Halobacterium salinarum: Polyextremophile Model for Life Inside Martian Halite. A. Srivastava[1], Department of Bioinformatics and Biotechnology, BioAxis DNA Research Centre Private Limited, Hyderabad (13-51, Sri Lakshmi Nagar colony, L B Nagar, Hyderabad-500068, A.P., India, anushree.srivastava02@gmail.com)

Introduction: It is essential to define and understand the limits of life here on Earth before we can anticipate the potential for life on extraterrestrial destinations. Indeed, when we consider the prospects of extraterrestrial life, we should not be confined to the Earth-centric point of view of life, however, there are compelling lines of evidence at terrestrial analogues for extraterrestrial environments that project them as plausible models to those extraterrestrial sites, to study life at those extreme ends. The present work briefly reviews the recent studies on long-term survival potential of Halobacterium salinarum in ancient terrestrial halite, seeks to understand its poly-extremophilic life-style, and studies the possible survival potential of this archaeon inside Martian halite.

Evidence of Martian Halite and Long-term Survival Potential of Halobacterium salinarum: Significantly, halite was discovered from SNC meteorites [1] and their emergence from Mars was confirmed by several studies [2-4]. Recently, White et al, reviewed that nearly all Martian meteorites, which have been studied at microscopic details, have exhibited the "presence of secondary mineral assemblages and evaporitic deposits present within veins and internal fracture surfaces" and halite is one of those principal mineral phases associated with these "secondary alteration features" [5]. Halite, commonly called rock-salt, occurs as evaporite deposits in saline lakes and water courses or as bedded sedimentary deposits, results from the drying up of enclosed lakes and seas [6]. Masson et al. [7] extensively reviewed and suggested the presence of water activity in the distant Martian past [7], as well as, recent evidence for the former presence of salt water on the Martian surface was obtained by the NASA rovers.

Terrestrial analogs to Mars, where the presence of halite has been documented, have also been identified with the biological evidences. Notably, Atacama Desert (Chile) and Mars are analogous as both include hyperarid conditions, highly oxidizing chemistry, and intense UV radiation [8]. Fernández-Remolar et al [8] detected the excellent preservation of biomolecules in salty deposits, in Atacama Desert [8] and corroborated the possibility of long-term viability of these biological information in chloride-rich deposits [8]. They also suggested that possible subsurface salt-bearing deposits should be considered as high-priority targets for search for life on Mars [8]. Specifically, there are several studies have come into light that isolated and cultivated halophilic microorganisms from ancient salt deposits, provided detailed taxonomic descriptions, and retrieved DNA from ancient sediments [9-19], which again strongly supported the presence of biological material in evaporites of great geological age and suggested important astrobiological implications [20]. Among halophiles, Halobacterium salinarum seems to be a versatile microorganism and can be attributed as a poly-extremophile.

Halobacterium salinarum is a model organism from the halophilic branch of Archaea [21] that has been isolated from a single fluid inclusion in a 97 000-year-old halite crystal from Death Valley [13]. Several studies have discussed the dormant states of halophilic archaea, and other studies reported the presence of small spherical particles in fluid inclusions of modern and ancient halite [22-25]. Notably, a recent study reported that H. salinarum strain NRC-1 forms spheres apparently in response to low external water activity and suggested that spheres might represent dormant states and might facilitate survival over geological times [26]. Furthermore, Professor T. McGenity explained Halobacterium salinarum as long-lived poly-extremophiles, as it can grow in extremely high-salinity, can withstand high doses of UV radiation, and can survive over geological times buried within salt-crystals, living in tiny fluid-inclusions; therefore, proposed the super-survival of these microorganisms [27]. Also, to stay alive over long period of time and to obtain energy to repair proteins and nucleic acid, they can feed on organic matter from co-entombed microbial cells such as, D. salina and other dead cells of haloarchaea that are not hardy enough to survive in brine inclusions [28].

Conclusion: Indeed, the evidences of presence of salt-water in Martian past, the detection of halite of Martian origin, and several documentations that suggest the viability of H. salinarum for thousands and possibly millions of years in ancient terrestrial halite, compel to envisage the possible halophilic microbial life on Mars. As reviewed, H. salinarum are adept in employing multiple survival strategies to withstand adverse environmental conditions, such as, they are adapted to acquire dormant states by forming spheres when exposed to low-water activity, they can survive hyper-salinity and high-radiation, and can employ interspecies interaction to stay alive over geological time scales. Thus, given the poly-extremophilic nature and unique characteristics, H. salinarum deserves special interest in astrobiology. In particular, this haloarchaea may present a tractable model to ultimately understand the possible microbial life on Mars, if detailed understanding of its extreme survivability, energy metabolisms, and adaptive functions in the microenvironment of halite, which are still scarcely studied especially in astrobiological context, come into light in further studies.

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