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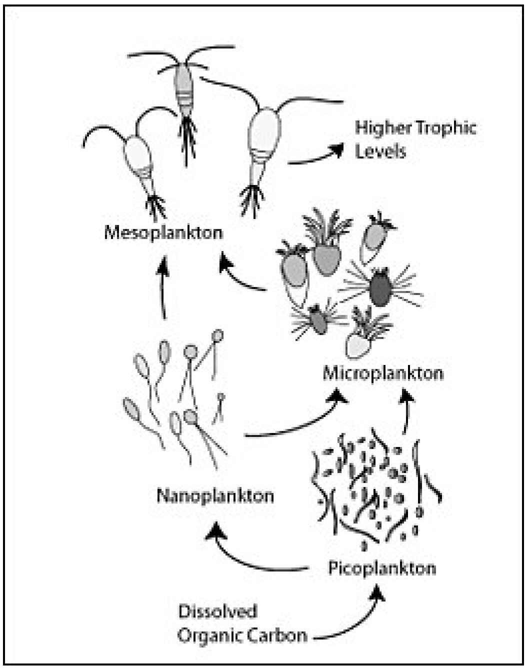
Microbial loop

The **microbial loop** describes a trophic pathway in the marine microbial food web where dissolved organic carbon (DOC) is returned to higher trophic levels via its incorporation into bacterial biomass, and then coupled with the classic food chain formed by phytoplankton-zooplankton-nekton. The term microbial loop was coined by Farooq Azam and Tom Fenchel et al.[1] to include the role played by bacteria in the carbon and nutrient cycles of the marine environment.



The microbial loop is a marine trophic pathway which incorporates dissolved organic carbon into the food chain.

In general, dissolved organic carbon (DOC) is introduced into the ocean environment from bacterial lysis, the leakage or exudation of fixed carbon from phytoplankton (e.g., mucilaginous exopolymer from diatoms), sudden cell senescence, sloppy feeding by zooplankton, the excretion of waste products by aquatic animals, or the breakdown or dissolution of organic particles from terrestrial plants and soils (Van den Meersche *et al.* 2004). Bacteria in the microbial loop decompose this particulate detritus to utilize this energy-rich matter for growth. Since more than 95% of organic matter in marine ecosystems consists of polymeric, high molecular weight (HMW) compounds (e.g., protein, polysaccharides, lipids), only a small portion of total dissolved organic matter (DOM) is readily utilizable to most marine organisms at higher trophic levels. This means that dissolved organic carbon is not available directly to most marine organisms; marine bacteria introduce this organic carbon into the food web, resulting in additional energy becoming available to higher trophic levels. Recently the term "microbial food web" has been substituted for the term "microbial loop".

Contents

History

Prior to the discovery of the microbial loop, the classic view of marine food webs was one of a linear chain from phytoplankton to nekton. Generally, marine bacteria were not thought to be significant consumers of organic matter (including carbon), although they were known to exist. However, the view of a marine pelagic food web was challenged during the 1970s and 1980s by Pomeroy and Azam, who suggested the alternative pathway of carbon flow from bacteria to protozoans to metazoans.

Early work in marine ecology that investigated the role of bacteria in oceanic environments concluded their role to be very minimal. Traditional methods of counting bacteria (e.g., culturing on agar plates) only yielded small numbers of bacteria that were much smaller than their true ambient abundance in seawater. Developments in technology for counting bacteria have led to an understanding of the significant importance of marine bacteria in oceanic environments.

In the 1970s, the alternative technique of direct microscopic counting was developed by Francisco *et al.* (1973) and Hobbie *et al.* (1977). Bacterial cells were counted with an epifluorescence microscope, producing what is called an "acridine orange direct count" (AODC). This led to a reassessment of the large concentration of bacteria in seawater, which was found to be more than was expected (typically on the order of 1 million per milliliter). Also, development of the "bacterial productivity assay" showed that a large fraction (i.e. 50%) of net primary production (NPP) was processed by marine bacteria.

In 1974, Larry Pomeroy published a paper in BioScience entitled “The Ocean’s Food Web: A Changing Paradigm”, where the key role of microbes in ocean productivity was highlighted. In the early 1980s, Azam and a panel of top ocean scientists published the synthesis of their discussion in the journal *Marine Ecology Progress Series* entitled “The Ecological Role of Water Column Microbes in the Sea”. The term ‘microbial loop’ was introduced in this paper, which noted that the bacteria-consuming protists were in the same size class as phytoplankton and likely an important component of the diet of planktonic crustaceans.

Evidence accumulated since this time has indicated that some of these bacterivorous protists (such as ciliates) are actually selectively preyed upon by these copepods. In 1986, *Prochlorococcus*, which is found in high abundance in oligotrophic areas of the ocean, was discovered by Chisholm, Olson, and other collaborators (although there had been several earlier records of very small cyanobacteria containing chlorophyll b in the ocean). Stemming from this discovery, researchers observed the changing role of marine bacteria along a nutrient gradient from eutrophic to oligotrophic areas in the ocean.

Factors controlling the microbial loop

The efficiency of the microbial loop is determined by the density of marine bacteria within it (Taylor and Joint 1990). It has become clear that bacterial density is mainly controlled by the grazing activity of small protozoans and various taxonomic groups of flagellates. Also, viral infection causes bacterial lysis, which release cell contents back into the dissolved organic matter (DOM) pool, lowering the overall efficiency of the microbial loop. Mortality from viral infection has almost the same magnitude as that from protozoan grazing. However, compared to protozoan grazing, the effect of viral lysis can be very different because lysis is highly host-specific to each marine bacteria. Both protozoan grazing and viral infection balance the major fraction of bacterial growth. In addition, the microbial loop dominates in oligotrophic waters, rather than in eutrophic areas - there the classical plankton food chain predominates, due to the frequent fresh supply of mineral nutrients (e.g. spring bloom in temperate waters, upwelling areas). The magnitude of the efficiency of the microbial loop can be determined by measuring bacterial incorporation of radiolabeled substrates (such as tritiated thymidine or leucine).

Importance in marine ecosystems

The microbial loop is of particular importance in increasing the efficiency of the marine food web via the utilization of dissolved organic matter (DOM), which is typically unavailable to most marine organisms. In this sense, the process aids in recycling of organic matter and nutrients and mediates the transfer of energy above the thermocline. More than 30% of dissolved organic carbon (DOC) incorporated into bacteria is respired and released as carbon dioxide. The other main effect of the microbial loop in the water column is that it accelerates mineralization through regenerating production in nutrient-limited environments (e.g. oligotrophic waters). In general, the entire microbial loop is to some extent typically five to ten times the mass of all multicellular marine organisms in the marine ecosystem. Marine bacteria are the base of the food web in most oceanic environments, and they improve the trophic efficiency of both marine food webs and important aquatic processes (such as the productivity of fisheries and the amount of carbon exported to the ocean floor). Therefore, the microbial loop, together with primary production, controls the productivity of marine systems in the ocean.

Many planktonic bacteria are motile, using a flagellum to propagate, and chemotax to locate, move toward, and attach to a point source of dissolved organic matter (DOM) where fast growing cells digest all or part of the particle. Accumulation within just a few minutes at such patches is directly observable. Therefore, the water column can be considered to some extent as a spatially organized place on a small scale rather than a completely mixed system. This patch formation affects the biologically-mediated transfer of matter and energy in the microbial loop.

More currently, the microbial loop is considered to be more extended (Kerner, Hohenberg, Ertl, Reckermannk, Spitzy 2003). Chemical compounds in typical bacteria (such as DNA, lipids, sugars, etc.) and similar values of C:N ratios per particle are found in the microparticles formed abiotically. Microparticles are a potentially attractive food source to bacterivorous plankton. If this is the case, the microbial loop can be extended by the pathway of direct transfer of dissolved organic matter (DOM) via abiotic microparticle formation to higher trophic levels. This has ecological importance in two ways. First, it occurs without carbon loss, and makes organic matter more efficiently available to phagotrophic organisms, rather than only heterotrophic bacteria. Furthermore, abiotic transformation in the extended microbial loop depends only on temperature and the capacity of DOM to aggregate, while biotic transformation is dependent on its biological availability (Kerner, Hohenberg, Ertl, Reckermannk, Spitzy 2003).

See also

- Biological pump
- f-ratio
- Microbial food web
- Plankton
- Marine snow
- Dissolved organic matter (DOM)
- Dissolved organic carbon (DOC)
- Phycosphere

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