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المرحلة الثالثة /فرع الاحياء المجهرية/

Lec (3): Aquatic Environments

Aquatic microbiology can **be defined as the study of microorganisms and microbial communities in water environments.** Aquatic environments occupy more than 70% of Earth's surface including oceans, estuaries, rivers, lakes, wetlands, streams, springs, and aquifers.

Aquatic environments, in addition to providing water for drinking, provide essential resources for agriculture, mining, power generation, semiconductor manufacturing, and every other industry .

Microorganisms are key components of the aquatic environment. As the most important primary producers were …

1. Are responsible for photosynthetically fixing carbon dioxide into organic matter.
2. Are responsible for production approximately 50% of all primary production on Earth.
3. Microorganisms are also the most important consumers, responsible for harvesting the organic matter produced through primary production and respiring it back into carbon dioxide.

The microbiota that inhabit aquatic environments include bacteria, viruses,fungi,algae and other microfauna. The four microbial habitats ((lifestyle)),**Community structural habitats** are **planktonic**, **sediment**, **microbial mat**, and **biofilm**.

The three main aquatic environments:

(1) Inland surface waters (lakes ,rivers, streams).
(2) Seas (ocean, harbors etc.)
(3) Groundwaters.

MICROBIAL HABITATS IN THE AQUATIC ENVIRONMENT

(A) Planktonic Environment: Plankton refers to the microbial communities suspended in the water column.

Phytoplankton: Photoautotrophic organisms within this community including both eukaryotes (algae) and prokaryotes (cyanobacteria) are collectively referred to as Phytoplankton.

Bacterioplankton: Suspended heterotrophic bacterial populations are referred to as bacterioplankton

Zooplankton: protozoan populations are referred to as the zooplankton.

Together these three groups of organisms make up the microbial planktonic community. Phytoplankton are the primary producers in the food web, using photosynthesis to fix CO_2 into organic matter. In the planktonic microbial community, this primary production is the major source of organic carbon and energy, which is transferred to other trophic levels within the web. The organic compounds produced by phytoplankton can be divided into two classes, **particulate** or **dissolved**, depending on their size.

Particulate organic matter (POM) compounds: are large macromolecules such as polymers, which make up the structural components of the cells, including cell walls and membranes.

Dissolved organic matter (DOM): is composed of smaller soluble material including amino acids, carbohydrates, organic acids, and nucleic acids, which are rapidly taken up by microbes and metabolized (recycled).

Primary Production: The amount of primary production within a given water column depend on a variety of environmental factors. These factors include

1. The availability of essential inorganic nutrients, Particularly nitrogen and phosphorus.
2. Water temperature; and
3. The turbidity of the water, which affects the amount of light transmitted through the water column.

Freshwater environments, **lakes, like the open seas**, are often low-productivity environments, particularly those that are large, deep, and nutrient-poor (oligotrophic) bodies of water.

In contrast, smaller and shallower freshwater bodies tend to be nutrient-rich or eutrophic Nutrient loading causes eutrophication of lakes. Nutrient loading can be

1. The natural evolutionary process or
2. The result of human activity.

Secondary Production: In a typical food web, phytoplankton (primary producers) are consumed by microfauna (zooplankton), which in turn are consumed by progressively larger organisms, such as fish or other. This is called the grazing food chain. DOM is rapidly utilized by heterotrophic bacteria (bacterioplankton), a pathway in the aquatic food web referred to as the microbial loop. In this loop, bacterioplankton mineralize a portion of the organic carbon into CO_2 and assimilate the remainder to produce new biomass. **This production of bacterial biomass is referred to as secondary production.**

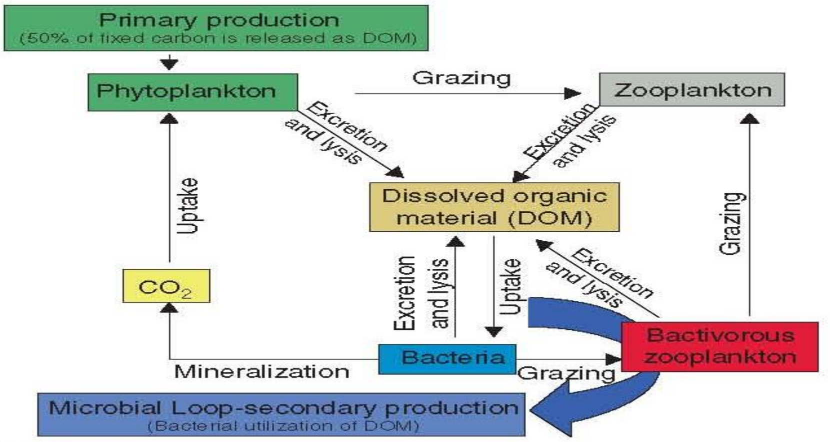


FIGURE 6.2 The microbial loop in the planktonic food web. The microbial loop represents a pathway in which the dissolved organic products are efficiently utilized. The role of bacterioplankton is to mineralize important nutrients contained within organic compounds and to convert a portion of the dissolved carbon into biomass. Grazing by bactivorous protozoans provides a link to higher trophic levels. Modified from Fuhrman, 1992. Reproduced with permission of Springer.

(B) Benthic Habitat: The benthos is a transition zone between the water column and the mineral subsurface. This interface collects the organic material that settles from the water column or that is deposited from the terrestrial environment.

The microbial concentration in benthic habitat depends on:

The availability of organic material and

The availability of oxygen,microbial numbers may decline because of oxygen depletion.

(C) Microbial Mats: Are an extreme example of an interfacial aquatic habitat in which many microbial groups are laterally and tightly compressed into a thin mat of biological activity. Mats are often found in extreme environments or in environments where conditions fluctuate rapidly. The thickness of mats ranges from several millimeters to a centimeter in depth.

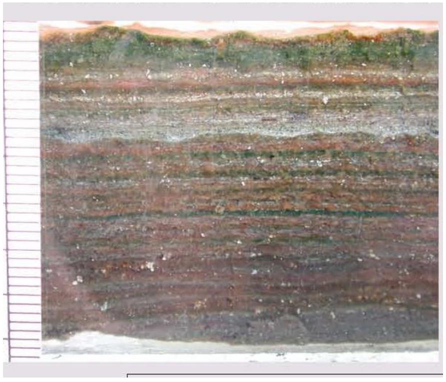
Cyanobacteria occupy the upper zone of the mat,where they have access to sunlight. It is the most important source of organic compounds within the microbial mat community, and creates an oxygenic environment in the upper layer of the mat.
Photosynthetic activity creates oxygen-supersaturated conditions during the day, but at night, in the absence of sunlight, microbial respiration rapidly depletes all the available oxygen.

A layer of sediment rich in oxidized iron may from directly under the cyanobacterial layer.
The purple sulphur bacteria also photosynthetic. The purple sulphur bacteria utilized a reduced sulphur compound (sulfide) as an electron donor.

Below the purple sulphur bacteria is an extensive black layer enriched by the precipitation of iron sulphide (Fes).

A microbial mats :

- sand layer
- Cyanobacteria
- Oxidized iron
- Purple sulphur bacteria
- Precipitated iron sulfide

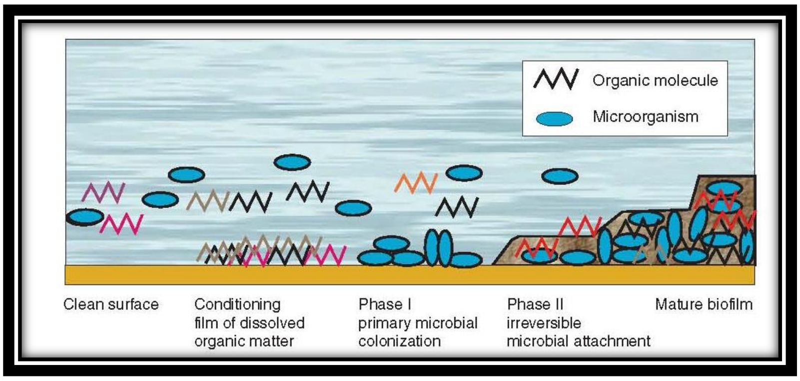


(D) A biofilm: Is a layer of organic matter and microorganisms formed by the attachment and proliferation of bacteria on the surface of an object. In most cases this surface is submersed in nonsterile water or surrounded by a moist environment. Biofilms have a role in nutrient cycling and pollution control within the aquatic environment, as well as for their beneficial or detrimental effects on human health.

Biofilm formation:

1. Dissolved organic molecules of a hydrophobic nature accumulate at the solid surface–water interface and create a visible " slimy " layer on a solid surface .
2. (phase I) reversible attachment: The initial adhesion leading to passive, reversible attachment to the surface is controlled by several competing forces, including
   - hydrophobic
   - electrostatic
   - van der Waals forces.

3. (phase II) irreversible attachment : Biofilm development which is a biologically mediated stabilization reaction ,time-dependent process related to the proliferation of bacterial exopolymers forming a chemical bridge to the solid surface By a combination of colonization and bacterial growth, the mature biofilm is formed.



The exact nature of the biofilm depends on numerous factors, including

- the type of solid surface
- the microbial composition of the biofilm
- the environmental conditions

Advantage of Microorganisms membership in a biofilm community for the member cells.

1. The matrix can act as an ion-exchange resin to filter and collect essential nutrients.
2. It can protect the attached community from environmentally stressful conditions such as desiccation or changes in pH and temperature.
3. It can also provide some protection of the cells from predation by protozoans.
4. Compared with planktonic cells, biofilm formations are far more resistant to antibacterial substances, such as antibiotics and disinfectants.

Advantage of biofilm community for **aquatic environments** Bacteria are predominantly found attached to rock surfaces (biofilm),

1. The continuous renewal of nutrients provided by water flow
2. Act as a biological filter to remove DOM from flowing waters. The filtration of DOM from the water by these attached communities represents a water purification system in natural environments.
3. Also been used for the degradation of a wide range of pollutants that may be present in wastewater streams including hydrocarbons, pesticides, and industrial solvents.

AQUATIC ENVIRONMENTS

(A) Freshwater Environments : Freshwater environments are inland bodies of water (such as springs, rivers and streams, and lakes) are those not directly influenced by marine waters. The science that focuses on the study of freshwater habitats is called limnology, and the study of freshwater microorganisms is microlimnology.

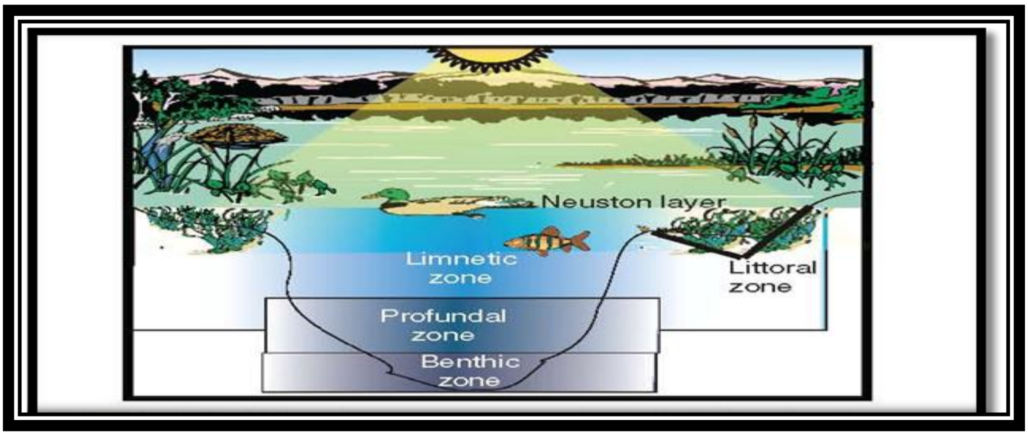
There are two types of freshwater environments:

1. standing water, or lentic habitats, including lakes, ponds, and bogs;
2. running water, or lotic habitats, including springs, streams, and rivers.

❖ Springs : Springs form wherever subterranean water reaches Earth's surface. There are many type of spring Cold spring when melted snow and ice in mountainous regions feed spring .Warm or Hot spring originated from volcanic areas . Microorganisms, especially bacteria and algae, are often the only inhabitants of springs. In general, photosynthetic bacteria and algae dominate spring environments. These primary producers are present in highest concentrations where light is available and inorganic nutrients are in highest concentrations.

❖ Lakes :Lakes vary in depth from a few meters to more than 1000 m. Salt lakes are distinguished by a high salt content and are examples of extreme environments . Other lakes are also characterized by chemical composition, such as bitter lakes that are rich in $MgSO_4$, borax lakes that are high in $Na_2B_4O_7$, and soda lakes that are high in $NaHCO_3$.

Lakes are divided into subsections based (A) on morphometric (depth, dimension, geology of shores, currents, etc.) and (B) physicochemical (temperature, pH, oxygen content) parameters.



A typical lake showing common designations based on sunlight:

1. The littoral zone :The edge of the lake, where sunlight can penetrate to the bottom.
2. neuston layer :The air–water interface including the upper few millimeters of the water column .
3. The limnetic zone: refers to the surface layer of open water away from the littoral zone where light readily penetrates.
4. profundal zone:The area below the limnetic zone, where light intensity is less than 1% of sunlight.
5. Finally, The benthic zone consists of the lake bottom and the associated sediments.

(B) Brackish Water and Marine Water : **Brackish water is a broad term used to describe water that is more saline than freshwater but less saline than true marine environments. Often these are transitional areas between fresh and marine waters. An estuary, which is the part of a river that meets the sea, is the best known example of brackish water. Estuaries are highly variable environments because the salinity can change .

**Marine water is characterized by salinity between 33 and 37% and can range in depth up to 11,000 m in the deepest of ocean. Oceans are not static in size or shape .Because the oceans are so expansive and their surface areas are so great, the effect of sunlight is important. The ocean is divided into two zones, the photic zone, through which light can penetrate, and the lower aphotic zone. Light is able to penetrate to a depth of 200 m, depending on the turbidity of the water. ocean contains diverse microbial habitats. Also, depending on location markedly different microbial populations predominate.

(C) Subterranean Water: The groundwater environment is found inland in the subsurface zone and includes shallow and deep aquifers. microorganisms are the sole inhabitants of these environments and bacteria are the dominant type of microbe present. In general, levels of microbial activity are low, especially in intermediate and deep aquifers. Activity is orders of magnitude lower in these aquifers than in other aquatic habitats , This is due to low nutrient levels.

Aquatic Microbes: Food for the Future: ***Spirulina*** **:** is a cyanobacterium (phytoplankton) that has potential to serve as an alternate dietary protein source. In fact, *Spirulina* is a traditional food for several cultures. This organism can be found growing naturally in warm-water alkaline volcanic lakes. Scientific studies suggest that Spirulina protein may be one of the highest quality types of protein available, because these cyanobacteria are up to 70% protein by weight and their protein contains all of the essential amino acids. In addition to being a high quality protein source, Spirulina is considered to be a vitamin and mineral " gold mine. " Spirulina is high in β -carotene, iron, vitamin B_{12} , and glycogen (a natural source of energy). NASA has considered use of Spirulina as a food of choice for space flight. Studies also suggest the possibility that consumption of these cyanobacteria can strengthen the immune system, enhancing the ability to fight infection.