Fresh Water Microbiology

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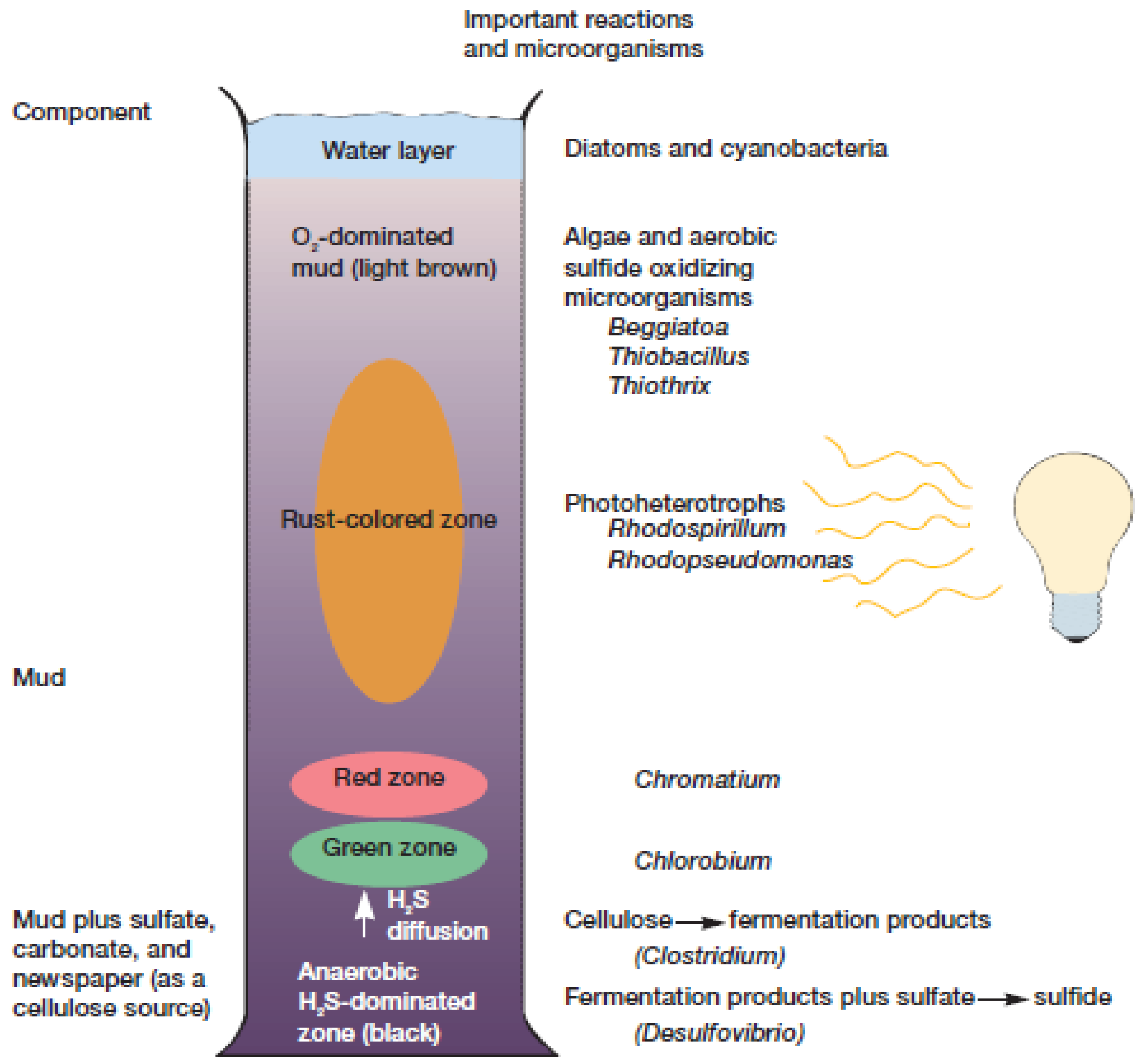
Gases and Aquatic Microorganisms

- The mixing and movement of nutrients, O_2, and waste products that occur in freshwater are the dominant factors controlling the microbial community.
- In deep lakes, organic matter from the surface can sink to great depths, creating nutrient-rich zones where decomposition takes place.
- In aquatic environments the distance (on a microbial scale) from an air bubble or the water surface limits oxygen diffusion.
- Thus aquatic environments are termed low oxygen diffusion environments.
- Because of limited solubility and the low oxygen diffusion in waters, oxygen can be used by aerobic microorganisms faster than it can be replenished, leads to the formation of hypoxic or anoxic zones in aquatic environments.
- These zones allow specialized anaerobic microbes, both chemotrophic and phototrophic, to grow in the lower regions of lakes where light can penetrate.
- The second major gas in water, CO_2, plays many important roles in chemical and biological processes.
- The CO_2 – bicarbonate - carbonate equilibrium can control the pH; When autotrophic microorganisms such as algae use CO_2, the pH will be increased.
- Other gases also are important in aquatic environments, includes nitrogen gas, used as a nitrogen source by nitrogen fixers; hydrogen, which is both a waste product and a vital substrate; and methane (CH_4).

Nutrients in Aquatic Environments

- With changes in nutrient levels, shifts between low nutrient responsive and high-nutrient responsive microorganisms can occur.
- The Winogradsky column, usually constructed using a glass graduated cylinder, illustrates many interactions and gradients that occur in aquatic environments.
- In this glass cylinder a layer of reduced mud is mixed with sodium sulfate, sodium carbonate, and shredded newspaper—a cellulose source—and additional mud and water are placed in the column, which is then incubated in the light.
- Fermentation products and sulfide migrate up from the reduced lower zone, and oxygen penetrates from the surface.
- This creates conditions similar to those in a lake with nutrient-rich sediments.
- Light is provided to stimulate the penetration of sunlight into the anaerobic lower region, which allows photosynthetic microorganisms to develop.

Winogradsky Column

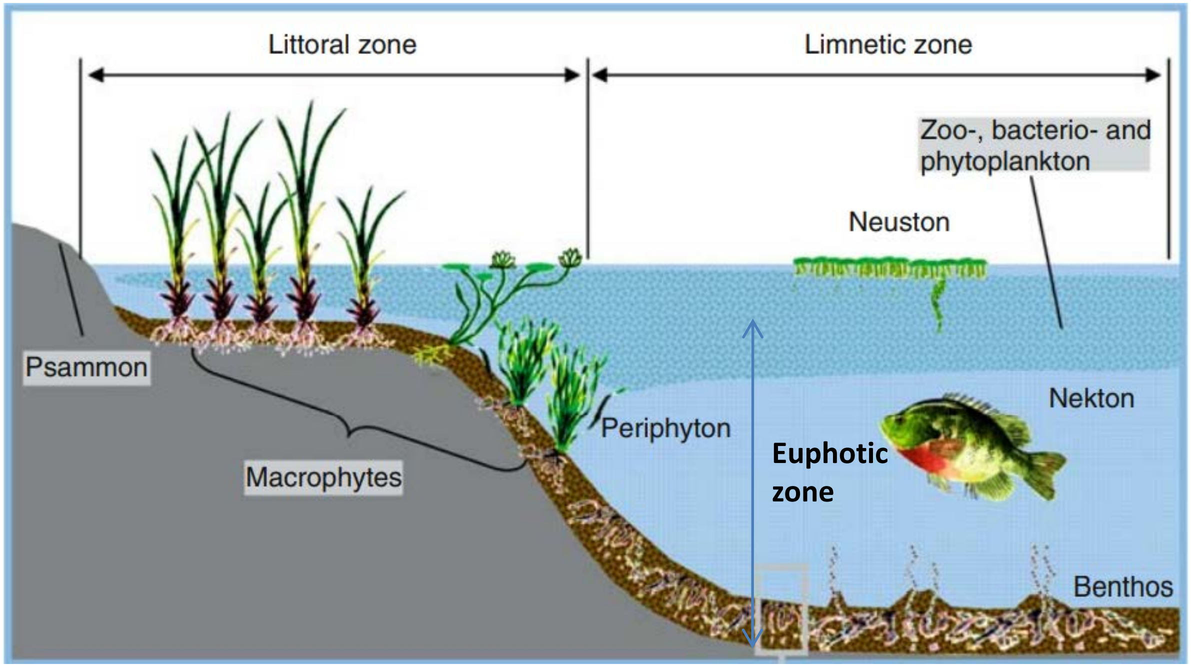


Nutrient Cycles in Aquatic Environments

- The major source of organic matter in illuminated surface waters is photosynthetic activity, primarily from phytoplankton.
- As they grow and fix carbon dioxide to form organic matter, the phytoplankton acquire needed nitrogen and phosphorus from the surrounding water.
- Once the phytoplankton have grown, much of the organic matter fixed by these minute photosynthetic organisms then enters the microbial loop.
- Dissolved organic matter (DOM) released by the phytoplankton is used by the heterotrophic bacteria.
- The DOM is transformed to bacteria, which become part of the particulate organic matter (POM) pool.
- These bacteria are then consumed and digested by a series of increasingly larger predators, including protozoa and metazoan zooplankters, releasing the carbon as CO2 and the other nutrients in mineral forms to be cycled through the phytoplankton again.

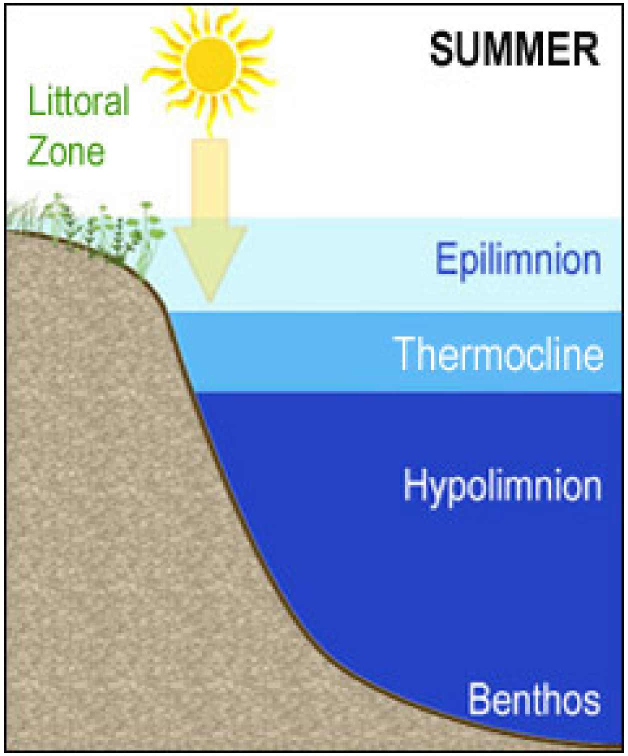
Freshwater Environments

- Most fresh water that is not locked up in ice sheets, glaciers, or ground waters is found in lakes and rivers.
- **A typical lake** has distinct zones of biological communities linked to the physical structure of the lake.
- The littoral zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow.
- Limnetic (pelagic) zone is the open waterarea where light does not penetrate to the bottom.
- The third component of lake habitat is benthic zone covered by the fine layer of mud.



Lake Environment

- Euphotic zone of the lake, is the layer from the surface down to the depth where light levels become too low for photosynthesizers.
- Nutrient-poor (oligotrophic) lakes remain aerobic throughout the year, and seasonal temperature shifts do not result in distinct oxygen stratification.
- Nutrient-rich (eutrophic) lakes usually have bottom sediments that contain organic matter.
- In the summer, the sun heats the top layer of a lake, the epilimnion, which causes it to become less dense.
- The bottom layer of the lake, the hypolimnion, does not receive sunlight and therefore remains cold.
- Since the epilimnion is less dense, it floats on top of the hypolimnion and the two do not mix.
- The thermocline is the dividing area between the top and bottom layers.

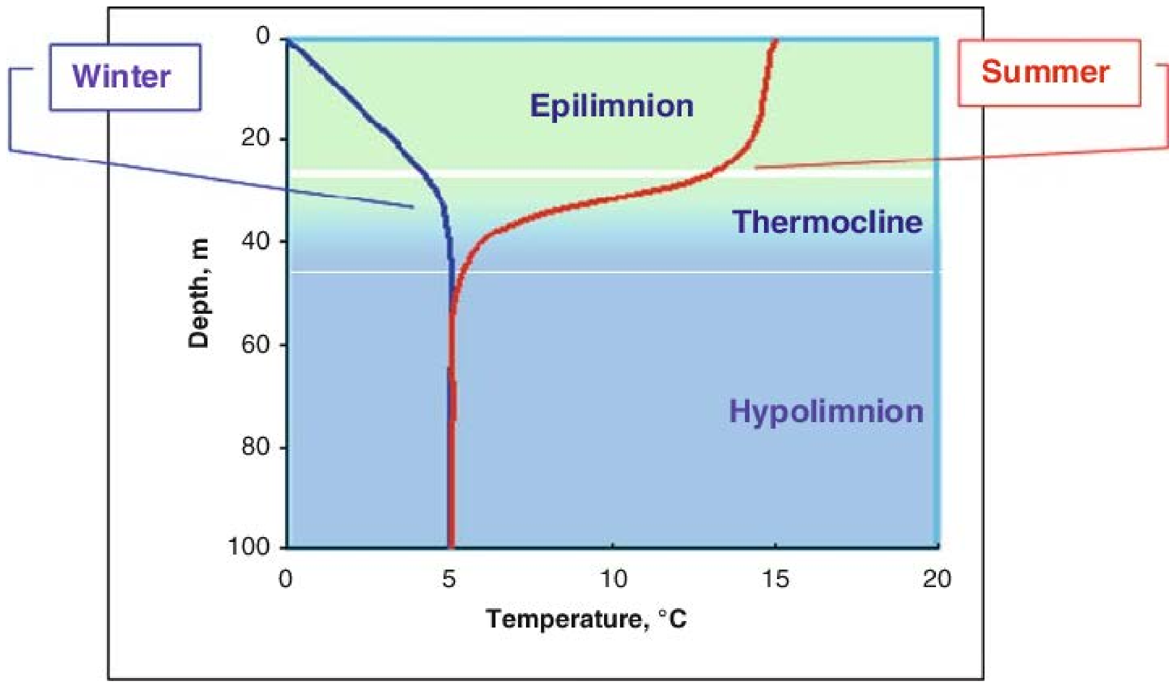


Temperature-driven stratification of lake in summer and winter

- With the onset of autumn, the epilimnion cools and the water becomes denser, sinking and mixing with the hypolimnion.
- The work required to mix the two layers is provided by wind, and the lake circulates, or overturns, completely.
- Circulation continues until the surface ice protects the lake from further wind action.
- The lake overturns again in spring after surface ice melts, and by summer it is stratified once again.
- After such mixing occurs, motile bacteria and algae migrate within the water column to again find their most suitable environment.

*Meromictic lake: layers of water do not intermix.

*Holomictic lakes: at least once per year, there is a physical mixing of the surface and the deep waters.



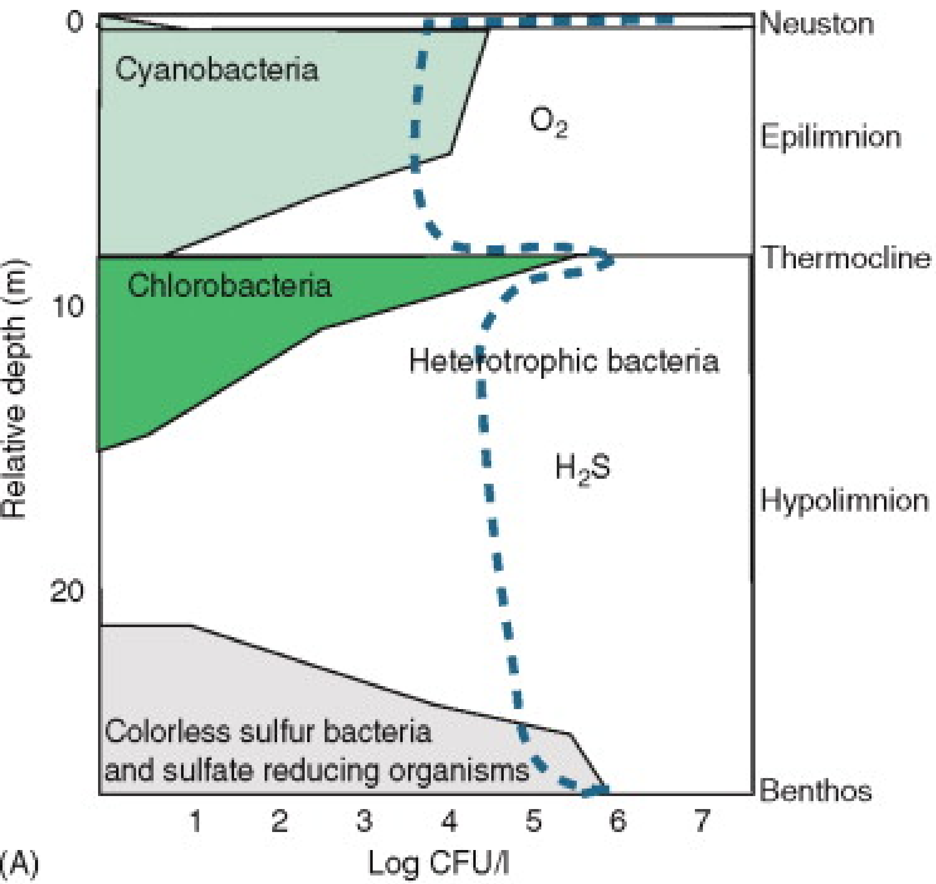
Microbial community of lakes

- **Neuston:** The term neuston refers to the assemblage of organisms associated with the surface film of lakes, oceans, and slow-moving portions of streams.
- It generally includes species:
  - living just underneath the water surface (hyponeuston),
  - individuals that are above but immersed in the water (epineuston),
  - taxa that travel over the surface on hydrophobic structures (superneuston or, more properly, a form of epineuston).
- The density of neustonic organisms decreases with increasing turbulence.
- Consequently, most neuston is confined to lentic habitats or some lateral components of the riverscape.
- The neustonic food web is primarily supported by a thin bacterial film on the upper surface of the water, a concentration of phytoplankton near the surface, and allochthonous inputs from trapped terrestrial and aquatic organisms.
- Protozoa are common in this assemblage, which also includes bacteria, algae, and floating macrophytes.
- The surface microlayers of alpine lakes were characterized by higher concentrations of DOC of smaller molecular size, and microbial cell numbers, particularly of Betaproteobacteria, tended to be higher in the bacterioneuston than in the subjacent water layer.
- Archaea, presumably Thaumarchaeota, were also found to be enriched in the neuston layer of high mountain lakes.

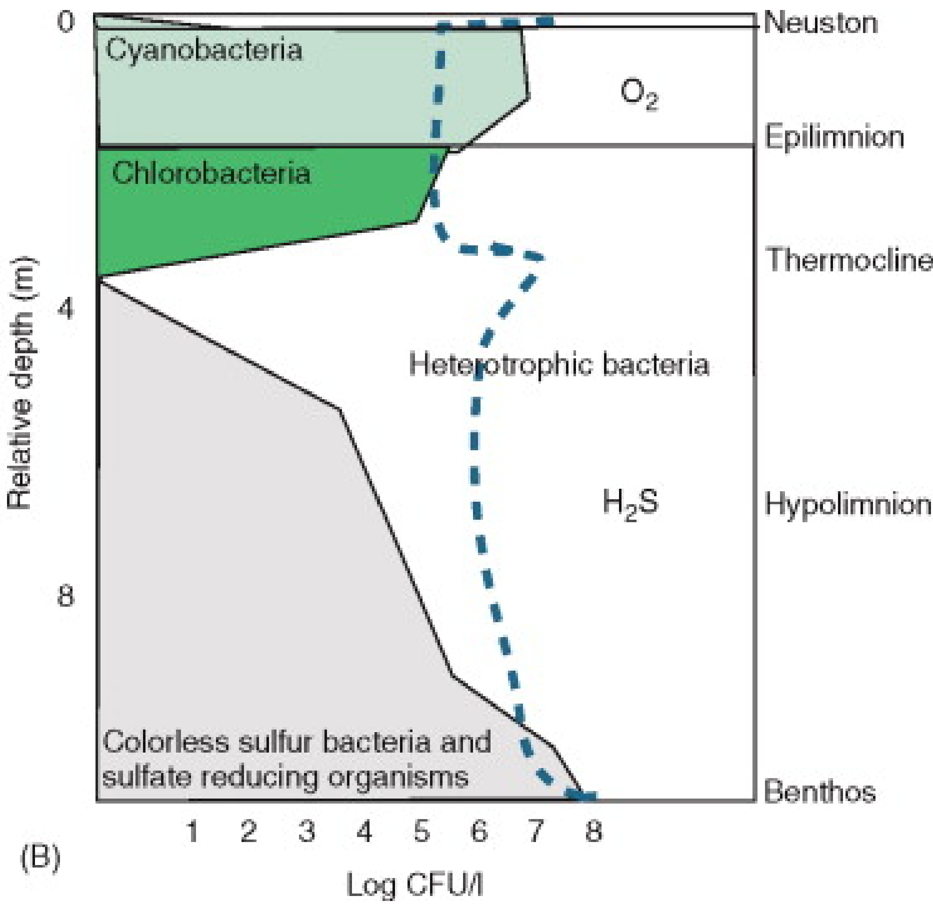
… **Microbial community of lakes**

- Prominent populations of autotrophic Chromatiaceae (Gammaproteobacteria) from the genera Chromatium, Amoebobacter, and Lamprocystris (Tonolla et al. 1999), as well as green non-sulfur bacteria from the Chloroflexus group, which are known for photoautotrophic or photoheterotrophic growth
- Archaeal methanogenesis usually dominates anaerobic carbon mineralization in anoxic hypolimnetic zone.
- Microbial assemblages in benthic region comprise a great variety of physiological groups , including—but not limited to—denitrifying bacteria, methano- and methylotrophs, fermenting and syntrophic bacteria, manganese-, iron-, and sulfate-reducers, and methanogens.

Vertical distribution of bacterial population within a lake



Oligotrophic lake



Eutrophic lake

Streams and Rivers

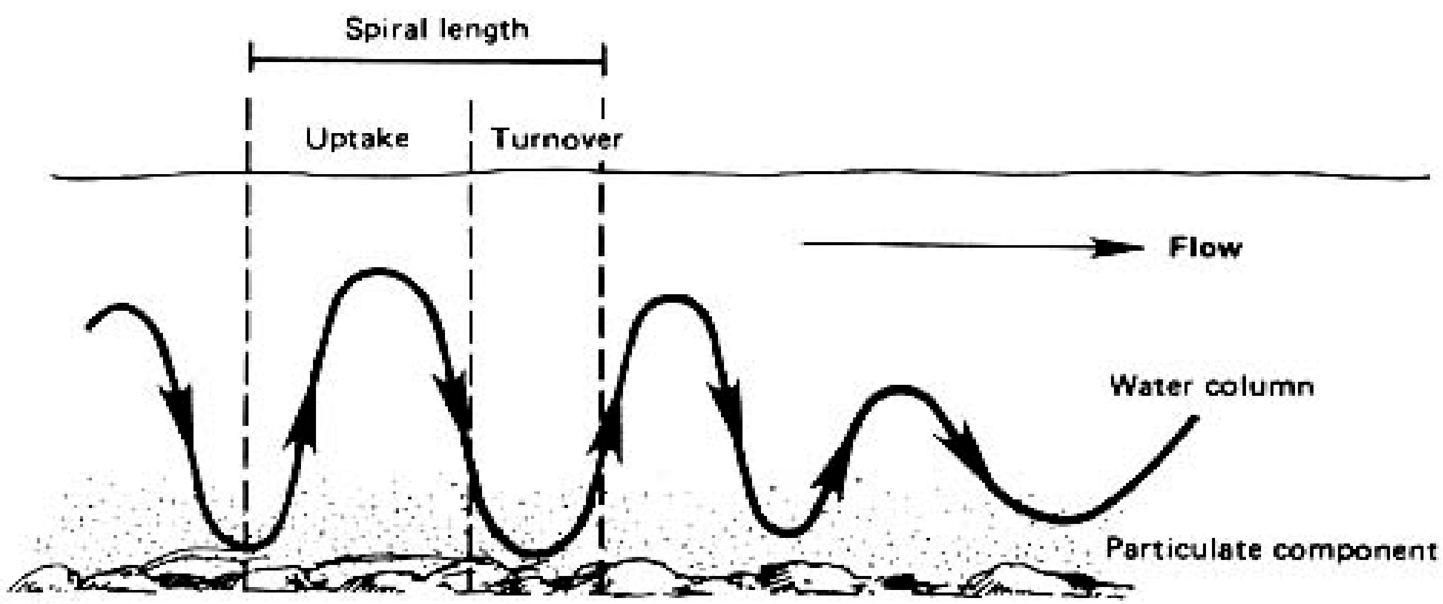
- There is sufficient horizontal water movement to minimize vertical stratification; in addition, most of the functional microbial biomass is attached to surfaces.
- Only in the largest rivers will a greater relative portion of the microbial biomass be suspended in the water.
- Depending on the size of the stream or river, the source of nutrients may vary.
- The source may be in-stream production based on photosynthetic microorganisms **.**
- Nutrients also may come from outside the stream, including runoff sediment from riparian areas (the edge of a river), or leaves and other organic matter falling directly into the water.
- Chemoorganotrophic microorganisms metabolize the available organic material and provide an energy base for the ecosystem.
- Under most conditions the amounts of organic matter added to streams and rivers will not exceed the system's oxidative capacity, and productive, aesthetically pleasing streams and rivers will be maintained.

...Streams and Rivers

- The capacity of streams and rivers to process such added organic matter is, however, limited.
- If too much organic matter is added, the water may become anaerobic.
- This is especially the case with urban and agricultural areas located adjacent to streams and rivers.
- The release of inadequately treated municipal wastes and other materials from a specific location along a river or stream represents a point source of pollution.
- Such point source additions of organic matter can produce distinct and predictable changes in the microbial community and available oxygen.
- Runoff from fields and feedlots, which causes algal blooms in eutrophic water bodies, is an example of a nonpoint source of pollution.
- When the amount of organic matter added is not excessive, the algae will grow using the minerals released from the organic matter.
- This leads to the production of O2 during the daylight hours, and respiration will occur at night farther down the river, resulting in diurnal oxygen shifts.
- Eventually the O_2 level approaches saturation, completing the self-purification process.

Spiraling of nutrients in the river

- Most microbial and many microscopic organisms in rivers are attached to surfaces such as submerged rock.
- Dissolved nutrients are rapidly absorbed by these attached organism and are liberated upon death and decay only to be absorbed again a small distance downstream.
- As a consequence, nutrients do not move with the speed of the current but exhibit a much slower movement.
- The path of a nutrient can be viewed as a spiral rather than a cycle, a phenomenon known as nutrient spiraling.



Microbial population

- Protozoa: *Paramecium*, *Didinium*, *Vorticella*, *Stentor*, *Amoeba*
- Bacteria: *Achromobacter, Flavobacterium, Brevibacterium, Micrococcus, Bacillus, Pseudomonas, Nocardia, Streptomyces, Micromonospora, Cytophaga, Spirillum, Vibrio*
- Stalked bacteria: *Caulobacter, Hyphomicrobium* (submerged surface)
- Cyanobacteria: *Microcystis, Anabaena, Aphanizomenon*
- Photoautotrophs: members of chlorobiaceae, chromatioceae (autochthonous in great deapth)
- Anaerobes: *Clostridium, Desulfovibrio, Methanogens*
- Fungi: *Torulopsis, Candida, Rhodotorula, Cryptococcus*
- Algae: members of chlorophycophyta (*Euglena*), chrysophycophyta, cryptophycophyta, pyrrhophycophyta, dinoflagellates, diatoms

Questions

- Write an essay on fresh water environment and its effect on microbial community.
- Discuss lake environment in terms of microbial community.
- Write short note on:
  - Effect of gases and nutrients on aquatic environment or fresh water environment
  - Thermal stratification of lakes
  - Neuston
  - Microbial community of lakes
  - River microbiology
  - Winogradsky column