Chapter 1

Cyanobacteria: The Wonderful Factories

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Additional information is available at the end of the chapter

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Abstract

Cyanobacteria are photosynthetic algae with outstanding endeavor to inhabit diverse habitats and are crowned with special metabolic acumen. Their morphological diversity is vivid and their ecological roles are magnificent and vital in nature ranging from nitrogen cycle to carbon dioxide mitigation. Their applications are now extensively explored and many novel compounds have been reported. The pigments, vitamins, lipids, proteins, polyketides, antioxidative enzymes, polysaccharides etc. derived from cyanobacteria are envisaged worldwide. Their diligent acumen makes them ideal tiny microbial factories for nutraceuticals, biofuels, cosmetics, pharmaceuticals, wastewater remediation and many more. Further investigations can aid in elucidating more cyanobacterial secondary metabolites and innovative approaches towards their wider applicability in plethora of avenues as sustainable reservoirs.

Keywords: cyanobacteria, novel compounds, nutraceuticals, secondary metabolites, wastewater remediation

1. The extraordinary photosynthetic microbes

Cyanobacteria are a distinctive class of extraordinary prokaryotes with photosynthetic capability loaded with immense potentials and diverse applications. Traditionally they were called '**blue-greens**', as the first cyanobacteria reported were bluish-green in color. The fossils of cyanobacteria are 3.8 billion years old, among the oldest fossils currently known. They are pioneers of the major transformation that occurred in the due course of evolution contributing towards the aerobic metabolism as the photosynthetic machinery of angiosperms and photosynthetic eukaryotes are presumed to be developed from primitive cyanobacterium billions of years ago. Initially, Cyanobacteria was placed in the class of algae owing to their morphology, photosynthetic pigments and oxygenic photosynthesis with photosystems (PS II and PS I) similar to the algae. Later on, Herdman et al. [1] reported that the genome size of cyanobacteria (1.6 × 109 to 8.6 × 109 Da) was similar to bacteria (1.0 to 3.6 × 109 Da) and it was advocated that cyanobacteria are more related to bacteria.

Cyanobacteria are microscopic in size but their colonies or mats are quite conspicuous. The habitats of cyanobacteria are quite diversified in terms of their unique adaptability to an array of climatic conditions ranging from glaciers, sea, and lake to deserts. They are one of the harbingers of the biological organism that evolved on earth perhaps after the first bacteria, billions of years ago long prior to mankind. They are dynamic organisms inhabiting the most extreme habitats on the planet and can be readily relocated to new avenues via air. The morphological dynamics include unicellular, filamentous and colonies. The cells of cyanobacteria are bigger in size compared to usual cells of bacteria. The nature of cell wall is peptidoglycan and is multi-layered with photosynthetic pigments in the outer part of protoplast. A covering of mucin is seen on the filament and no locomotion system has been reported, though some forms exhibit oscillatory motion [2].

They are photosynthetic in nature yet they are reported to inhabit marginally illuminated caves while on the other extreme end, they dwell well at salty marshes, exposed to high light intensity [3]. The photosynthetic machinery of cyanobacteria is armored with a myriad pigments- chlorophylls, carotenoids, and phycobiliproteins-phycoerythrin, phycocyanin and allophycocyanin [4, 5]. The pigment system enables the wide range of adaptations to the alterations in light intensities [6, 7]. An outstanding phenomenon called complementary chromatic adaptation is evident in cyanobacteria wherein they adapt to changes in the intensity of light due to the phycobiliprotein synthesis in response to the wavelength of light. The pigments also aid in protecting the cells from the detrimental effects of harmful radiations [5]. They inhabit virtually all major aquatic and terrestrial biome on the earth by virtue of their unique adaptability. The low water potential dwelling cyanobacteria resist the desiccations by adapting to the high salinity as seen in the ponds with hypersaline conditions [8]. The temperature range that permits the growth of cyanobacteria is quite large ranging from freezing to 40°C, though the optimum temperature lies in between 20 and 35°C, while the open ocean cyanobacteria are exposed to the temperature nearly 30°C [9]. The pH requirements of cyanobacteria generally range from neutral to alkaline, but they have also been reported to inhabit hot springs which are acidic in nature [10, 11]. The primary mode of nutrition in cyanobacteria is photosynthesis but in the hydrogen sulfide-rich environment, switching from oxygenic to anoxygenic photosynthesis is reported [12, 13] which is similar in nature to the bacterial type photosynthesis.

Cyanobacteria are very significant prokaryotes for the environment and plant growth. Though they are free-living organisms few live in symbiotic association with other eukaryotes and perform profound new roles essential for the ecosystem. They are the natural nitrogen fixings icons, which is quite essential for the entire biological system. The capability of converting atmospheric nitrogen into organic ammonia, nitrite or nitrate is called biological nitrogen fixation, though possessed by few organisms and essential for the growth of the plants. The talent of some cyanobacteria to bring about nitrogen fixation allows them to inhabit low nitrogen concentration ambiance, which is an added advantage in terms of survival and adaptability in the environment.

Cyanobacteria can serve as excellent sources of eco-friendly and renewable biofuels ranging from hydrogen to lipids as they are ideal microbes for production of biofuel based on their photosynthetic proficiency and their ability for genetic engineering [14]. They expedite in managing stress through an advanced antioxidative system. The antioxidative enzymes of cyanobacteria are efficient in protecting the cells from the damaging impact of free radicles generated through aerobic processes. The antioxidative enzymes Catalase, peroxidase, Superoxide dismutase, peroxiredoxins, Ascorbate Peroxidase etc. can be employed for commercial purposes and antioxidative therapy is the emerging concept in medical science [2]. The cyanobacterial pigments phycocyanin and phycoerythrin have great therapeutic value and are widely used in food, cosmetics and therapeutics in many parts of the globe. They are also reported to possess hepato-protective, antioxidants, anti-inflammatory and anti-aging activity along with positive effect in therapeutics of Alzheimer and cancer owing to their unique magnificent absorbance and fluorescence [15].

The Secondary metabolites from cyanobacteria are concomitant with hormonal, toxic, antineoplastic and antimicrobial effects [16, 17]. The range of antimicrobial efficacy ranges from the plethora of microorganisms, prokaryotes and eukaryotes. They are great reservoirs of diverse varieties of secondary metabolites. The toxins secreted by cyanobacteria are diverse from hepatotoxins to lipopolysaccharides and are extensively research worldwide [18].

Cyanobacteria have multifaceted applications in the modern biotechnological and pharmaceutical arena. They are also broadly used in the treatment of wastewater, in aquaculture as fish feed, food, fertilizers, and various secondary metabolites like toxins, exopolysaccharides, enzymes, vitamins, and nutraceuticals [19]. Cyanobacteria also find applications as UV-absorbing amalgams, bioplastics (polyhydroxyalkanoates, PHAs) and coating material etc. and have tremendous bioindustrial potential [2]. These wonderful tiny factories are yet to be explored so that they can be exploited for a sustainable world, a better tomorrow. This book highlights the significant studies on Cyanobacteria by authors from the parts of the world envisaging the characteristics features and applicability of these special prokaryotes.

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