RAMIFICATIONS OF A STERILE MARS

Gilbert V. Levin
Adjunct Professor, Beyond Center
College of Liberal Arts and Sciences
Arizona State University, Tempe, AZ
gilbert.levin@asu.edu

ABSTRACT

The seldom considered ramifications of a sterile Mars are explored.

Very much is now known about the environment on Mars. Herein, the individual and collective environmental parameters are examined with particular consideration of those that might be inimical to life as we know it, or as might reasonably be assumed to be so to alien life. It is shown that no single measurement or combination of them precludes the ability of Mars to support even a wide number of terrestrial microbial species, let alone the likely greater tolerance and/or adaptability of possible alien life forms. Some yet unknown factor or combination of factors would have to be responsible for Mars' failure to generate life or to successfully harbor viable forms received from space. Since Mars is so Earth-like, the red planet's sterility could deliver a fatal blow to the growing concept of a cosmic Biologic Imperative, and would raise the daunting prospect that Earth is a unique or a very rare habitat.

Introduction

The first recorded concept of life transported through space was that of Anaxagoras (c. 500 BC – 428 BC), a Pre-Socratic Greek philosopher, who, thereby, initiated the theory of panspermia[1]. Though widespread interest arose and prevailed, it took until 1864 for the first direct experimental investigation. Shortly after the Orgueil meteorite fell that year, Louis Pasteur attempted to culture microorganisms from a piece of the Orgueil aseptically removed and placed into his hay infusion broth. No growth occurred. Interest in extraterrestrial life, however, continued unabated, indeed increased with the rise of technology that facilitated remote and direct probing of the heavens. Early focus was on Mars[2]. It was the nearest planet to Earth, therefore easiest to observe, and it was conceived to share the life-habitable zone in which Earth life thrived. However, it wasn't until 1976, with the landings of the Viking spacecraft[3] on Mars, that the next direct extraterrestrial life-seeking experiments were conducted. One of those experiments, the Labeled Release (LR)[4] obtained responses[5] from samples of Martian soils duplicating responses it had obtained from a number of terrestrial soils. Although satisfying the pre-mission criteria for the detection of life, the Martian LR results were not accepted as proof of life by the consensus of interested scientists. A wide variety of chemical and physical reactions mimicking life was proposed to explain away the positive results. After a decade of studying the LR results and pertinent new data, the author published[6] his conclusion that extant microbial life had, indeed, been detected in the topsoil of Mars. That conclusion was based on the strong legacy provided by the thousands of pre- and post-Viking tests on a wide variety of terrestrial soil which never produced an erroneous response. In addition, the conclusion was supported by many new facts learned about the Martian environment and the finding of extremeophiles inhabiting Mars-like niches on Earth.

Much controversy followed and continues today. Despite rebuttals[7] to the chemical and physical propositions, and despite the lack of a demonstration of an abiotic simulation of the LR Mars data, the consensus, while somewhat yielding, remains strongly against the biological interpretation. The copious arguments expressed in the literature for more than a third of a century have stridently taken one or the other side of the issue. While a number of the pro-biology papers have considered the import of finding life on Mars, none has considered the impact on science, philosophy, religion and society that would accompany the finding, or even the acceptance of the concept, of a sterile Mars.

Pertinent Data

The Martian environment has now been extensively defined by analyses performed by 22 successful missions, composed of eight landers and 14 flybys and orbiters which have mapped the entire surface of Mars, and by countless Earth-based observations, plus the detailed examination of Martian meteorites. The information gathered by 22 successful missions, composed of eight landers and 14 flybys and orbiters, and by countless Earth-based observations, plus the detailed examination of Martian meteorites found on Earth has been summarized[8]. Table 1, adapted from that paper, **lists** a comparison of such environmental factors on Mars and Earth.

TABLE 1. COMPARISON OF ENVIRONMENTAL FACTORS ON MARS AND EARTH

Selected Parameters Influencing Biological Evolution on Mars and Earth

Parameter (Values from various published sources)	Mars	Earth
Age	**~4.6 billion years**	**~4.6 billion years**
Diameter	**4,217 miles**	**7,922 miles**
Mean density	**3933 kg/m^3**	**5515 kg/m^3**
Surface gravity	**3.69 m/s^2**	**9.78 m/s^2**
Escape velocity	**11,185 mph**	**25,055 mph**
Atmosphere	**7 - 9 mb; 95% CO_2, 3% N; 0.13% O_2; ~0.3ppm CH_4 Total density at surface 0.20 kg/m^3**	**1014 mb; 77% N; 21% O_2 0.03% CO_2; 1.7 ppm CH_4 Total density at sea level 1.23 kg/m^3**
Liquid water at surface	**Diurnally on surface, as moisture in soil, inter-crystalline films**	**Copious**
Organic matter	**?**	**0.1%**
Bio-Chirality	**?**	**L-amino acids, D-carbohydrates**
Selected crustal elements	**44% O, 22% Si, 12.1% Fe, 3.8% Ca, 1.8% S , 1% P, 0.8% K, , 0.5% Mn, ?% C**	**47% O, 28.2% Si, 5.6% Fe, 4.15% Ca, 0.03% S, 0.1% P, 2.1% K, 0.1% Mn, 0.02% C**
Distance from Sun	**128-155 million miles**	**91-94 million miles**
Incident solar flux	**Total: 589.2 W/m^2, UV ~ 50 W/m^2, up to 400 nm (280-315 nm is bio-damaging zone), significantly higher than Earth in bio-damaging frequencies, greatly attenuated by dust in atmosphere**	**Total: 1,367.6 W/m^2, UV ~ 50 W/m^2, up to 400 nm, greatly attenuated by ozone layer, clouds and dust in atmosphere**

Ionizing Radiation	**Protons 6,000 MeV/cm2/sec** **Neutrons 1,400 MeV/cm^2/sec** **Highly variable**	**Less than Mars** **Highly variable**
Albedo	**0.250**	**0.306**
Surface temperature	**-126 ^{o} C to + 22 ^{o} C**	**-33 ^{o} C to + 58 ^{o} C**
Rotation period (day)	**24.62 hrs**	**23.93 hrs**
Flattening	**0.00648**	**0.00335**
Orbital eccentricity	**0.093**	**0.017**
Revolution period (year)	**687 days**	**365 days**
Moons	**2**	**1**
Catastrophic events	**Atmosphere and oceans lost: 3.8-4.6 ga**	**Extinctions: 450, 350, 250, 200; 60 mya** **Oxygen poisoning: 3 ga**
Magnetic Field at Surface	**> 5,000 nT**	**> 40,000 nT**

From Levin, G. V., "Mars Life – how Darwinian pressures might have shaped its form and function," Instruments, Methods, and Missions for Astrobiology, Proc., 5906, OD 1 – 10, 2005. Revised and augmented for this paper.

Analysis of Data

An examination of the factors on Mars that singly, or in combination, have the potential for being antithetical to life finds the following: atmosphere, liquid water at surface, organic matter, selected crustal elements, incident solar flux, ionizing radiation, surface temperature, orbital eccentricity, catastrophic events; magnetic field at surface. Each is treated below.

Atmosphere: The high percentage of CO2 reduces to (~8/1014) x 95 = ~0.75% when extrapolated to the Earth's atmosphere. Organisms on Earth have been successfully grown in much higher concentrations of CO2, even up to 100%[9]. Perhaps of greater concern is limitation by the absolute amount of CO2 available. However, this would only result in limiting the amount of biomass, not precluding its existence.

Liquid water at surface**:** This is, perhaps, the most challenging problem. The existence of any liquid water on or near the surface of Mars was long denied. However, gradually the evidence, culminating in images of liquid water drops on the Phoenix lander, is generally accepted. Now, there is little resistance to recognizing that, at a minimum, thin films of liquid water do exist, at least diurnally, over vast regions of current Mars, including at both Viking landing sites. On Earth, such films provide enough available water to support continual microbial growth. Moreover, such films exist within the perpetual ice at Earth's South Polar Cap, within which microorganisms have been found[10].

Organic matter: The long-claimed lack of organic matter on Mars was an impassable barrier to life as we know it, or as it might reasonably be conceived. A variety of theories involving putative oxidants on the surface of Mars were advanced to explain this lack. Since then, a number of reports now claim that the Viking Molecular Analysis instrument may well have been in error when it failed to find organic matter. However, until organic matter is found, this barrier will exist. If the lack of organic matter is confirmed, this would argue strongly for some mechanism of destroying the organic matter plummeting to Mars in meteorites, interplanetary dust and that demonstrated to be synthesized by sunlight shining on the Martian atmospheric CO and CO_2. That this mechanism is the putative oxidants is unlikely in view of negative sensitive searches[11] and theoretical rationales. (Oxidants are not listed in Table 1, because no direct evidence for them has been found).

Selected crustal elements: No element yet detected on Mars presents a lethal threat. However, some might yet be discovered, such as toxic heavy metals. However, even if it exists on Mars, Martian biology might be expected to cope with it, as has terrestrial biology living in and metabolizing high concentrations of arsenic[12].

Incident solar flux: Despite its greater distance from the Sun, Mars is subject to a significantly denser surface flux of the more damaging portion of the biologically harmful portion of the spectrum. The precise flux numbers remain to be determined, along with the daily factors that cause the surface flux to vary significantly below the value at the top of the troposphere. However, terrestrial microorganisms exposed to estimated Martian levels of UV have survived[13]. Moreover, endoliths on Earth have evolved to live within rocks where they are shielded from UV and find sufficient water presumably from the thin films between the mineral crystals. Life on Mars would likely have followed the same Darwinian path.

Ionizing radiation: Its small magnetic field and thin atmosphere allow most incident ionizing radiation to reach the surface of Mars. It had been widely thought that damage to DNA through long-term exposure to ionizing radiation precluded an on-going biology. However, studies[14, 15] have shown that the Martian incident flux is readily be withstood by many terrestrial species of microorganisms, especially under temperatures as low as those on Mars. Whether this viability is attributable to rapid DNA repair or sufficiently frequent microbial reproduction is still under study, but it seems ionizing radiation incident to the Martian surface is not inimitable to life.

Orbital eccentricity: The orbital eccentricity of Mars is almost 5.5 times that of Earth. This means a much longer seasonal effect with greater temperature extremes on Mars, which might be thought to adversely impact the ability of life, especially if similar to terrestrial life, to survive. However, this is unlikely to apply to microbial species. It is common laboratory practice to maintain microbial cultures for periods of time far in excess of terrestrial seasons.

Catastrophic event: Mars is believed to have suffered a catastrophic event in its early history, removing most of the planet's atmosphere and water. The principal effect with respect to life has been presumed to have been the subsequent unavailability of liquid water. The resultant low atmospheric pressure has been cited as preventing water in the liquid phase. However, at the two Viking sites, for their whole functional period (up to six years), the total atmospheric pressure never fell below 6.1 mb, the triple point pressure below which water does not occur in liquid phase. The case for liquid water on present-day Mars has been made above.

Magnetic field at surface: Mars' low magnetic field allows higher fluxes of ultraviolet and ionizing radiation to reach the surface implying significant hazards to life. These have been addressed above and not found inimical to many terrestrial species of microorganisms. However, it has been found[16] that Mars' magnetic field indicates that plate tectonics do operate within the planet. This is important in dispelling thoughts that, absent plate tectonics, organic and other surface matter would not be recycled as is believed essential for long-term continuation of life on Earth.

This truncated review of what might be called habitat factors on Mars reveals no single parameter that would preclude even some species of terrestrial microbes, without even requiring an invocation of Darwinian adaptation to such a condition had it been found. Nor is any obvious combination of these factors more potent in this context.

The Biologic Imperitive:

Next, it might be instructive to consider recently gained knowledge on the limits, rather non-limits, of these factors on terrestrial extremeophiles. It is now known that life pervades our total environment, above, on and beneath the entire surface of our planet, with the possible exception of extremely high temperatures, such as in magmas. Not only does life astound us by invading and adapting to severe natural environmental conditions, moreover it even frustrates man's best intellectual efforts to defeat it. These unwanted invasions of life occur in carefully sterilized products ranging from band-aids to surgical instruments and supplies, to foods, and to spacecraft assembled from "sterilized" parts in clean rooms. No matter how stringent our efforts, sooner or later, before or after the pull-date on "sterilized" cans of food, microorganisms inexorably reclaim their domain. It thus seems that the long-considered "Biologic Imperative" does, indeed, apply to Earth. Is it a great leap of faith to wonder whether it might also apply to Mars and elsewhere? As presented in Figure 1, cross-contamination with living biota has likely been going on between Mars and Earth since life appeared on either planet. And in the last half century, we, ourselves, have contaminated Mars with our spacecraft landings bearing substantial, likely viable, microorganisms[17].

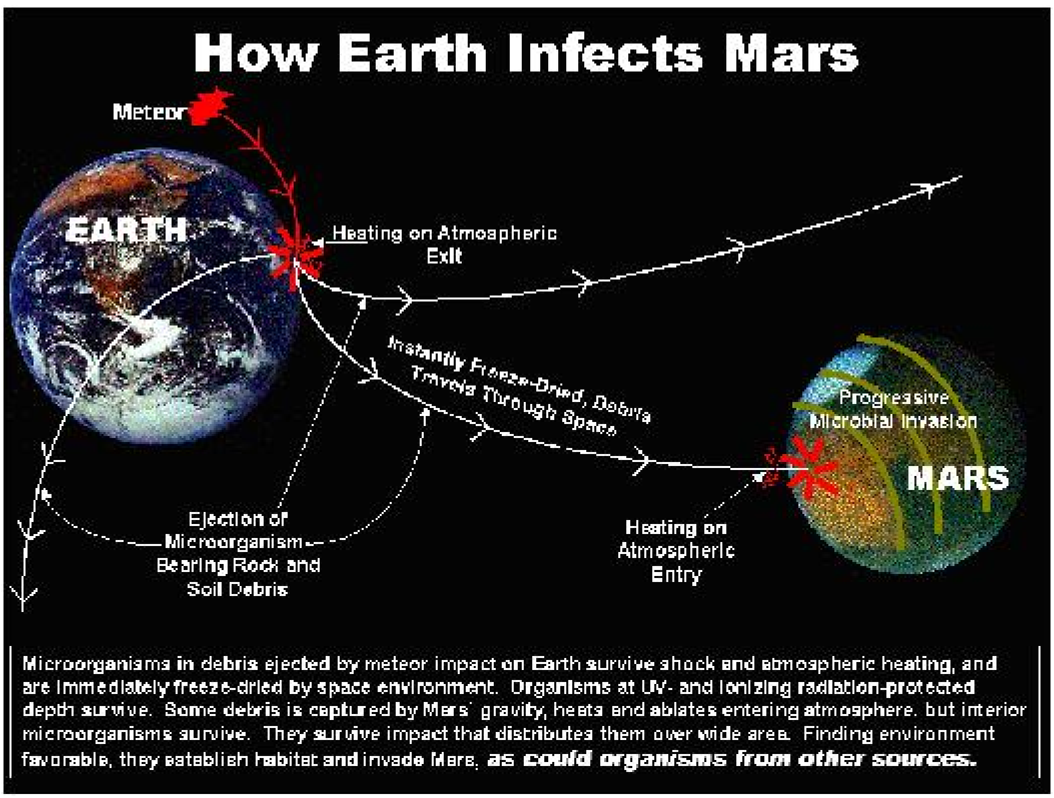

Fig. 1. How Mars and Earth Cross-Contaminate Each Other.

And, of course, either or both planets might have been infected by microorganisms from another source or sources. We have seen above that there is no apparent environmental condition(s) to prevent life from either originating on Mars, or having survived arrival from space. Once there, the Biologic Imperative, impelled by Darwinian pressure, might well prevail. And, if so, why would that pressure not have driven adapting life forms to the "four corners" (actually eight corners considering three dimensions) of that planet as we now realize it has on Earth? This realization casts doubt of the "oases of life" proposed by various authors. Planetary penetration would be expected unless some severe lethal localized factor(s) has eluded the above review.

The Moon, the Moon!

A ready example of such an inhospitable place might be our Moon, which warrants close study in that regard. The surface samples returned from the Moon have been rigorously examined, and have revealed no evidence of extant, recently living, or ancient life. Amino acid content of the samples is very low, raising questions of whether those found might be terrestrial contaminants. Inasmuch as the Moon constantly receives IDP infall, meteor and comet impacts, all containing organic matter, as do Earth and Mars, this raises a question of why so little, if any, amino acids have been found in the lunar samples. The immediate answer would seem to be that, lacking any measurable atmosphere, and lacking a magnetosphere, the Moon receives the full impact of solar and cosmic radiation in intensities great enough to destroy any organic matter. Recently, water ice has been detected in the sun-shaded bottoms of deep craters on the Moon. Huge volumes of ice have been detected[18] at both North and South Polar regions as seen in the referenced paper's radar image of the North Pole in Figure 2.

{ INCLUDEPICTURE "http://www.circleofblue.org/waternews/wp-content/uploads/2010/03/aWater-North-pole.jpg" * MERGEFORMATINET }

Fig. 2. Ice at the Moon's North Pole

Since the Moon, like Earth and Mars, receives IPDs, meteorites and comets from space, it would be very interesting to examine the lunar ice for organic matter, including amino acids, and for fossil microorganisms that might be preserved there. It is perhaps likely that any such fossils would have arrived in meteoritic ejecta from Earth, but it is also possible that their source(s) is more distant. In either event, fossils on the Moon would make a case for panspermia. They would be of even greater interest should examination of the fossils show them to be alien.

The Miracle of Life:

In view of our current understanding[19] of Mars, it is more likely to harbor life than not. Paraphrasing and updating Sagan's statement addressed to the Viking LR's claim of finding life on Mars, "Extraordinary claims require extraordinary evidence," it might now be said that the claim for life has become ordinary and the evidence for it has become extraordinary. If the red planet is sterile, this has great impact on the status of astrobiology. This would mean that, for reason unknown to us, the Biologic Imperative does not necessarily apply beyond Earth, and, therefore is impugned. With two negative samples, Mars and the Moon, panspermia would suffer a fatal blow. We might, indeed, be "**Alone, alone, all all alone, Alone on a wide wide sea!"** Immediately, life on Earth would be considered more precious, perhaps unique, as some, citing religious reasons, have claimed. Those of this bent regard life on Earth as a miracle. However, it might also be considered a miracle if there were no life on Mars.

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