**Module Essay 1**

Generally, the community of microbiology experts have reached the consensus that humans would not be able to live without microbes. Falkowski et al.(1) commented that “*Microbial life can easily live without us; we, however, cannot survive without the global catalysis and environmental transformations it provides.".* It may be bold to assume they are essential for our survival, but they are necessary to maintain our current quality of life. Microbial metabolism is responsible for providing nutrients to us indirectly through carbon and nitrogen fixation, maintaining an atmosphere that can support human life. Moreover, microbial life forms metabolic networks that are diver and large, making it difficult to reconstruct them.

Microbes are necessary for the biogeochemical processes that facilitate the fixation and recycling of essential nutrients. Carbon and nitrogen are necessary for the production of biological building blocks that make up our body (2), but they cannot be utilized as our nutrients unless they are either converted from its inorganic form or reduced. Nitrogen can only be incorporated into biological molecules through nitrogen fixation, where nitrogen gas (N2) is reduced to ammonium. Microbes are the only organisms that can accomplish this biotically, since their genes encode the enzyme nitrogenase—a heterodimeric complex that breaks apart the N≡N bond of N2 (1). Similarly, the carbon cycle cannot function without microbial life. There are three times as many global organic carbon stocks stored in soil as the amount of inorganic carbon stored in the atmosphere as CO2 (3). If microbial respiration were to cease, current primary production would deplete atmospheric CO2 stocks in 12 years (4) and dramatically decrease the rate of photosynthesis in our crops.

The same biogeochemical processes microbial life is also crucial for maintaining a livable atmosphere. They are responsible for almost all the oxygen we breathe (5). Both plants and microorganisms produce oxygen through the photosynthesis, which is written as CO2 + H2O -> CH2O + O2. While the process of microbial respiration in soil balances the oxygen produced by terrestrial photosynthesis, marine photosynthesis is a net source of O2. A small percentage (0.1%) of the organic matter synthesized in the oceans is buried in sediments, preventing it from contributing to the reverse reaction (5). Without the marine photosynthesis executed by single-celled organisms such as diatoms and coccolithophorids, net production of O2 would cease and atmospheric O2 would gradually be exhausted through respiration.

There is considerable difficulty in replicating the microbial metabolic networks facilitating biogeochemical processes. Some pathways in biogeochemical cycles are catalyzed by diverse multispecies microbial interactions. In the nitrogen cycle, NH4+ is first oxidized to NO2- by a group of Bacteria or Archaea then a different group of nitrifying oxidizing bacteria oxidizes NO2- to NO3- (6). Currently, we cannot afford to remove these assemblages of microorganisms from the biosphere since we lack the technology to imitate the individual redox reactions they carry out (1). The scale of these reactions is another challenging aspect we would need to overcome. There are approximately prokaryotes on earth in total (7) and these numbers do not include eukaryotic microorganisms. The sheer abundance of these microorganisms demonstrates that these microbial metabolic networks exist at a large scale that we may never be able to reconstruct entirely.

Our access to nutrients and a livable atmosphere would be severely compromised should microbial life cease to exist due to their crucial roles in biogeochemical processes, and we do not yet have the means to replace them. Although there have been successful attempts to replace some of the redox reactions carried out by microbial life, this is not done without consequences. Humans have acquired the ability to fix nitrogen through fossil fuel combustion, leading to a rise in atmospheric N2O, a greenhouse gas that has 300 times global warming potential of CO2. If we are not careful, our intervention in microbial-driven biogeochemical processes can lead to irreversible changes.

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