

The H₂O₂-H₂O Hypothesis: Extremophiles Adapted to Conditions on Mars?

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The discovery of extremophiles on Earth is a sequence of discoveries of life in environments where it had been deemed impossible a few decades ago. The next frontier may be the Martian surface environment: could life have adapted to this harsh environment?

What we learned from terrestrial extremophiles is that life adapts to every available niche where energy, liquid water and organic materials are available so that in principle metabolism and propagation are possible. A feasible adaptation mechanism to the Martian surface environment would be the incorporation of a high concentration of hydrogen peroxide in the intracellular fluid of organisms. The H₂O₂-H₂O hypothesis suggests the existence of Martian organisms that have a mixture of H₂O₂ and H₂O instead of salty water as their intracellular liquid (Houtkooper and Schulze-Makuch, 2007). The advantages are that the freezing point is low (the eutectic freezes at 56.5°C) and that the mixture is hygroscopic. This would enable the organisms to scavenge water from the atmosphere or from the adsorbed layers of water molecules on mineral grains, with H₂O₂ being also a source of oxygen. Moreover, below its freezing point the H₂O₂-H₂O mixture has the tendency to supercool.

Hydrogen peroxide is not unknown to biochemistry on Earth. There are organisms for which H₂O₂ plays a significant role: the bombardier beetle, *Brachinus crepitans*, produces a 25% H₂O₂ solution and, when attacked by a predator, mixes it with a fluid containing hydroquinone and a catalyst, which produces an audible steam explosion and noxious fumes. Another example is *Acetobacter peroxidans*, which uses H₂O₂ in

its metabolism. H_2O_2 plays various other roles, such as the mediation of physiological responses such as cell proliferation, differentiation, and migration. Moreover, most eukaryotic cells contain an organelle, the peroxisome, which mediates the reactions involving H_2O_2 . Therefore it is feasible that in the course of evolution, water-based organisms evolved into employing H_2O_2 as an antifreeze, which would also have the function as a water collector.

If we would find life on Mars based on an intracellular H_2O_2 - H_2O mixture, this would not necessarily imply an independent origin of terrestrial and martian life. For that, a detailed study of the biochemistry and genetics is needed. The transfer of terrestrial organisms to Mars or vice versa is a possibility given favorable conditions for the origin and persistence of life on both planets early in solar system history (Schulze-Makuch and Houtkooper, 2007). The transfer of terrestrial organisms by early spacecrafts to Mars that either landed or crashed is a possibility, but it is not plausible that these organisms evolved in a few years. We suggest that we already have evidence of their existence from the Viking landers in two widely distant locations. The H_2O_2 - H_2O hypothesis does explain the Viking observations remarkably well, especially (1) the lack of organics detected by GC-MS, (2) the lack of detected oxidant(s) to support a chemical explanation, (3) evolution of O_2 upon wetting (GEx experiment), (4) limited organic synthesis reactions (PR experiment), and (5) the gas release observations made (LR experiment)(Houtkooper and Schulze-Makuch, 2007).

From the amounts of evolved CO_2 , O_2 and N_2 in the GEx experiment it can be concluded that the organisms have an excess oxidative content. This is a problem since in any destructive test, even by laser desorption-mass spectrometry (LDMS), the organisms may decompose completely into H_2O , CO_2 , O_2 , and N_2 . The same will occur if the organisms are exposed to excess water, as they will perish due to hyperhydration. The consequence for future biology experiments is that the most fruitful approach may be the detection of metabolism under close to local environmental conditions, especially avoiding the addition of too much water. Of the Viking experiments, the PR experiment which aimed at carbon assimilation was the closest to natural conditions. And, in fact, the PR experiment did detect organic synthesis (Klein, 1978, 1999).

For future missions to Mars, anticipation of what we might find is a dire necessity because of the slowness of the empirical cycle of observation, interpretation, the choice of the next instrument suite, and execution of the next mission. A sample return mission could provide more clarity by making all the analytical abilities available that present technology affords. However, the conditions under which the hypothesized, but unknown, organisms would survive a sample return journey is a formidable challenge, requiring the possibilities of in situ research to be exhausted first.

References: Houtkooper, J.M., and Schulze-Makuch, D. (2007) A Possible Biogenic Origin for Hydrogen Peroxide on Mars: The Viking Results Reinterpreted. In press at *Int. J. of Astrobiology*. Klein, H.P. (1978) The Viking biological experiments on Mars. *Icarus*, 34, 666-674. Klein, H.P. (1999) 'Did Viking discover life on Mars?', *Origins of Life and Evolution of the Biosphere*, 29: 625-631, 1999. Schulze-Makuch, D., and Houtkooper, J.M. (2007) Martian Extremophiles? The H₂O-H₂O₂ Hypothesis and Its Implications for the Mars Phoenix Mission. LPSC XXXVIII, abstract #1171.