructures, or cellular remains. A minority is porostromatic, with a recognized microstructure; they are largely unknown in the Precambrian but persist in the Paleozoic and Mesozoic. Since the Eocene, porostromatic stromatolites are known only from freshwater (Fig. 5 and 6).

Time photography of modern microbial formation of mats in the laboratory provides some revealing clues to the behavior of cyanobacteria in stromatolites. Biddanda *et al*. (2015) found that cyanobacteria exposed to localized light beams moved to light or expressed phototaxy and increased their photosynthetic efficiency, which is necessary for survival. In a new experiment, the scientists designed a school logo on a Petri dish containing the organisms, which gathered under the illuminated region, forming the logo in bacteria. The authors speculate that such motility allows cyanobacteria to look for light sources that support the colony. In both light and dark conditions, cyanobacteria form groups that then spread outward, with individual members remaining connected to the colony by long lines. This can be a protective mechanism that provides evolutionary benefits to the colony in harsh environments where mechanical forces act to break microbial mats. Thus, these sometimes elaborate structures, built by microscopic organisms that function somewhat in unison, are a means of providing shelter and protection against a harsh environment.

Fig. 5: Fossilized stromatolites, about 425 million years old, in the Soeginina Beds (Paadal Formation, Ludlow, Silurian) near Kübassaare, Estonia.

Fig. 6: Paleoproterozoic oncoids from the Franceville Basin, Gabon, Central Africa. Oncoids are unfixed stromatolites ranging in size from a few millimeters to a few centimeters.

Lichen stromatolites are a proposed mechanism for the formation of the types of stratified rock structures that form above water, where the rock meets the air, through the repeated colonization of the rock by endolithic lichens (Biddanda *et al*., 2015; Duda *et al*., 2016; Grotzinger and Rothman, 1996; Lepot *et al*., 2008; Monty, 1981; Allwood *et al*., 2009; McMenamin, 1982).

Some archaic rock formations have a macroscopic resemblance to modern microbial structures, which leads to the deduction that these structures are evidence of ancient life, namely stromatolites. However, others believe that these patterns are due to the deposition of natural materials or another abiogenic mechanism. Scientists have argued a biological origin of stromatolites due to the presence of groups of organic globules in the thin layers of stromatolites, aragonite nanocrystals (both characteristics of current stromatolites) and the persistence of a biological signal deduced by changing environmental circumstances.

Stromatolites are a major constituent of fossil records of the first life forms on earth. They reached their peak about 1.25 billion years ago and have since fallen in abundance and diversity so that at the beginning of the Cambrian they fell to 20% of their peak (Fig. 7-13).

The most common explanation is that stromatolite builders were victims of walking creatures (the Cambrian substrate revolution); this theory implies that sufficiently complex organisms were common over 1 billion years ago. Another hypothesis is that protozoa such as foraminifera were responsible for the decline.

Proterozoic stromatolite microfossils (preserved by permineralization in silica) include cyanobacteria and possibly some forms of eukaryotic chlorophytes (i.e., green algae). A very common type of stromatolite in geological records is Collenia.

The link between pasture and stromatolite abundance is well documented in younger Ordovician evolutionary radiation; the abundance of stromatolites increased even after the disappearance of the end of the Ordovician order and the end of the Permian, which decimated marine animals, returning to previous levels as marine animals recovered. Fluctuations in the metazoan population and diversity could not have been the only factor in reducing stromatolite abundance. Factors such as environmental chemistry could have been responsible for the changes.

While prokaryotic cyanobacteria reproduce asexually by cell division, they have been essential in preparing the environment for the evolutionary development of more complex eukaryotic organisms. Cyanobacteria (as well as extremophilic Gammaproteobacteria) are thought to be largely responsible for increasing the amount of oxygen in the Earth's primordial atmosphere through their continuous photosynthesis (see The High Oxygenation Event). Cyanobacteria use water, carbon dioxide and sunlight to create their food. Often a layer of mucus forms over the cyanobacterial cell mats. In modern microbial mats, debris from the surrounding habitat can become trapped in mucus, which can be cemented together by calcium carbonate to increase thin limestone laminations. These laminations can accumulate over time, resulting in the banded pattern common to stromatolites. The "domestic" morphology of biological stromatolites is the result of the vertical growth necessary for the continuous infiltration of the sun into organisms for photosynthesis. Stratified spherical growth structures called oncolites are similar to stromatolites and are also known from fossil records. Thrombolites are poorly laminated or non-laminated coagulated structures made from cyanobacteria, common in fossil records and modern sediments. There is evidence that thrombolites form in preference to stromatolites when foraminifera are part of the biological community (Bernhard *et al*., 2013; Sheehan and Harris, 2004; Riding, 2006; Peters *et al*., 2017; Feldmann and McKenzie, 1998; Chen *et al*., 2010; Gischler *et al*., 2008; Braithwaite and Zedef, 1994; Ferris *et al*., 1997; Brady *et al*., 2010; Cox *et al*., 1989).

The Zebra River Canyon area of the Kubis platform in the deeply dissected Zaris Mountains in southwestern Namibia provides an extremely well exposed example of thrombolite-stromatolite-metazoan reefs that developed in the Proterozoic period, with stromatolites being better developed in deep locations. higher current velocity and higher sediment flow.

Modern stromatolites are mostly found in hypersaline lakes and marine lagoons where extreme conditions due to high saline levels prevent animals from grazing. One such location where excellent modern specimens can be seen is the Hamelin Pool Marine Nature Reserve, Shark Bay in Western Australia. Another location is the Pampa del Tamarugal National Reserve in Chile. A third is Lagoa Salgada ("Salt Lake"), in the state of Rio Grande do Norte, Brazil, where modern stromatolites can be seen both as bioherms (domal type) and as beds. Inland stromatolites can also be found in the salt waters of the Cuatro Ciénegas Basin, a unique ecosystem in the Mexican desert and Lake Alchichica, a Maar Lake in the eastern basin of Mexico. The only open marine environment in which modern stromatolites are known to thrive is the Exuma Cays of the Bahamas (Fig. 11).

In 2010, the fifth type of chlorophyll, namely chlorophyll f, was discovered by Dr. Min Chen from stromatolites in the Gulf of Sharks (Fig. 14), Bacalar Lagoon in the southern Yucatan Peninsula of Mexico, in the state of Quintana Roo, has a formation extended by living giant microbes (i.e., stromatolites or thrombolites). The microbial bed is over 10 km (6.2 mi) long, with a vertical growth of a few meters in some areas. These can be the largest living microbial dimensions of freshwater or any organism on Earth (Bernhard *et al*., 2013; Sheehan and Harris, 2004; Riding, 2006; Peters *et al*., 2017; Feldmann and McKenzie, 1998; Chen *et al*., 2010; Gischler *et al*., 2008; Braithwaite and Zedef, 1994; Ferris *et al*., 1997; Brady *et al*., 2010; Cox *et al*., 1989).

Lake Crater Alchichica in Puebla Mexico has two distinct morphological generations of stromatolites: Aragonite-rich column-like structures that form near the shore, dating from 1100 ybp and thrombolytic structures that dominate the lake from top to bottom, consisting primarily of hydromagnesite. Huntite, calcite and dates from 2800 ybp.

A little further south, a 1.5 km stretch of stromatolite that forms reefs (mainly of the genus Scytonema) appears in the Chetumal Gulf of Belize, just south of the mouth of the Rio Hondo and the Mexican border.

Freshwater stromatolites are found in Lake Salda in southern Turkey. The waters are rich in magnesium and the stromatolitic structures are made of hydromagnesite.

Two cases of freshwater stromatolites are also found in Canada, at Lake Pavilion and Lake Kelly in British Columbia. Lake Pavilion has the largest freshwater stromatolites known and NASA is currently conducting research in xenobiology there. NASA, the Canadian Space Agency and many universities around the world are collaborating on a project to study microbial life in lakes. Called the "Pavilion Lake Research Project" (PLRP), its purpose is to study which conditions on the bottom of lakes are most likely to harbor life and to develop a better hypothesis about how environmental factors affect life. microbial. The ultimate goal of the project is to better understand the conditions that could harbor life on other planets. There is an online citizen science project called "MAPPER", in which anyone can help sort thousands of photos with the bottom of the lake and label microbial algae and other features of the lake bed (Bernhard *et al*., 2013; Sheehan and Harris, 2004; Riding, 2006; Peters *et al*., 2017; Feldmann and McKenzie, 1998; Chen *et al*., 2010; Gischler *et al*., 2008; Braithwaite and Zedef, 1994; Ferris *et al*., 1997; Brady *et al*., 2010; Cox *et al*., 1989).

Stromatolites are layered sedimentary formations that are created by photosynthetic cyanobacteria. These microorganisms produce adhesive compounds that cement sand and other rocky materials to form mineral “microbial mats”. In turn, these mats build up layer by layer, growing gradually over time. A stromatolite may grow to a meter or more. Although they are rare today, fossilized stromatolites provide records of ancient life on Earth.

The microbialites were discovered in an open pond at an abandoned asbestos mine near Clinton Creek, Yukon, Canada. These microbialites are extremely young and probably began to form shortly after the mine closed in 1978. The combination of a low sedimentation rate, a high rate of calcification and a low rate of microbial growth appears to result in the formation of these microbialites. Microbialites from a historic mine site demonstrate that an anthropogenic built environment can promote the formation of microbial carbonate. This has implications for the creation of artificial environments for the construction of modern microbialities, including stromatolites.

A very rare type of stromatolite that does not live in the lake lives in Nettle Cave in Jenolan Caves, NSW and Australia. Cyanobacteria live on the surface of limestone and are supported by calcium-rich dripping water, which allows them to grow to the two open ends of the cave, which provide light.

Fig. 7: Fossilized stromatolites in the Hoyt Limestone (Cambrian) exposed at Lester Park, near Saratoga Springs, New York

Fig. 8: Precambrian fossilized stromatolites in the Siyeh Formation, Glacier National Park

Fig. 9: Fossilized stromatolites (Pika Formation, Middle Cambrian) near Helen Lake, Banff National Park, Canada

Fig. 10: Stromatolites at Lake Thetis, Western Australia

Fig. 11: Stromatolites at highborne cay, in the exumas, the bahamas

Fig. 12: Microbialite towers at pavilion lake, british columbia

Fig. 13: 'Crayback' stromatolite-Nettle Cave, Jenolan Caves, NSW, Australia.

Stromatolites composed of calcite have been found both in the Blue Lake in the latent volcano, Mount Gambier and in at least eight cenote lakes, including the Little Blue Lake in the lower southeast of South Australia (Fig. 13) (Bernhard *et al*., 2013; Sheehan and Harris, 2004; Riding, 2006; Peters *et al*., 2017; Feldmann and McKenzie, 1998; Chen *et al*., 2010; Gischler *et al*., 2008; Braithwaite and Zedef, 1994; Ferris *et al*., 1997; Brady *et al*., 2010; Cox *et al*., 1989).

Results

Bacalar is the municipal residence and the largest city in the municipality of Bacalar (until 2011 part of the municipality of Othón P. Blanco) in the Mexican state of Quintana Roo, about 40 kilometers north of Chetumal, at 18°40 '37 "N, 88°23 '43 "W. At the 2010 census, the city had a population of 11,084 people. At that time, it was still a part of Othón P. Blanco and was the second-largest city (locality), after Chetumal.

The name probably derives from the Mayan languages: B'ak halal, which means "surrounded by reeds", the name of the city attested by the Spanish arrival in the 16th century.

Bacalar is also the name of the lagoon, Laguna Bacalar in the eastern part of the city.

Bacalar was a city of Mayan civilization in the pre-Columbian period. It was the first city in the region that the Spanish Conquistadores managed to take and own in 1543. In 1545 Gaspar Pacheco established here the Spanish city called Salamanca de Bacalar with the help of Juan de la Cámara. The region in the southern half of present-day Quintana Roo was ruled by Bacalar, who was accountable to the captain-general of the Yucatán in Mérida.

After the city was captured by pirates in the 17th century, the Fortress of San Felipe Bacalar was completed in 1729 and can be visited today.

In 1848 Bacalar had a population of about 5,000 people. In 1848, during the caste war in the Yucatan, the rebel Chan Santa Cruz Maya conquered the city. It was not resumed by Mexicans until 1902.

Bacalar was named "Pueblo Mágico" in 2006.

With a total length of over 10 km, the Holocene microbialites in Laguna Bacalar, Mexico, belong to the largest occurrences of freshwater microbialites. Microbialites include domes, curbs and oncolites. Domal forms can grow to diameters and heights of 3 m. Microbialites are composed of low-magnesium calcite, which is largely precipitated due to the metabolic activity of Homeothrix and Leptolyngbya cyanobacteria and associated diatoms. Photosynthesis removes carbon dioxide and triggers the precipitation of carbonate. Also, an increased concentration of carbonate in the lagoon waters, derived from the dissolution of Cenozoic limestone in a karstic system, supports carbonate precipitation. It is also observed catching and tying detrital grains, but they are not as common as precipitation. Bacalar microbialites are mostly thrombolytic, however, stromatolite sections also occur. Most Bacalar microbialites probably formed in the late Holocene (about 1 kyr BP to date). According to the ^{14}C dating, the microbialites accumulated 9 to 8 cal kyr BP; however, these ages may be too old due to the strong effect of hard water. This effect is seen in the ^{14}C era of live bivalve shells and gastropod mollusks in the Bacalar Lagoon, which is 8 to 7 horsepower KP BP. The associated modern microbial fauna is characterized by low diversity and high abundance of bivalve mollusks Dreissena sp. and the gastropod Pomacea sp. Abundant grazing gastropods probably prevent the modern formation of microbialites. A comparison of Bacalar microbialites with other modern microbialite occurrences around the world shows only a few models: Size, shape, microbial taxa, mineralogy, accumulation type and settings, including water properties of microbialite occurrences, show high variability. A trend can be observed in grazing metazoans, which are rare to absent in marine and brackish examples, but apparently present in all freshwater occurrences of microbialites. Also, freshwater examples are usually characterized by high concentrations of carbonate and/or calcium ions in the surrounding waters. Microbialites are the oldest life forms on our planet that played an important role in the early history of life on Earth, their growth depending on the physicochemical conditions of the water in which they exist, which is why a correlation of conditions is possible in the environment with the sedimentary record produced by microbialites in a very long time.

Bacalar Lagoon is one of the largest occurrences of freshwater microbialite (stromatolites) in the world, with variable morphologies in different parts of the lagoon due to the dynamics and composition of the lagoon. Bacalar

Lagoon is facing anthropogenic activities derived from tourism and agriculture, constantly taking place changes in the composition of the water column derived from these activities and natural changes in the system (Fig. 14-16).

Stromatolites are organic sedimentary carbonate deposits formed by the interaction between benthic microbial communities and detrital sediments; their growth is influenced by local climate change and other environmental factors, such as system dynamics, changes in depth, the direction of light, substrate, etc. (Castro *et al*., 2014). The structures preserve the physicochemical conditions of the water in which they deposit, for this reason, the stromatolites consider a great proxy to make a hydrological reconstruction (Woo *et al*., 2004; Riding, 1999, 2000a; Kendall and Mcdonell, 1998).

Paleohydrological reconstructions allow us to know the dynamic variation and composition of different water systems over time. Due to the difficulty of having a direct record of previous hydrological conditions, it is necessary to use indirect proxies, in the sedimentary record there are both biological (fossil) and non-biological (isotopic signals) proxies (Wefer *et al*., 1999; Lowe and Walker, 1997).

Stable isotopic analyzes of stromatolite sedimentary records reveal information about water temperature and geochemical composition (Andrews, 2006), such as carbonate content and trace elements (Stumm, 1992).

Stromatolites grow under specific conditions of light, pH, depth, temperature, nutrient content, waves and currents, etc., so that it is possible to link environmental conditions with lithological parameters in a paleohydrological record (Beraldi-Campesi, 2014).

The carbonate structures of the Bacalar Lagoon are unique because they are one of the largest occurrences of freshwater microbialites in the world (Centeno *et al*., 2012; Gischler *et al*., 2008; 2011) and because they retain previous information about climatic and environmental conditions and life during the sedimentation process.

As well as other karst systems such as Laguna CuatroCienegas, Gulf of Sharks, Lake Pavilion, Lake Van, etc. (Gischler *et al*., 2008), Bacalar lagoon has carbonaceous structures (stromatolites), with an extension of 10 km along the western side. The presence of these structures is related to the concentration of carbonates and the dynamics of the lagoons. The western part of the lagoon is directly connected to sinkholes and aquifers, this interaction results in a high concentration of carbonate compared to the entire lagoon. Also, the interaction and dynamics between the lagoon and the aquifer are some of the physical processes that can lead to the growth of stromatolites. In the narrowest part of the lagoon, called "Los Rapidos", the flow is highest, inducing a mixture of water, nutrient and carbonate concentrations increase and stromatolites also tend to increase (Castro *et al*., 2014; Bąbel *et al*., 2011; Gischler *et al*., 2011).

Bacalar Lagoon ecosystems need protection, governance and policies in climate change adaptation/resilience programs. Defining policies based on scientific research, using ancient structures such as stromatolites as a proxy, explaining the past and helping us face current challenges and visualize future transformations, is a fundamental order to make decisions and make decisions. measures to manage Mexican coastal lagoons in the Caribbean.

Through this investigation, the changes in the composition and dynamics of the lagoon could be seen and the results can allow the realization of some projections (climatic, recharging and anthropogenic). A paleohydrological reconstruction can be done with the analysis sedimentary record of these structures, to know how the Bacalar lagoon has changed over time, in terms of chemical composition, changes in temperature and precipitation (climate change) and due to the contribution of groundwater and other factors.

The lagoon is an oligotrophic system, with a maximum depth of 15 m and the presence of seasonality is low, the temperature in winter is ~28°C, while in summer it is ~29°C. A constant and pleasant temperature, warmer than cold, makes the area a small climatic paradise.

The lagoon is a freshwater system (conductivity of 0-2.3 mS/cm), a pH between 7.6 and 8.3 (Beltrán, 2010).

The climate of the study site is subtropically humid modulated by two meteorological processes, the first consisting of cold fronts, locally called "Nortes", present in winter and in the dry period from March to May. The second meteorological process is tropical storms with precipitation (900 mM/year) and hurricanes. The rainy season is between June and September (1250-1500 mM/year) (Conagua, 2015).

BacalarLagoonis located in the hydrological region no. 33 (RH 33), on a karst platform, with five sinkholes in the western part of the lagoon with a depth of ~ 90 m, three (Cocalitos, Esmeralda and Negro) are in the lagoon with the connecting surface, Cenote Azul has only an underground connection.

The Xul-Ha pit is connected to the lagoon through a canal (Gischler *et al*., 2011; Perez-Ceballos *et al*., 2012; Beltrán, 2010; Perry *et al*., 2009).

The eastern part of the lagoon is connected to the Chetumal Gulf of Rio Hondo and the lagoons of Chile Verde and Guerrero. The variation of the groundwater layer of the lagoon was estimated at ~30 cm (Gischler *et al*., 2011).

Due to the lagoon landscape nature, the main economic income of the population comes from tourism. However, the growth of tourism and associated aquatic activities in the lagoon (some of which are not properly regulated) has a negative impact on the ecosystem, especially in stromatolites.

Fig. 14: The stromatolites in the gulf of sharks, bacalar lagoon in the southern yucatan peninsula of mexico, in the state of quintana roo

Fig. 15: Stromatolites in the gulf of sharks, bacalar lagoon in the southern yucatan peninsula of mexico, in the state of quintana roo

Fig. 16: Stromatolites in the gulf of sharks, bacalar lagoon in the southern yucatan peninsula of mexico, in the state of quintana roo

Bacalar Lagoon does not have regulation as a protected area and the development plan has been evaluated. The main activities of the area are agriculture (sugar cane, rice and corn), animal husbandry (pigs and cattle) and beekeeping.

The stromatolite cores were collected in the western part of the lagoon with a pushing core 5 cm in diameter and a length of 11-40 cm. In addition, the core of the lake sediments was collected with plastic liners with a diameter of 5 cm and a length of 11-43 cm. Each core was stored in a cooler at 4°C and transported to the laboratory of the Water Science Unit (Velázquez, 2017).

The cores (lacustrine sediment and stromatolites) were divided every 5 cm for stable isotopes of ^{18}O and ^{13}C and trace element analyzes. The samples were dried at 50°C and ground with an agate mortar.

For isotope analysis, a secondary sample was selected and the organic matter was removed, adding 50% H_2O_2, for 48 h, the remaining sediment was rinsed with Milli-Q water and dried at 50°C.

To establish the chronology of the lake sequence, the nuclei were dated by 14°C Accelerator Mass Spectrometry (AMS) at the Laboratory of Marine Sciences of the University of California Santa Cruz. To identify the entry of terrigenous from the lagoon, changes in magnetic sensitivity were registered at the Institute of Geophysics of UNAM (Velázquez, 2017).

The temperature profiles along the lagoon were not variable indicating that the lagoon is very homogeneous, due to the depth is very low (15 m) and permit the water mix (Fig. 17). Only in the sinkholes temperature profiles were observed a thermocline around 23 m (Fig. 18), (Velázquez, 2017).

The values of alkalinity in the west part of the lagoon were greater (more than the average of the sea 140 mg/L) than the samples taken in the east part. These values show that there is an inflow of water enriches of carbonates. The nitrate concentrations and TDS were very homogeneous in all the sites, while the nitrites and phosphates were lower to the limits of detection of the chromatographer (<1 ppb). The values of chlorides and sulfates are greater in the east part, while the western is lower, due to the proximity to the sea (Velázquez, 2017).

Lacustrine Sediment Core Description

RAP: The total length of 11 cm, the surface was green with a little brown and the grain size was variable sands, the surface part has more big size and contains some green rocks. The last cm has very fine coffee color sediment and the presence of matter organic. CCoc: 36 cm length, the first 3 cm are grey darker than the rest of the core. The presence of red plant remains is observed in the entire core. BAC1: 27 cm length, grey color core, except the first 5 cM (brown). Throughout the core, plant remains are observed, maybe part of the mangrove.

BAC2: 43 cM length, the first 5 cm is green, the middle core is brown and the last 8 cm are grey with fine grains as silts. BAC3: 19 cM length, very fine sediments, the last 12 cm are finer than the rest of the core. In general, the core is brown, with a grey color at the lower part. The surface sediment is green maybe to the presence of cyanobacteria (Velázquez, 2017).

Stromatolites core description

Rap: The total length is 10 cm, the size grain is variable but the last 4 cm are finer. The core is between green and brown and there are present some green rocks. In the base of the core, organic matter is observed. CCoc; The total length is 20 cm, the upper part is green and the rest is brown, there are present a lot of bivalve fragments, the sediment is sandy but in the last part the sandy is thicker. In this core, it was observed the presence of mollusks that could indicate the presence of some contaminants. BAC3: The total length is 40 cm, the first 5 cm are green and the rest of the core is brown and the base is grey. The sediment is sandy, however as the depth increases the grain size too. In some parts of the core, it is observed some mollusks (Velázquez, 2017).

The stromatolites of the Bacalar lagoon show that the morphology of these structures depends on the dynamic and composition of the lagoon. The zone of Los Rapidos (Rap) and BAC 3 has the highest stromatolites due to the flow of the water is greater than the rest of the lagoon and this promoted the water mix and thus the increment of the nutrients. In addition, in the western part of the lagoon, the carbonate concentrations are greater than in the eastern part, suggesting a groundwater inflow. This lagoon could have some changes in its composition due to human activities, this because in the place it is observed that some of the stromatolites are affected by boats, trash, wastewater, etc., for that reason it is necessary to implement some security politics to prevent the damage of the stromatolites (Velázquez, 2017).

Stromatolites are stratified microbialites, while thrombolites have rather coagulated and unclassified textures. The relatively high abundance of Precambrian microbialites compared to the younger deposits was interpreted as a consequence of an increased grazing pressure from the evolving metazoan in Earth's history (Garrett, 1970). Subsequently, this view was modified due to the discovery of more and more Precambrian and Phanerozoic microbialites appearances. These events have proven to be quite diverse in terms of shape, texture and organic content (Pratt, 1982; Riding, 2000b). Not only did microbes evolve and algae came into play, environmental conditions, such as the carbonate content of ocean water, also changed throughout the Phanerozoic. Carbonate saturation is of great importance for the formation of microbialites because non-enzymatic precipitation of calcium carbonate in biofilms is only partially organically controlled (Riding and Liang, 2005). Modern microbialites, which can be used as analogs for their fossil counterparts, occur in a wide variety of environments. There are examples of hypersaline, such as the classical location of Shark Bay in Western Australia (Reid *et al*., 2003), stromatolites of the Bahamas submarine, which form in areas with extensive sediment redeposition (Dill *et al*., 1986; Reid *et al*., 2000), “kopara” in shallow Pacific atoll lagoons, microbialites in protected reef cavities (Reitner, 1993; Camoin *et al*., 1999), in willow environments (Rasmussen *et al*., 1993) and in alkaline lakes (Kempe *et al*., 1991). Microbialites also occur in freshwater lakes and lagoons, for example, in Western Australia (Moore, 1987; Moore and Burne, 1994), Western Mexico (Winsborough *et al*., 1994; Garcia-Pichel *et al*., 2004) and Canada (Laval *et al*., 2000). In some of these locations, metazoan pastures are rare; however, there are also examples in which pastors are present. The freshwater lagoon and lake waters containing microbialites are usually characterized by a high carbonate content. To understand the formation of fossil microbialites, it is crucial to study modern examples.

However, not all fossil examples have modern counterparts and so do not all modern occurrences they have equivalents in the fossil records (Golubic, 1991). Therefore, it is important to increase knowledge about the emergence of modern microbialites and fossils. This study describes the newly discovered Bacalar location, which is one of the largest occurrences of freshwater microbialites in the world. On the one hand, the advantages over the system are the oxygenation of water and air and on the other hand the sweetening of saltwater and restoring its quality especially based on calcium and other minerals permanently donated by Stromatolites to the system in which they live and fall. It is realistically assumed that these stromatolites, being the oldest life forms on our planet, were the first living systems to produce oxygen on our planet, long before plants. On the other hand, where they had symbiosis with water, they managed to permanently restore the quality of that water, refreshing it with various minerals, sweetening it and turning it into fresh and potable water.

The most complete results of water and freshwater analyzes (microbialites, Bacalar, Mexico) were performed by Gischler and his collaborators, being fully presented in the paper (Gischler *et al*., 2008) and we will briefly present them here within the table of Table 1.

Why we consider Stromatolites to be extremely important. Besides being extremely old terrestrial life formations, probably the oldest, they have the ability to donate oxygen to the environment, creating oxygenated air as we know it today. Some studies suggest a very old concentration of oxygen in the air much higher than today, about 25-30%, along with nitrogen.

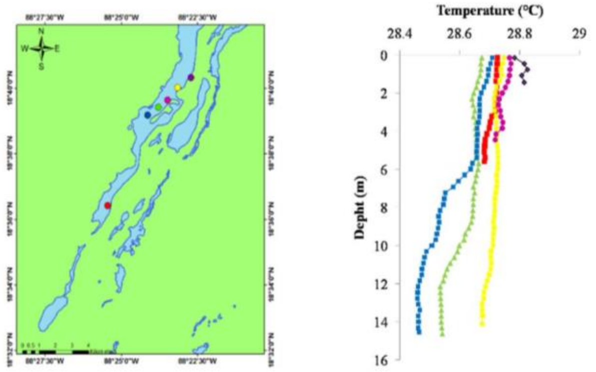

Fig. 17: Temperature profile along the lagoon (left, point sites of profiles; right, profiles with the respective color of sites in the left picture)

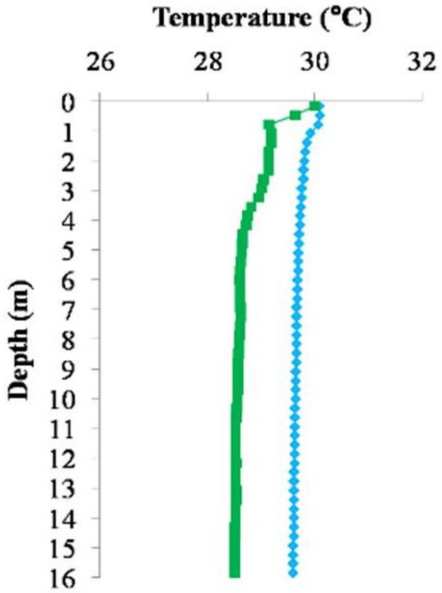

Fig. 18: Temperature profiles of cenotes (green: Cocalitos; blue: Cenote Azul)

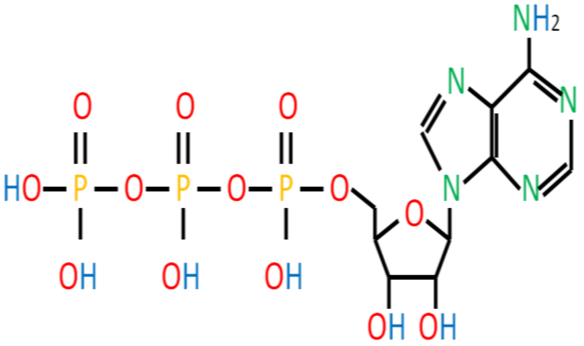

Fig. 19: How the atoms of the four elements are connected on one ATP molecule

Discussion

Due to the reduction of the living area and manifestation of stromatolite formations on our planet, as well as the fact that few of them are still active or fully active today, the oxygen in our planet's atmosphere has decreased and with it its concentration reaching only 22%, because given that our technological age has rapidly produced ultra-polluting technologies and most forests have been and still are massacred and the planet's ecosystems have had the same fate, the percentage of the atmospheric oxygen has dropped to about 20% today, in some more polluted places on the planet this percentage can even be reduced to 18%.

It is not the aim of this study to demonstrate the importance of oxygen for life and the fact that it has a lower concentration in air and water, but also in the soil, its power to give life is greatly diminished.

To this deficit is added the greenhouse effect due mainly to high oxygen consumption by burning classical fuels, fossil fuels and the elimination of carbon products extremely toxic to air, water and our entire planet, as well as the fact that a good period of while the main shield for the protection of our planet's atmosphere, the ozone shield, was also attacked, dimmed, drilled (we don't want to explain now how, being important the fact that it has long since begun its restoration, in 2018 the big holes much diminished).

Given that not enough trees are planted annually and forests are burned or cut down without control and/or restrictions and other man-made devices that generate a lot of oxygen and ozone on the planet have not yet been installed, the few ecosystems made up of stromatolites still active, they are of major importance for the further creation of clean oxygen for the atmosphere but also the water of our planet.

Imagine that we want to become galactic conquerors in the future, because this is perhaps the most important task of creative humanity, still undetected, although it is already prepared in the last 70 years by several developed countries. We will certainly need to produce massive clean oxygen on the planets we will form in the future and moving such stromatolite formations to those new places will perhaps be a future possibility and a great chance for humanity. Of course, today there is a chance that we will produce oxygen by other means, but this rare and old possibility should still be taken into account.

In any case, these rare but important formations must, at least from now on, be protected by law, so that they can develop quietly in the future as well. The modern man who ceases today, we hope to attack the planet he lives on, will also take into account the protection of these extremely vital formations for man, for plants and animals and will protect them in the future, through measures and norms that will be imposed.

Another important idea that must be pointed out in the current work is that these wonderful natural formations on earth contain and work with the vital element phosphorus, phosphorus being the energetic element of life. Of the four general energy elements but especially of life (O, H, N, P) phosphorus is the element that makes the difference between dead and living matter. With its appearance, it is considered that life appeared on earth. Although it generally occurs in small quantities, phosphorus is the basic vital element and especially the primary element of life, as we know it today on our planet (Aversa *et al*., 2016h, 2016m).

An obscure compound, known as pyrophosphite, could have been a source of energy that allowed the formation of the first life on Earth.

The author suggests that pyrophosphate was relevant in the transition from basic chemistry to complex biology when life began on earth (Aversa *et al*., 2016h).

They have even provided further evidence of the importance of this molecule and intend to further investigate its role in abiogenesis - this is how life on Earth came from inanimate matter billions of years ago. In reality, there are several contradictory theories about abiogenesis, each trying to bring something new about how life appeared on Earth.

What is essential in these studies, in the end, is energy. Living matter constantly needs energy to exist and function. The main energy source of living matter is produced in molecules known as ATP (adenosine triphosphate).

An ATP molecule can change any heat of the sun into a form of energy that can be used by plants, humans and animals. An ATP molecule contains these four vital elements: Oxygen, hydrogen, nitrogen and phosphorus (thirteen oxygen atoms, eight hydrogen atoms, five nitrogen atoms and three phosphorus atoms).

Basically, it is important how the atoms of the four elements are connected in an ATP molecule (Fig. 20). ATP is constantly used and regenerated in cells through a process known as respiration, a process driven by natural catalysts called enzymes.

ATP carries chemical energy inside cells to carry out metabolic processes.

It is one of the final cellular respiration and fermentation and is used by enzymes and structural proteins in many cellular processes, such as motility, biosynthetic reactions and cell division.

An ATP molecule contains three phosphate groups, which are produced by a wide variety of enzymes, including the synthesis of ATP to Adenosine Diphosphate (ADP), Adenosine Monophosphate (AMP) and various donors of a phosphate group.

Metabolic processes that use ATP as an associate in energy supply then turn it into precursors. In this way, ATP is continuously recycled in the body. The human body contains, for example, an amount of about 250 g of ATP (the equivalent of a single AA battery). ATP is used as a substrate in signal transduction pathways by kinases that phosphorylate proteins and lipids. It is also used by adenylate cyclase which uses ATP to deliver cyclic AMP to the second travel molecule. The magnitude relationship between ATP and AMP is used as how a cell can feel the proportion of energy that exists and manages the metabolic pathways that produce and consume ATP.

Except for its role in signal and energy metabolism, ATP is further incorporated into nucleic acids by polymerases in the transcription method. Moreover, ATP is that the neurochemical is considered to signal the sense of taste.

One important reaction (biochemical reaction) is the hydrolysis of ATP into AMP in cells: ATP → AMP + PPi.

By this biochemical reaction (ATP hydrolysis) one ATP molecule becomes one AMP molecule and results in addition one pyrophosphate (PPi), which is an anion P2O74− noted with PPi. The pyrophosphate (diphosphate or dipolyphosphate) anion having structure “P2O74−” is an acid anhydride of phosphate (Fig. 21).

The pyrophosphate is unstable in aqueous solution and hydrolyzes into inorganic phosphate (Hydrogen phosphate, Fig. 22) HPO_4^{2-} (notted with Pi) by reaction: $PP_i + H_2O \rightarrow 2\ P_i$

One phosphate ion (Fig. 23) is a polyatomic ion having the formula PO_4^{3-} and a mass molar of 94.97 g/mol. It is builded from one central atom of phosphorus which is surrounded by four atoms of oxygen (in a tetrahedral arrangement). A phosphate ion carries a charge negative-three and is the conjugate base of the hydrogen phosphate ion, HPO_4^{2-}, who is the base conjugate of H_2PO^{4-}, the dihydrogen phosphate ion, which in turn is the conjugate base of H_3PO_4, phosphoric acid.

As in the animal and plant worlds, there are many categories, groups and species and in the world of microorganisms. Specifically, bacteria have a very remarkable advantage for their various benefits: Cyanobacteria. They are usually related to algae and marine and aquatic plants of bluish and green tones.

These organisms were of the greatest ecological and evolutionary importance. His discovery was a success in the world of botany.

Among the bacteria, there are various threads or categories, one of them being cyanobacteria. They have the ability to perform oxygen photosynthesis, in which they acquire electrons from water, thus releasing oxygen as a byproduct. Because they are the only prokaryotes to do this, they are often called oxyphotobacteria.

For a long time, cyanobacteria have been known as cyanophytic algae, which literally means "blue plants" or cyanophytes, which translates to "blue algae." But in Spanish, they have often been referred to as blue-green or blue-green algae. After discovering the differentiation between eukaryotic and prokaryotic cells, it was found that there are only these prokaryotic algae, hence the name cyanobacteria.

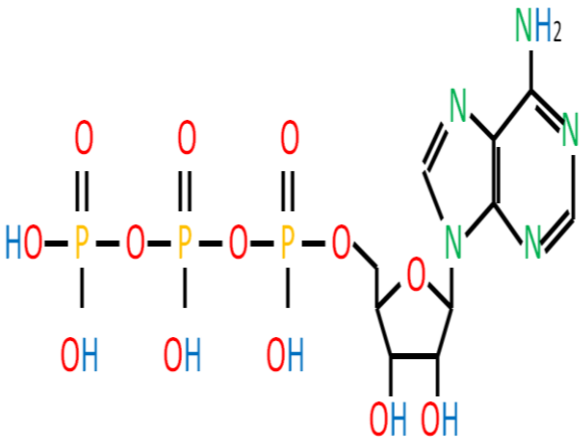

Fig. 20: How the atoms of the four elements are connected on one ATP molecule

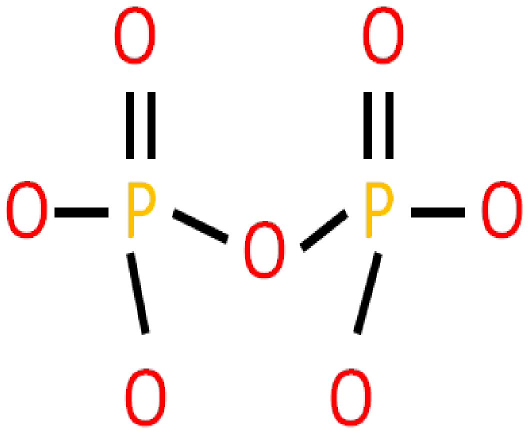

Fig. 21: A pyrophosphate anion having structure “P2O74–”

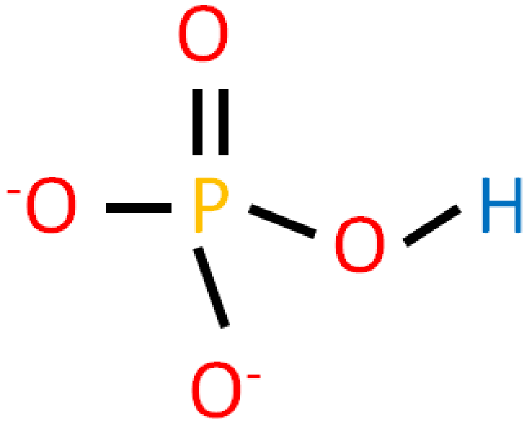

Fig. 22: Hydrogen phosphate, HPO42− (notted with Pi)

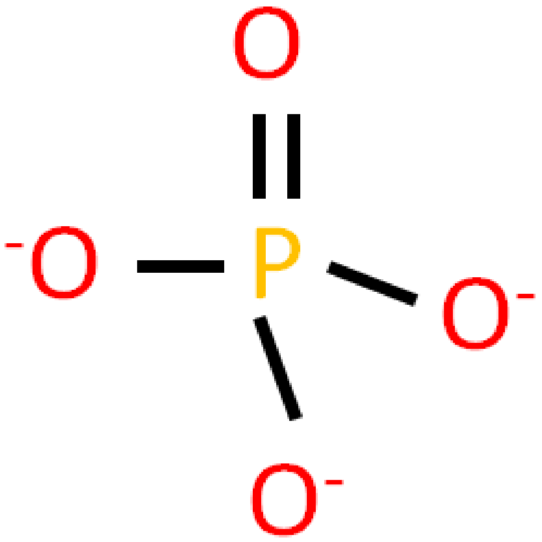

Fig. 23: One phosphate ion

There are several main characteristics of cyanobacteria that we want to highlight. As I said, they are prokaryotes and unicellular. In addition, they live in colonies in the form of hollow spheres, leaves, or filaments.

Another feature to note is that its most common habitat is wetland and water. It is also interesting to know that they are able to survive in both high and low temperatures.

In terms of reproduction, this is done by fragmenting their filaments. Although the existence of cyanobacteria is very beneficial to ecosystems, some species produce a toxic material capable of poisoning other living things that share the same environment.

The most common habitats of cyanobacteria are those slow environments, ie ponds and lakes, in addition to dead trunks, bark and moist soils. Also, some species are halophilic and live in the oceans. Others, on the other hand, are thermophilic and live in geysers.

Because cyanobacteria are very old, the niches they have come to colonize are very diverse. Although they are not very demanding in terms of the environment, they are related to water. We can find these organisms both on land and in water and in areas with high or low temperatures. Cyanobacteria are able to form calcareous structures and even live in wastewater.

Although there are many cyanobacteria that we have evidence of today, we will highlight just a few. An example would be bacteria called Aphanizomenonfls-aquae. They are found in both freshwater and saltwater. Moreover, they are cultivated for use as fertilizer, to create drugs, or for food.

Another example would be bacteria called arthrospiraplatensis, also called Spirulina. They are very common in tropical and subtropical waters. In addition, we can find them in water whose carbonate content is high.

Lateral view of the sample (cut polished face) in approximate growth position. Contact with rock can be seen on the left-hand side. The upper depositional surface was active at the time of collection in 2008 and covered with a thin layer of bacterial slime. The semicircular bites on the right-hand side are erosional and at the time of collection were obscured by a thick layer of bacterial slime. The bottom of the sample seen in this section is a fracture surface. The unbroken base of the sample also shows circular erosional hollows underneath the slime cover. Scale is in cm. The approximate locations of B, C and D (taken from other parts of the sample) are shown with white arrows. B: looking down on the upper surface where the organic slime has dried out and cracked. C: Detail of the dried cracked organic material coating the erosional hollow. D: Detail of the columnar nature of the initial growth at the rock contact (scale in mm) Fig. 24 (Lundberg and McFarlane, 2011).

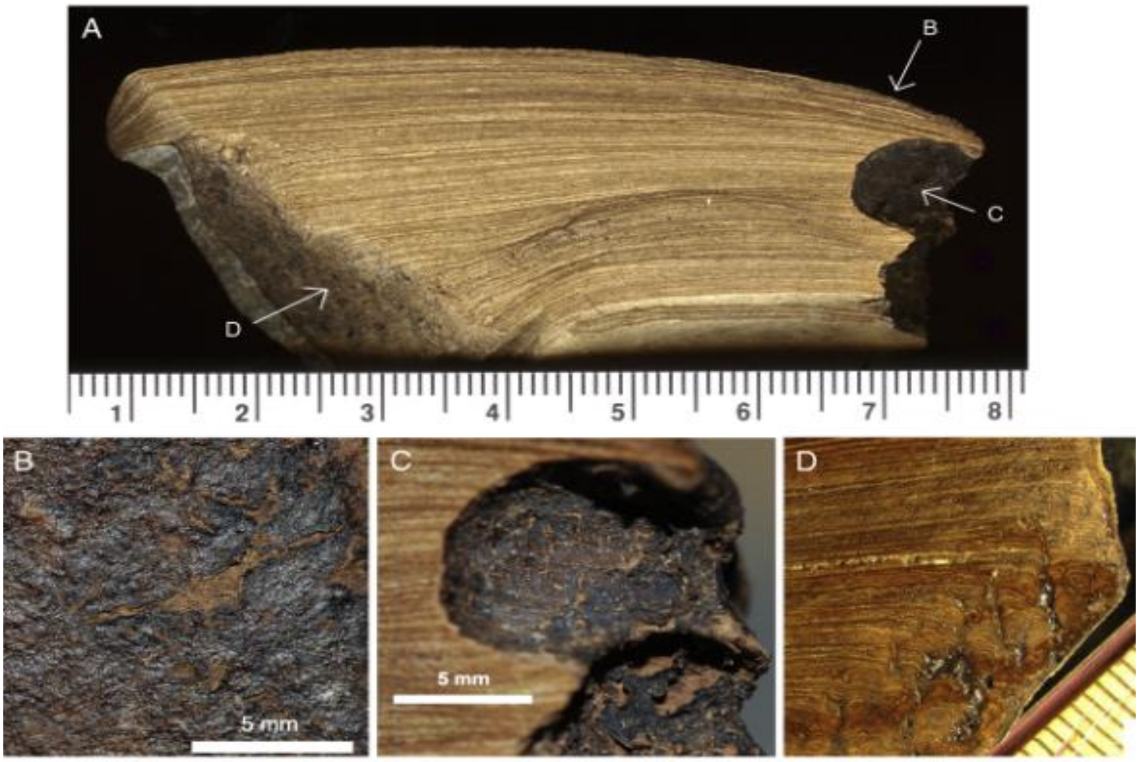

Fig. 24: Lateral view of the sample (cut polished face) in approximate growth position (Lundberg and McFarlane, 2011)

Like many other bacteria, cyanobacteria are very important ecologically and evolutionarily. Through the photosynthetic oxygen process, they contribute especially to the oxygenation of the primitive atmosphere. Apart from this very important task, they are the only organisms that can fix atmospheric nitrogen.

This ability is vital for those creatures that live in symbiosis with cyanobacteria, as it provides the nitrogenous compounds they need. These include mushrooms, protozoa and some plants. A curious fact is that cyanobacteria do not have a cell wall in lichens, functioning as chloroplasts that produce food for their symbiotic companion.

In the same way, the incorporation of nitrogen into the soil makes it a good choice for fertilizers, as they improve the quality of the soil. Moreover, cyanobacteria were the first in terms of the production of chlorophyll A and B and other photosynthetic pigments. They are also the precursors of chloroplasts in both terrestrial flora and algae.

Morphology

Cyanobacteria have a Gram-negative wall, can live as single cells (e.g., Dermocarpa), or are clustered in colonies of various shapes, from rounded to filamentous (e.g., Nostoc).

In some species there is a morphological differentiation: There may be specialized cells with thick and usually larger walls called heterocysts: These are the place of the process of fixing atmospheric nitrogen and if in the basal position they serve for adhesion to the substrate.

Physiology

Photosynthesis of cyanobacteria takes place in their thylakoid membrane, similar to what happens in the chloroplasts of algae, muscles, ferns and seed plants.

For photosynthesis, cyanobacteria do not use only that part of the visible spectrum that green plants use: In addition to chlorophyll a, they also have other photosynthetic pigments, especially phycobilins, including phycocyanin (blue), phycoerythrin (red) and allophycocyanin. in phycobilisomes.

Cyanobacteria are thought to be the organisms that first produced atmospheric oxygen as waste from oxygen photosynthesis.

Phycocyanin gives many cyanobacteria their characteristic blue color, but sometimes (for example in the case of spirulina and Oscillatoria rubescens) the color is red, due to phycoerythrin.

The ratio of individual pigment concentrations can vary greatly, staining bacteria in green or even black (streaked staining). Phycobilins allow the exploitation of a large part of the visible spectrum (in plants the wavelength used varies from 500 to 600 nm, while phycobilins allow the extension of this range up to 650 nm).

The efficiency of the light collection process is even higher for phycoerythrin than for chlorophyll. In this way, cyanobacteria can survive successfully even in low light conditions, such as in the depths of the sea or in aquatic ecosystems characterized by strong currents. Other photosynthetic pigments of cyanobacteria are β-carotene, zeaxanthin, echinone and myxoxanthophyll.

Cyanobacteria accumulate, as reserve substances, cyanobacterial starch, cyanophycin granules (amino acid polymer arginine and asparagine, as reserve nitrogen) and volutin granules (consisting mainly of polyphosphates, as reserve phosphorus).

Cyanobacteria should be considered among bio-building organisms, as their photosynthetic activity removes CO_2 from the environment, inducing the precipitation of calcium carbonate ($CaCO_3$).

These organisms give rise to real carbonate platforms in both the marine and the lake environment.

Many cyanobacteria can fix nitrogen by reducing elemental nitrogen (N_2) to (NH_4^+) inside heterocysts, cells dedicated to this task, with a thick wall that is impermeable to oxygen (which inhibits the nitrogen fixation process).

All species are capable of producing toxins, called cyanotoxins, sometimes used as a defense against attacks by planktonic species and which may belong to the category of neurotoxins such as β-methylamino-alanine, anatoxin-a, saxitoxin; the latter can prevent communication between neurons and muscle cells and therefore interfere with the nervous system and cause death by paralysis of the respiratory muscles; they were responsible for the deaths of animals in the countries of northern Europe and North America.

Another category of toxins is that of hepatotoxins, which can induce liver damage and stagnation of blood in the organ; their effect is to damage liver cells by intervening on the cytoskeleton, as well as to inhibit protein phosphatase which plays an important role in cell division.

Studies are underway to verify the link between chronic changes in the digestive tract and exposure to specific toxins, as well as the relationship between hepatotoxins and tumors.

Finally, cyanobacteria also produce a number of cytokines, which can damage cells but are not harmful to multicellular organisms and indeed studies and research are underway to use them against algae, bacteria and cancer cells.

Microcystins of the species Microcystis are well known. By ingesting fish and shellfish, some toxins, such as BMMA, can reach the human and animal body, occasionally leading to deadly poisoning. The first description of the dangerous effects of cyanobacteria dates back to May 1878 by the Australian George Francis who sent a letter to Nature. Carnegie researchers discovered in 2006 that day-and-night cycle cyanobacteria live in Yellowstone National Park: They perform chlorophyll photosynthesis during the day and nitrogen fixation at night. This feature is so far unique.

Reproduction

Cyanobacteria, like all prokaryotes, reproduce asexually through the décolleté. Cell division in filamentous bacteria occurs through the centripetal formation of a transverse cell wall. Colon multiplication, on the other hand, occurs by breaking the filament or by forming hormones, that is, segments of a few cells, young and unspecialized, which detach from the mother filament to produce a new one.

In some single-celled cyanobacteria, a cell can divide into numerous spherical endospores to survive adverse conditions. Other forms of resistance, in filamentous cyanobacteria, are acinetins, enlarged cells with a resistant wall and rich in reserve substances, which germinate under favorable conditions forming hormones.

Ecology

Cyanobacteria are cosmopolitan aquatic organisms that can be found in both freshwater and saltwater, from cold mountain waters to hot springs up to 75 ° C. There are both planktonic and benthic species or species attached to the substrate in the sea, it forms blackish films on the rocks at the upper limit of the tide and on the carbonated rocks, where water flows, it forms linear patinas called "ink streaks".

In particularly favorable conditions, for example towards the end of summer, they can reach high concentrations, causing characteristic "flowering". Moreover, the detergents and fertilizers that contaminate the pools tend to increase the concentration of nitrogen and phosphorus, which in the cascade induce the proliferation of cyanobacteria, sometimes harmful. High temperature and water alkalinity are two other ideal factors for the spread of cyanobacteria.

Most cyanobacteria live free, but some live in symbiosis with plants: For example, Anabaena azollae lives in symbiosis with Azolla and in the roots of many Cycads; Nostoc with liver, anthoceros and a few mushrooms. They formed stromatolites by trapping calcareous sediments in the mucilaginous mucosa. They manage to survive in extreme conditions by turning into spores through a process called sporulation.

Some cyanobacteria can form living rocks or Trovants, which, although they do not work, are active and vital, given the activity of these bacteria, which by photosynthesis of chlorophyll produce a muddy substance (mucus) which, by sedimentation and stratification, forms these rocks apparently are you coming (Börner, 2001).

The main difference between bacteria and cyanobacteria is that the bacteria are mainly heterotrophic, while cyanobacteria are autotrophic. Furthermore, bacteria do not contain chlorophyll, while cyanobacteria do not contain chlorophyll.

Bacteria and cyanobacteria are the two types of prokaryotes that do not contain membrane-related organs, such as the nucleus, mitochondria, chloroplasts, Golgi, ER, etc.

There are two main types of bacteria that are Gram-positive and Gram-negative. The cell walls of Gram-positive bacteria are rich in peptidoglycans. The three basic forms of bacteria are the bacillus, the coccus and the spirillum. Bacterial sexual reproduction takes place mainly through binary fission, while sexual reproduction takes place through conjugation.

Cyanobacteria are unicellular or multicellular prokaryotes that can undergo photosynthesis. They are also called blue-green algae.

They live in soil, freshwater, or marine habitats and can tolerate harsh environmental conditions just like bacteria. Cyanobacteria can form spherical, filamentous, or sheet-like colonies covered with sheet-like mucilaginous structures. Heterocysts are nitrogen-fixing cyanobacteria.

The main photosynthetic pigment of cyanobacteria is chlorophyll, while the accessory pigments are phytocyanin and phycoeryrin. However, some cyanobacteria are saprotrophic. Flowering cyanobacteria produce cyanotoxins that can be poisonous to humans and animals.

Bacteria and Cyanobacteria are Prokaryotes

They do not contain membrane-related organs, such as the nucleus, mitochondria, chloroplasts, Golgi, ER, etc.

Their ribosomes are the 70S and do not contain true vacuoles or well-developed plastids.

Their cell wall contains muramic acid and diaminopimelic acid.

Both contain a mucilaginous sheath around the cells.

They can fix atmospheric nitrogen.

Both form spores as resting units.

These organisms are resistant to drying and high temperatures.

They are subject to asexual reproduction.

Both form colonies.

They can cause disease in other organisms.

Both have a similar sensitivity to antibiotics.

Bacteria refers to a member of a large group of single-celled microorganisms that have cell walls but no organelles and an organized nucleus, including some that can cause disease, while cyanobacteria refers to a division of bacteria-related microorganisms, but which are capable of photosynthesis.

Bacteria occur in every habitat on earth, while cyanobacteria occur mainly in the presence of the sun (regardless of temperature) and humidity (regardless of the nature of the water, sweet or salty).

Bacteria are unicellular, while cyanobacteria can be either unicellular or multicellular.

The cell wall of bacteria can be one or two layers, while the cell wall of cyanobacteria consists of four layers. Moreover, glycolipids and peptidoglycans are the main components of the bacterial cell wall, while cellulose and pectin are the main components of the cell wall of cyanobacteria.

Bacteria can be Gram-positive or -negative, while cyanobacteria are Gram-negative.

Some bacteria contain flagella, while cyanobacteria do not have flagella. Therefore, some bacteria are mobile, while cyanobacteria are immobile.

Some bacteria contain photosynthetic pigments, such as bacteriochlorophyll, while cyanobacteria contain chlorophyll-a. Furthermore, cyanobacteria contain accessory pigments such as phycocyanin and ficercetrin.

Most bacteria are heterotrophic, while cyanobacteria are autotrophic.

Photosynthesis is anoxygen in bacteria, meaning they do not produce oxygen at the end of photosynthesis, while it is oxygen in cyanobacteria.

Glycogen is the reserved form of food in bacteria, while cyanophyte starch is the reserved form of food in cyanobacteria.

Bacteria do not form heterocysts, while cyanobacteria forms heterocysts, which are nitrogen-fixing cells.

Bacterial sexual reproduction takes place by conjugation, transformation, or transduction, while sexual reproduction is absent in cyanobacteria.

Cyanobacteria are very old organisms. Microfossils very similar to modern cyanobacteria have been found in deposits dating back 2.1 billion years. Characteristic biomarker molecules of cyanobacteria have also been found in 2.7 and 2.5 billion-year-old marine deposits.

Due to the ability of cyanobacteria to produce and release oxygen as a byproduct of photosynthesis, it is believed that its appearance on earth allowed the atmosphere to change, causing a major oxygenation event.

The increase in oxygen could have led to a decrease in atmospheric methane concentration about 2.4-2.1 billion years ago, causing the extinction of many species of anaerobic bacteria.

Some strains of cyanobacterial species can produce strong toxins in aquatic environments. These toxins are secondary metabolites that are released into the environment when environmental conditions are extreme, in eutrophic environments, with high concentrations of mineral nutrients such as phosphorus and particular conditions of pH and temperature.

Conclusion

Bacteria refers to a member of a large group of single-celled microorganisms that have cell walls but no organelles and an organized nucleus, including some that can cause disease, while cyanobacteria refer to a division of bacteria-related microorganisms, but which are capable of photosynthesis.

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Stromatolites and cyanobacteria can teach us how to produce natural oxygen on a new uninhabitable planet. Life on Earth was born at least 3.7 billion years ago, but since then the number of living things has grown exponentially. Surprisingly, some of the earliest life forms on our planet exist and not just in fossilized form - stromatolites - a life form that has witnessed the entire evolution of our planet can still be discovered in certain areas of the globe. Stromatolites are living fossils, the oldest life forms on Earth. Their existence spans an incredible period - stromatolites have existed for 75% of the period since the formation of the solar system. These are defined simply as rock structures built by colonies of microscopic organisms that do photosynthesis. These organisms are known as cyanobacteria. As the soil settled in the shallow waters, bacteria began to grow on it, joining the sedimentary particles and building additional layers until the mounds formed. These constructions of microorganisms in the earth are probably the essential element in the emergence of more complex life on earth - through their respiration they produced and developed oxygen on Earth until it reached 20% of the Earth's atmosphere. Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex.

A major process of microbial formation in the Bacalar Lagoon was and remains the precipitation of calcium carbonate in the cyanobacterial filaments of Homeothrix and Leptolyngbya. Withdrawal of CO2 during the photosynthesis of these oxygen phototrophs and increase in pH probably triggers carbonate precipitation. Evidence of carbonate precipitation is found in the SEM of live and calcified microbial mats microbialitis. Similarly, the photosynthesis of diatoms probably contributed to the precipitation of calcium carbonate. It is also possible that some precipitates appeared inside the microbialites in process of degradation of organic matter. A crucial factor in the carbonate precipitation in the Bacalar Lagoon is clearly and probably always has been, the high carbonate content in the waters of the southwest lagoon, which, in turn, is a consequence of karstic aquifer circulation through the cenotes. Far from the cenotes, the carbonate content of the lagoon waters is significantly lower and microbialites are absent. Agitation and water washing are important, as seen in the dense formation of microbialites in the "Rapids", where high currents of water are observed. In addition to precipitation, there is evidence of sediment trapping in both live microbial mats and calcified microbialites, as seen in SEM. The great abundance of herbivorous pomace gastropods in the Bacalar Lagoon and around the appearance of microbialites supports the claim that grazing takes place and is currently an important factor for the erosion of microbialites. However, this factor is clearly outweighed by the accumulation and cementation of microbialites in the waters of carbonate-rich lagoons. It is not at all clear whether the existence versus the absence of pastures has always been or not great importance for the formation of microbialites in Laguna Bacalar. The high abundance of grazing gastropods of the genus Pomacea in the modern lagoon and the rare appearance of gastropods in the basic material suggests that grazing has recently become important among Bacalar microbialites.

A question posed at the end of the paper in the conclusions is "will scientists be able to produce energy and oxygen in the future according to the microbial model of these microorganisms?".

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Author’s Contributions

All the authors contributed equally to prepare, develop and carry out this manuscript.

Ethics

This article is original and contains unpublished material. Author declares that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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