DIVERSITY OF ARCHAEAL PHOTOPIGMENTS AND IMPLICATIONS FOR BIOSIGNATURES. S. DasSarma[1], P. DasSarma[1], V.J. Laye[1], P. Basting[2], and J. Slonczewski[2]. [1]University of Maryland School of Medicine, and Institute of Marine and Environmental Technology, Baltimore MD 21202 USA, [2]Biology Department, Kenyon College, Gambier, OH 43022 USA; sdassarma@som.umaryland.edu.

Introduction: Life on Earth evolved from a common ancestor into diverse species of organisms forming 3 distinct Domains of Life, Archaea, Bacteria, and Eukarya. Archaea, many of which are extremophiles, are thought to have been some of the earliest living cells occupying both the surface and subsurface of our planet [1]. Among the surface dwelling species, salt-loving halophilic Archaea (Haloarchaea) form spectacular highly visible blooms in hypersaline brines [2,3]. They have evolved a great variety of easily detected biomolecules such as purple retinal proteins which function in phototrophy, red-orange carotenoids for photoprotection and photorepair, buoyant gas-filled vesicles and flagella for photoresponse [4]. Their pigments contain conjugated double bond systems and delocalized π-electrons which absorb UV-VIS-NIR wavelengths and several of them are abundant enough to potentially serve as biosignatures [5].

We are focusing on two Haloarchaea, cold-adapted *Halorubrum lacusprofundi* from Deep Lake, Antarctica, and temperate *Halobacterium* sp. NRC-1, most likely from the San Francisco Bay salterns, to address the photobiology of Archaea [6,7]. Both organisms survive many extremes such as desiccation, high ionic strength, strong ionizing and UV radiation, and low oxygen concentration. They have been launched into Earth's stratosphere, where *H. lacusprofundi* exhibited greater survival than *Halobacterium* sp. NRC-1 primarily due to a more robust cold response [8]. Our recent efforts have been directed at characterizing their pigments with the goal of developing novel biosignatures for exploration.

Results and Discussion: We isolated phenotypic mutants in order to characterize haloarchaeal pigments. Mutations which reduced or increased pigment production resulted in the finding of genes coding light-driven proton pumps, e.g. bacteriorhodopsin, in purple membrane. This protein is the first member of a large and broadly dispersed family that converts light energy to chemical energy via a proton-motive gradient. We have observed that bacteriorhodopsin exhibits a reflectance spectrum complementary to plant and algal photosynthetic membrane (Fig. 1) [3]. This observation led to the proposal that retinal and chlorophyll-containing pigments may have co-evolved at an early evolutionary stage on an early 'Purple Earth'. As a result, bacteriorhodopsin may serve as a biosignature candidate.

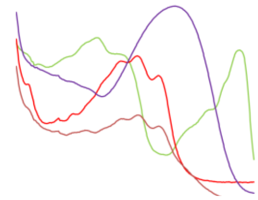

Fig. 1. Reflectance spectra of Haloarchaeal purple membrane and red-orange carotenoids compared to green algal photosynthetic membrane.

Additionally, the Haloarchaea produce plant-like carotenoid pigments, which serve as precursors to the purple membrane chromophore retinal as well as in photoprotection and photorepair. Mutants unable to produce such pigments have been important for understanding the pathway for retinal and carotenoid synthesis and for protection against UV radiation [4,9]. A general feature of the pathway is the presence of redundant enzymes mediating regulatory functions. These pigments also permit the direct photorepair of DNA lesions resulting from UV radiation [9,10].

Intracellular gas-filled vesicle nanoparticles (GVNPs) are buoyant, refract light and allow cells containing them, such as *Halobacterium* sp. NRC-1, to float to the surface of brine where they may be more easily detected [11,12]. Analysis of mutants which do not produce GVNPs have resulted in the finding of regulatory pathways in common with purple membrane and carotenoids, indicating that ancient Archaea are capable of coordinating the production of their various pigments. These primitive cells have the ability to respond to the available light quality depending on their exact location in the environment, and also to position themselves by regulating buoyancy and phototaxis.

Summary: Haloarchaea are commonly found floating at the surface of brine and exhibit spectra complementary to plants and algae. They are evolutionary relics and their novel photopigments provide new biosignatures for astrobiology.

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