MICROBES AND GLOBAL ENVIRONMENTAL CHANGE

Despite the diminutive size of individual microbial cells, the high abundance of microorganisms in virtually all habitats ensures that they contribute significantly to global biomass. It has been estimated recently that the carbon biomass of prokaryotic microbes is 60-100% of that thought to occur in plants worldwide, and microbial nitrogen and phosphorus biomass exceeds that of all other organisms.Because microbes are known to have potentially high metabolic and growth rates (in general observation that physiological rates per unit mass tend to increase with decreasing size), it follows that microbial participation in global carbon, nitrogen, and phosphorus cycles is quite large. This includes a major component of global photosynthesis and respiration rates.

A big unanswered question is how microorganisms might respond to global environmental change. Because of their major roles in biogeochemical cycles, changes in the functioning of microbes can have global consequences. Will they buffer some of the changes (by negative feedback) or accentuate them? These are difficult questions to answer, especially given the great diversity of microorganisms and their geochemical functions. A simplistic view might examine a process such as microbial respiration (oxidation of organic carbon), which typically increases with increasing temperature. In a global warming scenario, one might imagine a transient burst of increased microbial respiration, especially in polar climates where permafrost can melt and suddenly make organic matter available for microbial consumption. This would cause a transient increase in CO_2, lasting until frozen substrates get depleted. However, it is only to the extent that respiration uses old organic matter that it would cause a net increase in CO_2, because respiration of newly fixed carbon does not lead to a net release of CO_2.

The ultimate effects of global change on microbial activities, and vice versa, often relate to the complex interplay between physical, chemical, and biological factors. For example, in the sea, increased temperatures could cause changes in circulation patterns and an increase in aquatic stratification that might lead to a decrease in aquatic production due to the reduced availability of nitrogen and phosphorus nutrients. This could lead to the rain of particulate organic matter from surface waters to the deep sea, the so-called biological pump of carbon. Thus, less carbon might be removed from the atmosphere by this mechanism, and this can be a positive feedback with regard to global warming. However, would increased winds or storms cause deeper mixing and reduction of the stratification? This could have the opposite effect.

Microorganisms carry out especially important roles in the biogeochemical cycling of two other greenhouse gases besides CO_2, namely methane and nitrous oxide. The biological production of these substances is microbial, with the methanogenic archaea producing methane and the denitrifying bacteria producing nitrous oxide. Both gases also have significant non-biological or anthropogenic sources as well. Interestingly, the biological removal of both of these gases is also microbiological. Methane is oxidized by specialized bacteria (called methanotrophs), organisms that live where they have a supply of methane (most often from an anoxic zone) and oxygen. Some methanotrophs live as symbionts in invertebrates near natural methane sources, such as methane seeps. Nitrous oxide can be reduced denitrifying bacteria to N_2 gas under anoxic conditions. Although it is known that both methane and nitrous oxide are increasing in the atmosphere, there is still considerable uncertainty in the accounting of supply and removal processes and uncertainty about how much of the change is due to biological processes. Therefore, it is difficult to make mechanistic predictions about how microorganisms might lead to or respond to future changes in these gases.

Another microbial process of note in this regard is the formation and removal of dimethyl sulfide (DMS).This gas is an important regulator of climate because it leads to the production of sulfate aerosols that form nuclei necessary for cloud formation over much of the planet. Clouds affect reflection of sunlight into space and also the distribution of precipitation. DMS is formed from dimethylsulfonyl proprionate (DMSP), which is an osmotic regulator in certain groups of microscopic marine algae. DMSP is converted to DMS biologically by a variety of organisms (microbes and small herbivores). Its production and release to the atmosphere is controlled by the combined activities of these microbes and animals, as well as physical mixing and gas exchange. We know very little about the details of what controls the biological component of this production. Therefore, it is extremely difficult to predict how global change will affect this important gas.

(Courtesy: Chapter in Microbial Diversity by James T. Staley & Jed Fuhrman, USA)