REVIEW ARTICLE

Microbial Diversity in Freshwater and Marine Environment

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Abstract

Water covers seven tenths of the Earth's surface and occupies an estimated total volume of 1,386,000,000 cubic kilometers (km^3). Of all the water found on Earth, 97% is marine. Maximum of this water is at a temperature of 2 to 3°C and devoid of light; 62% is under high pressure (>100 atm). Microscopic phytoplankton and associated bacteria generate a complex food web that can extend over long distances and extreme depths. The marine environment looks so vast that it will not be able to be exaggerated by pollution; however, in coastal areas human activities are increasingly disrupting microbial processes and damaging water quality.

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Introduction

Microbial diversity that we see today is the result of nearly 4 billion years of evolutionary change. Microbial diversity can be seen in many forms, including cell size and cell morphology, physiology, motility, pathogenicity, developmental biology, adaptation to environmental extremes, phylogeny and mechanism of cell division [1].

Microorganisms are present everywhere on Earth that will support life. These include habitats we are all familiar with- soil, water, animal, and plants-as well as virtually any structures made by humans. Some microbial habitats are ones in which humans could not survive, being too hot or too cold, too acidic or too caustic, or too salty. Although such environments would pose challenges to any life forms, they are often teeming with microorganisms. Organisms inhabiting such extreme environments are called extremophiles, a remarkable group of microorganisms that collectively define the physiochemical limits to life [2].

Approximately 6000 species of prokaryotes and 100,000 species of protists have been formally described [3]. In the case of the diversity of microorganisms, even the right order of magnitude is unknown and the issue is highly controversial [4–6]. The total number of prokaryotic cells in the oceans has been estimated to be 1029 [7].

All prokaryotic organisms are classified as bacteria, whereas eukaryotic organisms include fungi, protozoa, and helminths as well as humans. Prokaryotic organisms are divided into two major groups: the eubacteria, which include all bacteria of medical importance, and the archaebacteria, a collection of evolutionarily distinct organisms [1].

Freshwater Microbial Diversity

Freshwater and marine environments differ in many ways including salinity, average temperature, depth, and nutrient content, but both provide many excellent habitats for microorganisms.

Large numbers of microorganisms in a body of water generally indicate high nutrient levels in the water. Water contaminated by inflows from sewage systems or from biodegradable industrial organic wastes is relatively high in bacterial numbers. Similarly, ocean estuaries (fed by rivers) have higher nutrient levels and therefore larger microbial populations than other shoreline waters [8].

In water, particularly water with low nutrient concentrations, microorganisms tend to grow on stationary surfaces and on particulate matter. In this way, a microorganism has contact with more nutrients than if it were randomly suspended and floating freely with the current. Many bacteria whose main habitat is water often have appendages and holdfasts that attach to various surfaces.

Freshwater environments are highly variable in the resources and conditions available for microbial growth. Both oxygen producing and oxygen-consuming organisms are present in aquatic environments, and the balance between photosynthesis and respiration controls the natural cycles of oxygen, carbon, and other nutrients (nitrogen, phosphorus, metals). Among microorganisms, oxygenic phototrophs include the algae and cyanobacteria. These can either be planktonic (floating) and distributed throughout the water columns of lakes, sometimes accumulating in large numbers at a particular depth, or benthic, meaning they are attached to the bottom or sides of a lake or stream. Because oxygenic phototrophs obtain their energy from light and use water as an electron donor to reduce CO to organic matter, they are called primary producers [9].

A typical lake or pond serves as an example to represent the various zones and the kinds of microbiota found in a body of fresh water. The littoral zone along the shore has considerable rooted vegetation, and light penetrates throughout it. The limnetic zone consists of the surface of the open water area away from the shore. The profundal zone is the deeper water under the limnetic zone. The benthic zone contains the sediment at the bottom [10].

Areas of the limnetic zone with sufficient oxygen contain pseudomonads and species of *Cytophaga, Caulobacter*, and *Hyphomicrobium*. Photosynthetic algae are located in the limnetic zone [11].

Deeper waters of the profundal and benthic zones have low oxygen concentrations and less light. Algal growth near the surface often filters the light, and it is not unusual for photosynthetic microbes in deeper zones to use different wavelengths of light from those used by surface-layer photosynthesizers. Purple and green sulfur bacteria are found in the profundal zone. These bacteria are anaerobic photosynthetic organisms that metabolize H2S to sulfur and sulfate in the bottom sediments of the benthic zone. *Clostridium* species are common in bottom sediments and may include botulism organisms, particularly those causing outbreaks of botulism in waterfowl [8].

Marine Microbial Diversity

The marine environment represents a major portion of the biosphere and contains 97% of the Earth's water. Much of this is in the deep sea at a depth greater than 1,000 meters, representing 75% of the ocean's volume. The ocean has been called a "high-pressure refrigerator," with most of the volume below 100 meters at a constant 3°C temperature. The ocean, at its greatest depth, is slightly more than 11,000 meters deep. The pressure in the marine environment increases approximately 1 atm/10 meters in depth, and pressures are in the vicinity of 1,000 atm at the greatest ocean depths [2].

Much of the marine environment is covered by sea ice that may comprise up to 7% of the world's surface. Microorganisms actually grow and reproduce at the interface between the ice and the seawater. The microbes that have been recovered from these ice cores have been given intriguing generic names: these include *Polaromonas, Marinobacter, Psychroflexus, Iceobacter, Polibacter*, and *Psychromonas antarcticus* [2].

The world's oceans are teeming with microscopic life forms. Nominal cell counts of >10^5 cells per ml in surface sea water [12, 13] predict that the oceans harbor 3.6 X 10^{29} microbial cells with a total cellular carbon content of 3 X 10^{17}g [7]. Communities of bacteria, archaea, protists, and unicellular fungi account for most of the oceanic biomass. These microscopic factories are responsible for 98% of primary production [7, 14] and mediate all biogeochemical cycles in the oceans [12].

Coastal and shelf sediments play a significant role in the remineralization of organic matter. In shelf areas, an estimated 32 to 46% of the primary production settles to the sea [15].

Much of the primary productivity in the open oceans, even at significant depths, comes from photosynthesis by prochlorophytes, tiny prokaryotic phototrophs that are phylogenetically related to cyanobacteria. Prochlorophytes contain chlorophylls a and b or chlorophylls a and d. The organism *Prochlorococcus* is a particularly important primary producer in the marine environment. Aerobic anoxygenic phototrophs include bacteria such as *Erythrobacter, Roseobacter*, and *Citromicrobium*, all genera of *Alphaproteobacteria.* Deep-water Archaea are almost exclusively species of *Crenarchaeota*, and many or perhaps even most are ammonia-oxidizing chemolithotrophs, these organisms play an important role in coupling the marine carbon and nitrogen cycles. Very small planktonic heterotrophic bacteria inhabit pelagic marine waters in numbers of 10^5 – 10^6 cells/ml. The most abundant of these is *Pelagibacter*, a genus of Class Alphaproteobacteria. Cells of *Pelagibacter* are small rods that measure only 0.2– 0.5 µm, near the limits of resolution of the light microscope. *Bacteroidetes* and *Actinobacteria*, and has also been found in nonhalophilic species of Archaea, such as the Thermoplasma group. In the oceans, viruses are more abundant than cellular microorganisms, often numbering over 107 virions/ml in typical seawater [1].

Conclusion

Major bacterial groups now recognized as abundant in the open ocean include Alpha- and Gammaproteobacteria, cyanobacteria, Bacteroidetes, and to a lesser extent, Betaproteobacteria and Actinobacteria; Firmicutes are only minor components. With the exception of the cyanobacteria, most marine Bacteria are thought to be heterotrophs adapted to extremely low nutrient availability, some augmenting energy conservation through proteorhodopsin or aerobic anoxygenic phototrophy. Recent anthropogenic interventions in marine environment have threatened all lives, including microorganisms. Study of marine microbial biodiversity is of dynamic importance to the understanding of the different processes of the ocean, which may present effective novel microorganisms for screening of bioactive compounds.

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