The Green Edge: Haloarchaeal Photopigments as Biosignatures for Detection of Extant Life on Mars. S. DasSarma and P. DasSarma. Institute of Marine and Environmental Technology and University of Maryland School of Medicine, Baltimore MD 21202 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 species of interest to extant life on Mars are the salt-loving halophilic Archaea (Haloarchaea) which are able to survive many of the extremes found on Mars and form spectacular highly visible blooms detectable by remote sensing [2,3]. They contain a variety of easily detected biomolecules such as purple retinal proteins which function in phototrophy and red-orange carotenoids, such as bacterioruberins used in photoprotection and photorepair [4]. Their pigments contain conjugated double bond systems and delocalized π-electrons which absorb UV-VIS-NIR wavelengths and exhibit characteristics ideal as biosignatures [5].

Results and Discussion: We are employing two model Haloarchaea, a cold-adapted *Halorubrum lacusprofundi* from Deep Lake, Antarctica, and a temperate *Halobacterium* species, NRC-1, from the South San Francisco Bay salterns, to address photobiology and remote detection [6]. Both organisms survive in addition to high salinity, Martian extremes such as desiccation, ionizing and UV radiation, and low oxygen concentration, with *H. lacusprofundi* able to grow at sub-zero temperatures. As a result, *H. lacusprofundi* exhibited greater survival after launches into Earth's stratosphere, an analog of Mars, primarily due to a more robust cold response [8,9].

Our recent efforts have been directed at characterizing their pigments with the goal of identifying novel biosignatures for Mars exploration. These molecules can only be formed by biological process, unlike many others which may also have non-biological origins. We have isolated mutants with reduced or increased pigment production and identified genes important for pigmentation. Initially, we studied 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 (ATP) by a simple phototrophic system. Bacteriorhodopsin exhibits a reflectance spectrum with a trough of 568 nm and a "green edge" which is distinctive and easily detected (Fig. 1) [3,10]. We propose that retinal-containing pigments may have evolved at an early stage in evolution and led to a 'Purple Earth' [10], where life predominantly used this facile system, as widely seen even today. This is a scenario which may also apply to Mars.

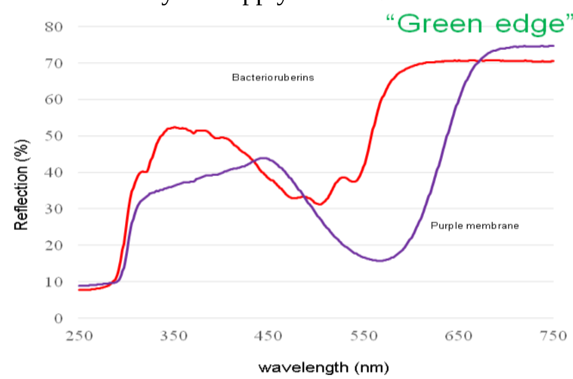

Fig. 1. *Reflectance spectra of Haloarchaeal pigments.*

Haloarchaea produce bright carotenoid pigments, lycopene and β-carotene, which serve as precursors to the purple membrane chromophore retinal. Additionally, they produce large amounts of bacterioruberins which are involved in photoprotection and photorepair. Mutants unable to produce these carotenoid pigments have been isolated and provided better understanding of their complex biosynthetic pathways. Using a genetic approach, as well as metabolic reconstruction, and transcriptomics, the biosynthetic pathways of pigment biosynthesis in *Halobacterium* sp. NRC-1 have been established [10,11]. A salient feature of the pathways is the presence of redundant enzymes mediating parallel reactions which are differentially regulated. The pigments also permit direct photorepair of DNA lesions resulting from UV radiation.

We propose that red-orange isoprenoid lipids, including carotenoids and retinal proteins, abundant in Haloarchaea and broadly distributed in all three Domains of Life represent excellent candidates for detection of extant life on Mars. Carotenoids exhibit three strong peaks, while purple membrane shows a single peak, all of which lead to the detectable green edge which may be used for detection of life on Mars.

References:

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