WHERE TO LOOK NEXT: EXTANT LIFE NICHES AND BIOMARKERS ON MARS. P. A. Johnson[1,3], J. C. Johnson[1,2,3], and A. A. Mardon[1,3], [1]Faculty of Medicine & Dentistry, University of Alberta (email: paj1@ualberta.ca), [2]Faculty of Engineering, University of Alberta (email: jcj2@ualberta.ca) [3]Antarctic Institute of Canada (103, 11919-82 Str. NW, Edmonton, Alberta CANADA T5B 2W4; email: aamardon@yahoo.ca)

Introduction: All life consumes energy, which can become converted and result in the production of some form of waste byproduct. Depending on the type of waste product removal system or excretion mechanism utilized by a life form, it may be possible to detect these compounds through indirect means. Currently, there is a lack of evidence for life on the surface of Mars suggesting life may have a specialized subsurface niche characterized by a microbial ecology. Furthermore, there is a possibility for carbon-based anaerobic systems to thrive in such a niche with or without liquid water. In fact, excavation missions have yet to dig underground and as such, there is a possibility an ecosystem for extant life exists beneath Martian surface. Therefore, extant life on Mars may not rely on solar energy but rather chemical energy.

The search for extraterrestrial extant life extensively relies on the assumption that a specialized environment to provide the basic requirements of life exist on Mars. It is therefore essential for there to be access to the requirements of life in this supposed environment. However, there is still no consensus regarding these requirements. Here, we identify and suggest potential areas for consideration in future missions and investigations.

Characteristics of Life-Sustaining Niches: Traditionally, there are seven characteristics associated with living things including: nutrition, respiration, movement, excretion, growth, reproduction and sensitivity. While water has commonly been recognized as a requirement for life on Earth, according to Benner *et al.*, there are only two absolute requirements for life to sustain these functions: (i) an energy source, such as light from the Sun or radioactive decay and (ii) a stable and suitable temperature range which can allow for chemical bonding. As such, the primary and foremost step in the search for extant life is to identify features, which could be utilized by remote sensing tools to detect these life-sustaining environmental niches.

Biogenic requirements based on the origins of life: the concept of the protobiont is one of popular interest in evolutionary biology. Protobionts are described as the precursors to prokaryotic cells which self-organized using microspheres of organic or inorganic compounds engulfed in lipid membranes. In these preliminary "cells", macromolecules consisting of peptides, carbohydrates, nucleic acids and other lipids arranged itself with water being a critical factor in the assembly of its endoplasm. Using this theory, it is possible to design remote sensing tools that specifically target sensing the presence of biogenic molecules, such as amino acids which could be an indicator of life on Mars.

Niches Requiring Solar Energy: Another approach is to precisely identify locations on Mars consistent with Benner and colleagues' definition. For instance, locations on Mars' surface receiving solar irradiance could be scouted using remote sensing for biogenic markers. Photosynthetic processes may additionally result in gas exchange, which could also be monitored in robotic probe missions to detect life-supporting niches on Mars.

Niches Requiring Chemical Energy: Chemosynthesis as opposed to photosynthesis, is also a means for primary energy production on Earth. There are certain lithotrophic microorganisms that survive in ecosystems which rely on inorganic compounds such as elemental sulfur, sulfur oxide, hydrogen sulfide or iron originating from hydrothermal vents on the ocean floor to meet their energy demands. This provides a basis for scanning similar surfaces on Mars where microorganisms have access to inorganic compounds such as sulfur which can be oxidized to produce energy.

Chemical Energy in the Core. Mars' core could additionally be a location of interest based on the requirement for energy. The core of Mars is hypothesized to consist of a mixture of iron, sulfur and perhaps even oxygen. These would be ideal for lithotrophic microorganisms. Volcanic surfaces may also be a source of interest particularly with the abundance of gases and compounds such as sulfur and iron for chemolithotrophs. Another source of energy which could be harnessed by life forms on Mars is radioactive decay, which may critically be involved in generation of heat in the core. Unfortunately, excavation missions have yet to dig past a layer of gravel to determine the composition or presence of life underneath soil.

Historical Evidence and Techniques: There have been several features previously utilized in the search for extraterrestrial extant life on Saturn's moon, Titan. In the Cassini-Huygens missions, aerial imaging was used for the identification of water ice and black methane lakes. These were identified polar regions of the moon. A similar approach can be used on Mars in the search for lake-beds of an essential compound for life. While several historical missions have determined no signs of water on Mars, sophisticated satellite imaging still reveal areas where rivers, lakes or ice in the ground or on glaciers could have existed.

Chemolithoautotrophs on Mars: Chemosynthesis in contrast to photosynthesis, is an alternate means for primary energy production on Earth and subcategory of life supported by chemical energy. There are certain chemolithoautotrophic microorganisms that survive in ecosystems which rely on inorganic compounds such as elemental sulfur, sulfur oxide, hydrogen sulfide or iron originating from hydrothermal vents on the ocean floor to meet their energy demands. As a form of autotroph, these organisms are capable of directly obtaining energy from a chemical source as opposed to having to consume other organisms to do so. Chemolithoautotrophs depend on inorganic compounds such as sulfur to be oxidized through a chemical reaction to generate energy. As such sources of inorganic compounds may become an optimal niche for organisms relying on the chemosynthesis for energy consumption.

Biomarkers for Extant Life. The reduction-oxidation reaction itself involves formation of byproducts, which could potentially be used in the detection of extant life. For example, a common pathway seen in chemosynthetic bacteria found in hydrothermal vents involves the carbon dioxide and hydrogen sulfide as reactants. The products of this reaction are carbohydrates and water and waste sulfur, which may be expelled or stored in the cytoplasm. However, chemosynthesis is not restricted to this pathway alone. In fact, certain bacteria are additionally able to utilize oxidizing and reducing agents including hydrogen and oxygen, divalent iron ions, ammonia and nitrates to produce energy. On Mars, waste byproducts of these reactions such as sulfur or other oxidized compounds may enable the detection of extant life.

Moreover, this theory suggests the use of remote-sensing probes or excavating robot to identify such biomarkers beneath Martian soil can validate the occurrence of metabolic reactions, which are inherent to chemolithoautotrophs.

Potential Regions to Search: With the vast and diverse geography and topology of Mars, identifying life-sustaining niches involves determining and targeting locations where these specific chemosynthetic organisms are able to thrive. A promising area are the polar ice caps along with regions characterized by surface frost and water ice glaciers, particularly because the presence of water in itself, is known to be key to life, although there are several hypotheses suggesting the feasibility of extraterrestrial extant life with a source of energy and stable environmental conditions alone. Volcanic surfaces may also be a source of interest particularly with the abundance of gases such as methane, hydrogen, and hydrogen sulfide, as well as elemental compounds such as sulfur and high iron content for chemolithoautotrophic microorganisms. The heat of geothermal activity may play a role in melting permafrost or other subsurface sources of water for a subsurface microbial community. Additionally, areas rich in iron oxides, once hypothesized to be Martian 'continents' and characterized by an intense reddish color, can also be mapped out through aerial imaging using remote drones.

Limitations: The successful implementation of these searches and/or excavation systems incorporating these approaches requires an advanced technological developments including probes, remote sensing systems and drones which may be resource-exhaustive. Excavation has also yet to have been performed due to the presence of a layer of thick gravel beneath Martian soil. Moreover, the current body of evidence limits the validation of these ideas and as such, the majority of evidence and knowledge remains hypothesis-based.

Conclusion: The search for extant life on Mars critically depends on the identification of life-sustaining environmental niches. These niches can be identified by sensing biogenic biomarkers, on the basis of sources of solar, chemical or radioactive energy, and based on historical evidence.

Chemolithoautotrophs may produce byproducts, which could be utilized as a biomarker in the search for extant life on Mars. Furthermore, there are regions in the Martian geography abundant with these biomarkers and promising for future exploration.

Acknowledgments: Thank you to all members of the public for supporting this research: this research would not have been possible without the resources and financial contributions of TakingITGlobal, the Government of Canada under the Canada Service Corps, and the Antarctic Institute of Canada.

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