Recent advances in the biogeochemistry of microbial lipids (C.C. Patterson Award Lecture)

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In the past two decades, biogeochemists have made great progress in uncovering the full diversity of the microbial lipidome in natural environments. This staggering lipid diversity is shaped, among other factors, by the taxonomic composition of natural communities and by the environment, to which microbes adapt via modulation of their lipid membranes. Lipids consequently provide unique opportunities for the exploration of modern biogeochemical processes in the environment and the microbial communities mediating them as well as for the development of molecular proxies through which past environmental conditions and ecosystems can be reconstructed. In this lecture I will highlight three themes of my group's research in which the interrogation of microbial lipids in geological samples addresses key questions in biogeochemistry: (I) We study the distribution and isotopic composition of intact polar membrane lipids in marine subseafloor sediments in order to constrain the size, composition, and activity of the deep biosphere. Despite one key challenge being the differentiation of lipids from decaying and extant biomass, we can identify lipid signatures consistent with adaptation of members of the deep biosphere to extreme energy starvation. (II) We interrogate model organisms and environmental microbial communities in the laboratory to determine how growth conditions influence the microbial lipidome and to constrain rates of lipid biosynthesis and microbial metabolism of natural populations. (III) We develop new protocols for the study of biomarker distributions in geological samples at an unprecendented spatial resolution (sub-mm scale). This is achieved by direct analysis of biomarker molecules in undisturbed sedimentary material via laser desorption ionization hyphenated to ultra high resolution mass spectrometry. Our goal is to study high-frequency climatic oscillations in the late Quaternary and their impact on marine ecosystems with up to subannual resolution. Moreover, biomarker analysis at this fine scale will open new avenues for the examination of microbial populations in highly structured sedimentary matrices such as microbial mats and along geochemical gradients and interfaces. I will showcase recent examples of research as well as methodological challenges in these three areas.