Cyanobacteria
From Wikipedia, the free encyclopedia

Cyanobacteria /saɪəˌnɒbækˈtɪriə/, also known as blue-green bacteria, blue-green algae, and Cyanophyta, is a phylum of bacteria that obtain their energy through photosynthesis.[4] The name "cyanobacteria" comes from the color of the bacteria (Greek: κυανός (kyanós) = blue).

By producing oxygen as a gas as a by-product of photosynthesis, cyanobacteria are thought to have converted the early reducing atmosphere into an oxidizing one, which dramatically changed the composition of life forms on Earth by stimulating biodiversity and leading to the near-extinction of oxygen-intolerant organisms. According to endosymbiotic theory, the chloroplasts found in plants and eukaryotic algae evolved from cyanobacterial ancestors via endosymbiosis.

Contents

- 1 Ecology
- 2 Characteristics
  - 2.1 Nitrogen fixation
  - 2.2 Ecology
- 3 Photosynthesis
  - 3.1 Carbon fixation
  - 3.2 Metabolism and organelles
- 4 Relationship to chloroplasts
- 5 Earth history
- 6 Classification
- 7 Biotechnology and applications
- 8 Health risks
- 9 Dietary supplementation
- 10 See also
- 11 References
- 12 Further reading
- 13 External links

Ecology

A cyanobacteria bloom near Fiji

Cyanobacteria can be found in almost every terrestrial and aquatic habitat—oceans, fresh water, damp soil, temporarily moistened rocks in deserts, bare rock and soil, and even Antarctic rocks. They can occur as planktonic cells or form phototrophic biofilms. They are found in almost every endolithic ecosystem.[5] A few are endosymbionts in lichens, plants, various protists, or sponges and provide energy for the host. Some live in the fur of sloths, providing a form of camouflage.[6]

Aquatic cyanobacteria are known for their extensive and highly visible blooms that can form in both freshwater and marine environments. The blooms can have the appearance of blue-green paint or scum. These blooms can be toxic, and frequently lead to the closure of recreational waters when spotted. Marine bacteriophages are significant parasites of unicellular marine cyanobacteria.[7]

Characteristics

Tolypothrix sp.

Scientific classification

Domain: Bacteria
Phylum: Cyanobacteria
Orders

The taxonomy is currently under revision[1][2]

- Unicellular forms
- Chroococcales (suborders-Chamaesiphonales and Pleurocapsales)
  - Filamentous (colonial) forms
- Nostocales (= Hormogonales or Oscillatoriales)
  - True-branching (budding over multiple axes)
- Stigonematales

Synonyms

- Cyanophyta
- Cyanophyceae
- Myxophyceae
- Phycocromophyceae
- Schizophyceae[3]
Nitrogen fixation

Cyanobacteria include unicellular and colonial species. Colonies may form filaments, sheets or even hollow balls. Some filamentous colonies show the ability to differentiate into several different cell types: vegetative cells, the normal, photosynthetic cells that are formed under favorable growing conditions; akinetes, the climate-resistant spores that may form when environmental conditions become harsh; and thick-walled heterocysts, which contain the enzyme nitrogenase, vital for nitrogen fixation. Heterocysts may also form under the appropriate environmental conditions (anoxic) when fixed nitrogen is scarce. Heterocyst-forming species are specialized for nitrogen fixation and are able to fix nitrogen gas into ammonia (NH₃), nitrates (NO₃⁻) or nitrites (NO₂⁻) which can be absorbed by plants and converted to protein and nucleic acids (atmospheric nitrogen is not bioavailable to plants).

Rice plantations utilize healthy populations of nitrogen-fixing cyanobacteria (Anabaena, as symbiotes of the aquatic fern Azolla) for use as rice paddy fertilizer.[8]

Cyanobacteria are arguably the most successful group of microorganisms on earth. They are the most genetically diverse; they occupy a broad range of habitats across all latitudes, widespread in freshwater, marine and terrestrial ecosystems, and they are found in the most extreme niches such as hot springs, salt works, and hypersaline bays. Photoautotrophic, oxygen-producing cyanobacteria created the conditions in the planet’s early atmosphere that directed the evolution of aerobic metabolism and eukaryotic photosynthesis. Cyanobacteria fulfill vital ecological functions in the world’s oceans, being important contributors to global carbon and nitrogen budgets.

- Stewart and Falconer[9]

Ecology

Many cyanobacteria form motile filaments of cells, called hormogonia, that travel away from the main biomass to bud and form new colonies elsewhere. The cells in a hormogonium are often thinner than in the vegetative state, and the cells on either end of the motile chain may be tapered. In order to break away from the parent colony, a hormogonium often must tear apart a weaker cell in a filament, called a necridium.

Each individual cell of a cyanobacterium typically has a thick, gelatinous cell wall. They lack flagella, but hormogonia of some species can move about by gliding along surfaces. Many of the multi-cellular filamentous forms of Oscillatoria are capable of a waving motion; the filament oscillates back and forth. In water columns some cyanobacteria float by forming gas vesicles, as in archaea. These vesicles are not organelles as such. They are not bounded by lipid membranes but by a protein sheath.

Some of these organisms contribute significantly to global ecology and the oxygen cycle. The tiny marine cyanobacterium Prochlorococcus was discovered in 1986 and accounts for more than half of the photosynthesis of the open ocean.[10] Many cyanobacteria even display the circadian rhythms that were once thought to exist only in eukaryotic cells (see bacterial circadian rhythms).

Photosynthesis

Carbon fixation

Cyanobacteria utilize the energy of sunlight to drive photosynthesis, a process where the energy of light is used to split water molecules into oxygen, protons, and electrons. While most of the high-energy electrons derived from water are utilized by the cyanobacterial cells for their own needs, a fraction of these electrons are donated to the external environment via electrogenic activity.[11] Cyanobacterial electrogenic activity is an important microbiological conduit of solar energy into the biosphere.

Metabolism and organelles

As with any prokaryotic organism, cyanobacteria do not have nuclei or an internal membrane system. However, many species of cyanobacteria have folds on their external membranes which function in photosynthesis. Cyanobacteria get their colour from the bluish pigment phycocyanin, which they use to capture light for photosynthesis. Photosynthesis in cyanobacteria generally uses water as an electron donor and produces oxygen as a by-product,
though some may also use hydrogen sulfide\cite{citation needed} a process which occurs among other photosynthetic bacteria such as the purple sulfur bacteria. Carbon dioxide is reduced to form carbohydrates via the Calvin cycle. In most forms the photosynthetic machinery is embedded into folds of the cell membrane, called thylakoids. The large amounts of oxygen in the atmosphere are considered to have been first created by the activities of ancient cyanobacteria. They are often found as symbionts with a number of other groups of organisms such as fungi (lichens), corals, pteridophytes (Azolla), angiosperms (Gunnera) etc.

Many cyanobacteria are able to reduce nitrogen and carbon dioxide under aerobic conditions, a fact that may be responsible for their evolutionary and ecological success. The water-oxidizing photosynthesis is accomplished by coupling the activity of photosystem (PS) II and I (Z-scheme). In anaerobic conditions, they are also able to use only PS I—cyclic photophosphorylation—with electron donors other than water (hydrogen sulfide, thiosulphate, or even molecular hydrogen\cite{12}) just like purple photosynthetic bacteria. Furthermore, they share an archaeal property, the ability to reduce elemental sulfur by anaerobic respiration in the dark. Their photosynthetic electron transport shares the same compartment as the components of respiratory electron transport. Their plasma membrane contains only components of the respiratory chain, while the thylakoid membrane hosts an interlinked respiratory and photosynthetic electron transport chain.\cite{citation needed} The terminal oxidases in the thylakoid membrane respiratory/photosynthetic electron transport chain are essential for survival to rapid light changes, although not for dark maintenance under conditions where cells are not light stressed.\cite{13}

Attached to thylakoid membrane, phycobilisomes act as light harvesting antennae for the photosystems. The phycobilisome components (phycobiliproteins) are responsible for the blue-green pigmentation of most cyanobacteria. The variations on this theme are mainly due to carotenoids and phycoerythrins which give the cells the red-brownish coloration. In some cyanobacteria, the color of light influences the composition of phycobilisomes. In green light, the cells accumulate more phycoerythrin, whereas in red light they produce more phycocyanin. Thus the bacteria appear green in red light and red in green light. This process is known as complementary chromatic adaptation and is a way for the cells to maximize the use of available light for photosynthesis.

A few genera, however, lack phycobilisomes and have chlorophyll b instead (Prochloron, Prochlorococcus, Prochlorothrix). These were originally grouped together as the prochlorophytes or chloroxybacteria, but appear to have developed in several different lines of cyanobacteria. For this reason they are now considered as part of the cyanobacterial group.\cite{citation needed}

### Relationship to chloroplasts

Chloroplasts found in eukaryotes (algae and plants) likely evolved from an endosymbiotic relation with cyanobacteria. This endosymbiotic theory is supported by various structural and genetic similarities.\cite{15} Primary chloroplasts are found among the "true plants" or green plants - species ranging from sea lettuce to evergreens and flowers which contain chlorophyll b - as well as among the red algae and glaucophytes, marine species which contain phycobilins. It now appears that these chloroplasts probably had a single origin, in an ancestor of the clade called Archaeplastida. Other algae likely took their chloroplasts from these forms by secondary endosymbiosis or ingestion.

### Earth history

**Main article: Stromatolite**

Stromatolites of fossilized oxygen-producing cyanobacteria have been found from 2.8 billion years ago,\cite{16} possibly from 3.5 billion years ago. The biochemical capacity to use water as the source for electrons in photosynthesis evolved once, in a common ancestor of extant cyanobacteria.\cite{citation needed} The geologic record indicates that this transforming event took place early in
our planet's history, at least 2450-2320 million years ago (mya), and probably much earlier. Geobiological interpretation of Archean (>2500 mya) sedimentary rocks remains a challenge; available evidence indicates that life existed 3500 mya, but the question of when oxygenic photosynthesis evolved continues to engender debate and research.

A clear paleontological window on cyanobacterial evolution opened about 2000 mya, revealing an already diverse biota of blue-greens. Cyanobacteria remained principal primary producers throughout the Proterozoic (2500-543 mya), in part because the redox structure of the oceans favored photoautotrophs capable of nitrogen fixation.

The most common cyanobacterial structures in the fossil record are the mound-producing stromatolites and related oncolites. Indeed, these fossil colonies are so common that paleobiology, micropaleontology and paleobotany cite the Pre-Cambrian and Cambrian period as an "age of stromatolites" and an "age of algae."

Green algae joined the blue-greens as major primary producers on continental shelves near the end of the Proterozoic, but only with the Mesozoic era (251-65 mya) radiations of dinoflagellates, coccolithophorids, and diatoms did primary production in marine shelf waters take modern form.

Today, the blue-green bacteria remain critical to marine ecosystems as primary producers in oceanic gyres, as agents of biological nitrogen fixation, and—in modified form—as the plastids of marine algae.[17]

Classification

See also: Bacterial taxonomy

Historically, bacteria were first classified as plants constituting the class Schizomycetes, which along with the Schizophyceae (blue green algae/Cyanobacteria) formed the phylum Schizophyta.[18] then in the phylum Monera in the kingdom Protista by Haeckel in 1866, comprising Protogens, Protamaeba, Vampyrella, Protonomae and Vibrio, but not Nostoc and other cyanobacteria, which were classified with algae[19] later reclassified as the Prokaryotes by Chatton.[20]

The cyanobacteria were traditionally classified by morphology into five sections, referred to by the numerals I-V. The first three – Chroococcales, Pleurocapsales, and Oscillatoriales – are not supported by phylogenetic studies. However, the latter two – Nostocales and Stigonematales – are monophyletic, and make up the heterocystous cyanobacteria. The members of Chroococcales are unicellular and usually aggregate in colonies. The classic taxonomic criterion has been the cell morphology and the plane of cell division. In Pleurocapsales, the cells have the ability to form internal spores (baeocytes). The rest of the sections include filamentous species. In Oscillatoriales, the cells are uniseriately arranged and do not form specialized cells (akinetes and heterocysts). In Nostocales and Stigonematales the cells have the ability to develop heterocysts in certain conditions. Stigonematales, unlike Nostocales, includes species with truly branched trichomes. Most taxa included in the phylum or division Cyanobacteria have not yet been validly published under the Bacteriological Code. Except:

- The classes Chroobacteria, Hormogoneae and Gloeobacteria
- The orders Chroococcales, Glacioeobacterales, Nostocales, Oscillatoriales, Pleurocapsales and Stigonematales
- The families Prochloraceae and Prochlorotrichaceae
- The genera Calothrix and Prochlorotrichaceae

Biotechnology and applications

The unicellular cyanobacterium Synechocystis sp. PCC6803 was the third prokaryote and first photosynthetic organism whose genome was completely sequenced.[21] It continues to be an important model organism.[22] The smallest genomes have been found in Prochlorococcus spp. (1.7 Mb)[23][24] and the largest in Nostoc punctiforme (9 Mb).[25] Those of Calothrix spp. are estimated at 12-15 Mb[26] as large as yeast.
Some cyanobacteria are sold as food, notably *Aphanizomenon flos-aquae* and *Arthrospira platensis* (Spirulina).\[27\]

Recent research has suggested the potential application of cyanobacteria to the generation of renewable energy via converting sunlight into electricity. Internal photosynthetic pathways can be coupled to chemical mediators that transfer electrons to external electrodes.\[28\] Currently efforts are underway to commercialize algae-based fuels such as diesel, gasoline and jet fuel.\[11][29][30]\n
Researchers from a company called Algenol have cultured genetically modified cyanobacteria in sea water inside a clear plastic enclosure so that they first make sugar (pyruvate) from CO₂ and the water via photosynthesis. Then, the bacteria secrete ethanol from the cell into the salt water. As the day progresses, and the solar radiation intensifies, ethanol concentrations build up and the ethanol itself evaporates onto the roof of the enclosure. As the sun recedes, evaporated ethanol and water condenses into droplets, which run along the plastic walls and into ethanol collectors, from where it is extracted from the enclosure with the water and ethanol separated outside the enclosure. As of September 2012, Algenol was claiming to have tested its technology on 4 acres in Florida and to have achieved yields of 7,000 US gallons per acre (65,500 litres per hectare) each year. This could potentially meet US demands for ethanol in gasoline in 2025, assuming a B30 blend, from an area of around half the size of California’s San Bernardino County, requiring less than one tenth of the area than ethanol from other biomass, such as corn, and only very limited amounts of fresh water.\[31\]

Cyanobacteria may possess the ability to produce substances that could one day serve as anti-inflammatory agents and combat bacterial infections in humans.\[32\]

Spirulina’s extracted blue color is used as a natural food coloring in gum and candy.\[33\]

**Health risks**

Some cyanobacteria produce toxins, called cyanotoxins. These include anatoxin-a, anatoxin-as, aplysiatoxin, cylindrospermopsin, domoic acid, microcystin LR, nodularin R (from *Nodularia*), neosaxitoxin and saxitoxin.

Cyanobacteria reproduce explosively under certain conditions. This results in algal blooms, which can become harmful to other species if the cyanobacteria involved produce toxins.

These toxins can be neurotoxins, hepatotoxins, cytotoxins, and endotoxins, and can be toxic and dangerous to humans as well as other animals and marine life in general. Several cases of human poisoning have been documented but a lack of knowledge prevents an accurate assessment of the risks.\[34][35][36]\ Recent studies suggest that significant exposure to high levels of some species of cyanobacteria producing toxins such as BMAA can cause amyotrophic lateral sclerosis (ALS, also known as Lou Gehrig’s Disease). The Lake Mascoma ALS cluster\[37\] and Gulf War veteran’s cluster are two notable examples.\[35][36][38]\n
**Dietary supplementation**

Microalgae contain substances of high biological value, such as polyunsaturated fatty acids, amino acids (proteins), pigments, antioxidants, vitamins and minerals.\[39\] Edible blue-green algae reduce the production of pro-inflammatory cytokines by inhibiting NF-κB pathway in macrophages and splenocytes.\[40\] Consumption of edible blue green algae may also reduce risks of cataracts and age related macular degeneration.\[41\] It has also shown mitigative effects in animal models of non-alcohol related liver disease, such as steatohepatitis,\[42\] and Parkinson’s disease.\[43\] Sulfate polysaccharides exhibit immunomodulatory, antitumor, antithrombotic, anticoagulant, anti-mutagenic, anti-inflammatory, antimicrobial, and even antiviral activity against HIV, herpes, and hepatitis.\[44\] They also improve insulin resistance in HIV.\[45\] They also protect against aflatoxin and cisplatin chemotherapy induced liver damage.\[46][47]\ These positive health benefits must be distinguished from non-edible species of algae, which are detrimental to health.\[48\]

**See also**

- Anatoxin
- Archean Eon of Earth’s prehistory
- Bacterial phyla, the other major lineages of domain Bacteria
References


3. ^ O. P. Sharma. Textbook of Algae


21. ^ T. Kaneko, et al.; Sato, S; Kotani, H; Tanaka, A; Asamizu,
Cyanobacteria - Wikipedia, the free encyclopedia


"Blue-Green Algae (Cyanobacteria) and their Toxins (http://www.hc-sc.gc.ca/ehw-semt/pubs/water-eau/cyanobacter_e.html)"


"Their toxins and health risks (http://quest.mda.org/news/als-research-poor-dirt-)."

Cyanobacteria - Wikipedia, the free encyclopedia


Further reading

- "Architects of the earth's atmosphere" (http://www.ucmp.berkeley.edu/bacteria/cyanointro.html), Introduction to the Cyanobacteria, University of California, Berkeley, 3 Feb. 2006.
- "From Micro-Algae to Blue Oil" (http://www.paristechreview.com/2011/12/01/micro-algae-blue-oil/)

External links

- What Are Cyanobacteria And What Are Its Types? (http://www.thebigger.com/biology/monera/what-are-cyanobacteria-and-what-are-its-types/)
- Overview of cyanobacteria (http://www.biologie.uni-hamburg.de/b-online/library/webb/BOT311/Cyanobacteria/Cyanobacteria.htm)
- Webserver for Cyanobacteria Research (http://www-cyanosite.bio.purdue.edu)
- CyanoBase (http://genome.kazusa.or.jp/cyanobase)

This article incorporates text from this source (http://dx.doi.org/10.1371/journal.pone.0010821), which is licensed under CC-BY 2.5 (http://creativecommons.org/licenses/by/2.5/).