# Mars life - how Darwinian pressures might have shaped its form and function

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## ABSTRACT

The possible existence of life on Mars is now gaining credence. Evidence consistent with or supporting the presence of extant microbial life, as reported by a life detection experiment on the Viking Mission in 1976, has been rapidly accumulating from spacecraft orbital and lander operations, and from terrestrial observations. Vast oceans of frozen water near the planet's surface are being discovered, with strong indications of recent or present liquid flows, and theory and laboratory experiment have demonstrated that liquid water should exist on the surface of Mars. The biosphere on Earth has been extended into extreme environments until recently thought inimical to life. Places void of life have become rare. No life requirement has been found lacking on Mars. It is possible that, by the time of this 50th Anniversary SPIE Meeting, the paradigm shift accepting life beyond the Earth may have been made. Mankind will then emerge from its ancient fear of loneliness into a new fear of anticipation of what that still unidentified life might portend.

The author attempts to apply Darwinian principles of evolution to life on Mars under the selection pressures, opportunities and constraints that have been imposed by past and present Martian conditions. Starting with the type of cell believed to have begun the evolutionary process on Earth, he speculates on what the current life on Mars may be like in form and function, including what threat or promise it might hold for Earth life.

**Key words:** Mars life, life on Mars, extant life on Mars, Martian biology, Martian life forms, evolution on Mars, astrobiology, extraterrestrial life

## 1. INTRODUCTION

The claim[1] that the 1976 Viking Mission Labeled Release Experiment (LR) detected living microorganisms in the Martian soil has been slow to gain support. Over the past decade, however, the known extent of Earth's biosphere has been increased to encompass virtually every environment, including those as severe as on Mars. It is now extremely difficult to find places on the surface of the Earth, in the atmosphere above it, in the deepest, "deadliest" regions of the seas, or even far underground where microorganisms have not been detected, and early[2] and late[3] reports of sterile areas have been refuted by retesting[4,5]. Recent evidence from: 1. Odyssey[6] reporting vast areas of water within several centimeters of the Martian surface, 2. both Mars Rovers Spirit[7] and Opportunity[8], finding water-related mineralogy, 3. the ESA Mars Express reporting evidence[9] of recent or current liquid water on the surface of the planet, and confirming[10] earlier Earth-based evidence[11] of methane in the Martian atmosphere, now coordinated with water vapor, are all favorable indicators for biology. Contrariwise, no factor antithetical to life has been discovered. A case[12] has been made that it is now more difficult to propose a sterile Mars than one with life. These developments have moved the majority of the space scientists attending a recent meeting to believe[13] it likely that life once existed on Mars, with some 25% believing life exists there today. This is a fitting time to apply Darwinian principles in an attempt to deduce the range of form and function of such life based on the opportunities and constraints available to and imposed upon it.

Mars could have generated life independently, could have been inoculated by ejecta from Earth, or could have been infected from some third source. To survive and evolve on Mars, life from any of these sources would have been subjected to the same opportunities and constraints dictated by the Martian environment. These commonly shared conditions would tend to evolve and restrict life forms from any source to the same limited range of variation.

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## 2. OPPORTUNITIES AND CONSTRAINTS

It is presumed herein that life on Mars began with a single-celled microorganism, be it generated *de novo* or be it imported. The former would certainly have begun as a single-celled organism. In event of the latter case, single-celled organisms, either lyophilized during travel through the space environment, and/or in spore form, would have been included in any life-bearing material reaching the planet. This is because single-celled microorganisms seem certain to be present on any life-bearing donor planet, may maintain their viability while in ejecta subjected to the rigors and duration of space travel, and satisfy the requirement for perpetuation of life through recycling.

Richard Dawkins[14] has summarized and extended earlier works[15, 16, 17] on how selection pressures open many opportunities for evolution, and how the environmental parameters, together with the materials and processes of life, constrain the range of those options or proscribe them entirely.

A selected list comparing key environmental parameters, garnered from a variety of published sources that would influence evolution on Mars and Earth is presented in Table 1. This paper will largely address the influence such factors would likely have had on the evolution of life on Mars, thereby permitting an extrapolation to the forms and functions of present day life there. Other of the many environmental parameters might also have influenced evolution, but those selected for treatment in this paper seemed strongest to the writer.

### 2.1 Parameters and Effects

Age of Planets: Current theories generally estimate the age of Earth at approximately 4.6 billion years. Accreted from the same primordial materials, Mars is thought to have formed at approximately the same time. Thus, essentially equal periods of time were available for the appearance and evolution of life on both planets. However, the other factors discussed below would have influenced the respective courses of evolution on the two planets. The deduced effect of these specific factors on Earth, compared qualitatively and quantitatively with their Martian counterparts, permits speculation as to the appearance and development of life on Mars.

Diameter, Density, Gravity, Escape Velocity: The smaller diameter of Mars would have made it easier for life forms to find and evolve to occupy specific habitats. The reduced gravity would aid in the movement, passive or active, over the planet. The lower density of Mars indicates easier access by organisms to deep sources of water or nutrients. The lesser gravity and its corollary, lower escape velocity, mean that Mars would have been less efficient than Earth at capturing meteorites and interplanetary dust particles. This would significantly reduce the amount of organic surface material available to an evolving biology, forcing a higher reliance on atmospheric carbon, thereby favoring development of phototrophs over heterotrophs. The lesser gravity would also reduce selective pressure on Martian life forms to develop supportive structural components.

Atmosphere: Since the atmosphere plays a key role in defining life on Earth, the Mars atmosphere would be expected to do the same on that planet. The key constituents of the Earth and Mars atmospheres are $CO_2$, $O_2$, $H_2O_v$ and $N_2$. One of the remarkable feats of biology on Earth is how plants, from giant trees down to the huge biomass of photosynthetic plankton, can garner their carbon constituent from an atmosphere containing a paltry 0.03 percent of carbon dioxide. By way of surprising contrast, despite the thin atmosphere of Mars, Table 2 shows that any photosynthetic organisms on Mars have 515 times as much $CO_2$ available as do their counterparts on Earth. On Earth, the Martian amount of $CO_2$ would constitute 0.03 x 515 = 15% of the atmosphere. The standard laboratory method of culturing algae and other single celled plants is to grow them under 5% $CO_2$, rather than under the 0.03% currently in the terrestrial atmosphere. Thus, the availability of $CO_2$ on Mars much more closely approaches the amount supplied in laboratories to maximize growth. This preference for concentrations of $CO_2$ higher than currently prevailing on Earth may constitute genetic evidence for the time of origin of life on Earth, or, perhaps, for another place of origin that supplied the genetically imprinted amount. From the standpoint of $CO_2$ availability, a strong advantage for photosynthesis prevails on current Mars. The increased availability of carbon may induce more growth, provide more energy and/or allow larger cell size, than on Earth.

If Martian organisms are photosynthetic, a larger concentration of atmospheric $O_2$ might be expected, unless only anaerobic photosynthesis is present. It can be imagined, however, that much of the $O_2$ produced is removed through oxidation of the large iron content of the regolith. In any case, the scant amount of $O_2$ in the Martian atmosphere would constrain life there to being anaerobic, facultative anaerobic or micro-aerophillic.

**TABLE 1: MARS/EARTH COMPARISON**

Selected Parameters Influencing Biological Evolution on Mars and Earth
(Value from various published sources)

| Parameter | 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 $CH_4$<br>Total density at surface 0.20 $kg/m^3$ | 1014 mb; 77% N; 21% $O_2$ 0.03% $CO_2$; 1.7 ppm $CH_4$<br>Total density at sea level 1.23 $kg/m^3$ |
| Liquid water at surface | Diurnally on surface, as moisture in soil, inter-crystalline films[a] | 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 | 589.2 $W/m^2$ , UV ~ 100 x Earth up to 300 nm to ~ 0.7 x Earth @ 300-400 nm (280-315 nm is bio-damaging zone), greatly attenuated by dust in atmosphere | 1,367.6 $W/m^2$, UV ~ 41 $W/m^2$ to 68 $W/m^2$, greatly attenuated by ozone layer, clouds and dust in atmosphere |
| 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 | Loss of atmosphere and oceans: 3.8-4.6 ga | Extinctions: 450, 350, 250, 200; 60 mya<br>Oxygen poisoning: 3 ga |

a. Levin, G.V. and R.L. Levin, "Liquid Water and Life on Mars," *Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings,* **3441**, 30-41, July, 1998.

The amount of atmospheric nitrogen, while significantly less than on Earth, could, nonetheless, support a significant population of nitrogen fixers. Of much recent interest, methane has been discovered in amounts and locations of the Martian atmosphere that has caused some speculation that this finding, by itself, may confirm the presence of life[18]. With the Odyssey findings[19] and much speculation on subterranean lakes of liquid water, methanogens might readily be thriving underground, having their satiety of basaltic rock and water.

<u>Liquid Water:</u> Over the 29 years since the positive results from the Viking LR experiment, many theories have been advanced to explain the LR data as being of chemical or physical origin, rather than biological. The only such rationale still enjoying general support (although strongly rebutted[20]) is the surmise that liquid water cannot exist on the surface of Mars (the Viking LR soil samples were limited to a depth of four cm.); therefore, neither can life. Published reports have ranged from the absolute denial of any liquid water on the surface of the planet[21], to "current" sporadic eruptions of liquid water from cliffs[22], to the possible presence of liquid water in lenses beneath the surface[23], to theoretical and

experimental evidence that the current Martian environment provides liquid surface water[24]. Furthermore, microorganisms have been reported[25] on ice near the South Pole where the temperature never rises to the melting point, demonstrating that the microbes either extract liquid water from the ice, or from water vapor sublimating from the ice. Viking sent images of ice surviving many months near the Viking I lander site. Viking data also showed the diurnal saturation of the near-surface atmosphere with water vapor[26]. Perhaps these observations by Viking assure the bioavailability of water. It has been shown[27] that lichen can survive by extracting water from atmospheric vapor if that is the only source. In the symbiosis of the yeast and algae in lichen, the yeast obtain the needed moisture. They extract water very rapidly, and lichen can continue metabolism under strongly desiccating conditions. Endolithic protection of microorganisms and of lichen, perhaps further evolved to Martian conditions, might have augmented this ability on Mars.

$CO_2$ constitutes only 0.03% by volume of Earth's atmosphere at sea level. Using 28.97 as the average "molecular weight" of air at sea level, 1.23 kg air/$m^3$ (from Table 1) x 0.0003 x 44/28.97 = 5.6 x $10^{-4}$ kg $CO_2/m^3$ air x 1000/44 = 1.27 x $10^{-2}$ moles $CO_2/m^3$ on Earth at sea level. Water vapor at the surface of Mars at the triple point condition (most conservative) of 6.1 mb and $0^o$ C, is shown (http://www.chemicool.com/idealgas.html) to be at a concentration of 0.269 moles/$m^3$. So the atmosphere at the surface of Mars provides at least 0.269/1.27 x $10^{-2}$ = 21.2 times as much water vapor as the Earth provides $CO_2$ at its surface.

Based on what they can see, the consensus of Martian scientists seeking life on Earth might well be, "That planet can have no life because there is not enough $CO_2$ to support it." If terrestrial life has overcome this severe constraint, it might seem that Martian organisms might have evolved to obtain sufficient water vapor from its more bountiful source.

Thus, from the standpoint of the physical kinetics of contact and absorption of water vapor, this source might seem sufficient for Martian microorganisms to glean their water needs. Even so, liquid water is clearly a limiting factor for life on Mars. Thus, there would be strong selection pressure for organisms to evolve mechanisms for the acquisition and maintenance of water in liquid form. Should liquid water not be available, Martian biology is likely to have evolved a system for the active transport, condensation and retention of water vapor. It is likely that spore formers are prevalent to accomplish survival through dry periods when even these mechanisms might be insufficient.

Atmospheric Pressure: The low atmospheric pressure on Mars, although generally above the triple point for water, imposes a narrow temperature range in which water may be in liquid form, thereby exacerbating the scarcity of this life-limiting factor. The result would be to constrain biological variety to a narrow niche, and to slow the metabolism of organisms that can occupy the niche, perhaps driving the development of sporulation to span periods of severe dryness.

Organic Matter: Essential for life is the presence of organic matter, either accreted through infall, or, in a new theory[28], generated from inorganic carbon heated by planetary core pressure or by magma. Mars' low gravitational well, only about one-third that of Earth, means that less space-borne matter, including interplanetary dust particles containing organic matter, would be swept out and accreted by Mars. Despite Mars' lower gravitational force and its lesser mass (only 0.11 that of Earth's, although Mars average density is 71% of Earth's), there has been considerable meteoritic infall, as evidenced by craters; and high temperatures provided by magmas that may still exist. Thus, amounts of organic matter sufficient for the development and support of life have been available on Mars.

Bio-Chirality: With rare exceptions, all known forms of life use and make L-amino acids and D-carbohydrates only. While the origin of, and any reason for, this phenomenon are unknown, it is testimony to their evolutionary relationship. There is now some indication[29] of how chirality might have originated abiogenically. Mineral crystals, such as calcite, have been shown to absorb chiral isomers preferentially from a racemic mixture of amino acids poured onto a chiral facet. Long oligomers of amino acids have been produced by pouring solutions of them over clay and other minerals, then evaporating, and repeating many times.[30] Had such amino acids, and perhaps chiral specific carbohydrates produced in the same manner, been available for incorporation into the process that produced living cells, this might explain the origin of biochirality. However, the benefit of this intrinsic characteristic remains obscure, as does any selective pressure of the terrestrial or Martian environmental parameters. Nonetheless, were Martian organisms homochiral with Earth life, this would constitute evidence of a common origin, whereas, were the chiralities different, or lacking on Mars, different origins would be implicated, perhaps the more exciting scientific prospect.

Based on the assumptions and deductions herein, it is expected that Mars organisms will show the same chirality as those on Earth.

Selected Crustal Elements: The crustal amounts of O, Si, and Ca do not differ radically between the two planets. Mars has about twice as much Fe, with neither planet seeming to be life-limited with respect to that element. However, the large amount of Fe on Mars may have supplied, and still may be supplying, an $O_2$ sink for oxygen-producing photosynthetic organisms. Martian metabolism may use iron by cycling electrons between the ferrous and ferric states. Mars has about 60 times as much S as Earth, and the Martian abundance might have selected for organisms obtaining energy through sulfur metabolism. Sulfur is second only to carbon in bonding to itself, and readily forms chains and rings. Sulfur-bearing molecules exposed to low levels of light have incorporated carbon to generate organic compounds[31]. Cyanobacteria and green sulfur bacteria, both very primitive life forms, metabolize sulfur[32].

Earth life is severely limited by the small amount of available P, a requisite for DNA. A "harsher" Martian environment might be at least partially compensated for by the increased availability of essential P to facilitate reproduction. Similarly, the overabundance of Mn on Mars might have selected for photosynthesis. The interesting thing about C is how little is in the Earth's crust and in its atmosphere. The large amount of C in the Martian atmosphere and its ready availability compared to crustal-bound C could supply an adequate amount of that element for metabolic and structural purposes. It thus seems that there is no limitation on Mars of elements essential for life, and, to the contrary, some may be in amounts and availability that pose an evolutionary advantage over Earth.

Solar Energy: Many factors affect the flux of solar energy available to biological organisms on Mars. The greater distance of Mars from the Sun, ~140 v ~92 million miles for Earth, results in a flux incident to Mars of only 43% of that arriving at Earth. While the flattening of Mars, nearly twice that of Earth, would indicate a greater reflection of the incident rays, the albedo of Mars, 0.250 compared to Earth's 0.306, indicates that some 20% more of the incident solar energy is absorbed on Mars. The Mars Pathfinder Mission has shown[33], that the atmospheric temperature very close to the surface of Mars rises exponentially, reaching into the 20 degrees C near the equatorial region. All factors considered, the temperature ranges on the surface of the two planets are -126$^{o}$ C to +22$^{o}$ C for Mars, and -33$^{o}$ C to +58$^{o}$ C for Earth. The UV spectrum on Mars up to ~300 nm is ~100 times that on Earth, with the strength of the portion from ~300 to ~400 nm essentially similar on both planets. On Mars, variable, but significant shielding of the UV spectrum is produced by atmospheric dust, as do dust, clouds and the ozone layer on Earth. Biological damage to terrestrial organisms principally occurs in the range of 280 to 315 nm. Despite the dust shielding, it is likely that the average UV flux in the bio-damaging range incident to the surface of Mars significantly exceeds that on Earth. The availability and characteristics of solar energy would certainly play a major role in the evolution of life on Mars, as it has, and does, on Earth. Selective factors on Mars would drive for development of UV resistance, tolerance of low temperatures and greater efficiency in absorption and utilization of solar energy. Endolithic microorganisms and endolithic lichen on Earth may have been transported to Mars in meteor-driven ejecta, protected from UV by the rock surrounding them. In lichen, the yeast supply the algae with water to which the algae respond by controlling transparency of the total organism to light. The attributes of this association may have prevailed and been selectively adapted to Martian conditions.

Growing Season: Mars' greater orbital eccentricity than Earth's results in a Martian year of 687 days (sols), nearly twice that of Earth. Thus, the growth and dormancy seasons would be nearly twice those on Earth. This means that mutation(s) accrued during a growth season would have to wait twice as long as on Earth, until the next growing season, in order to be passed along to the new generation. Two possible and opposing effects on the rate of evolutionary development on Mars seem likely. First, the longer dormancy period would greatly constrain the pace of evolution on Mars. Secondly, however, the longer growing period, during which it is presumed that mutations occur, would allow for the occurrence and accumulation of more mutations. Perhaps, the greater UV flux would offset, or overcompensate for the effects of the longer dormancy period.

Circadian Rhythm: All investigated forms of terrestrial life exhibit circadian rhythms, that is, endogenous oscillations in locomotor activity, sleep and waking, temperature, metabolism, hormone release etc., with a period close to, but not exactly, 24 hours. Non-biological phenomena do not exhibit circadian rhythms (although they may exhibit 24-hour rhythms entrained to the rotation of the earth, e.g., daily temperature cycles). Thus, circadian rhythmicity is an excellent biosignature. The ability to entrain behavior to the light/dark cycle is adaptive, e.g., nocturnal animals forage at night and sleep during day to minimize exposure to predators. It is thought that an endogenous clock evolved as a kind of fall-back timekeeping mechanism. With such an internal clock it is possible to determine approximate time of day even when light/dark cues are obscured (e.g., during severe rain, fog etc.). It is reasonable to suggest that similar selection pressures should drive the evolution of endogenous clocks in any life forms on other planets subject to entraining features.

The length of days on Earth and Mars are very similar, 24.62 hours on Mars, 23.93 hours on Earth (each varying by a matter of seconds depending upon influences of a number of transient physical forces). Therefore, an evolved biological clock on Mars would probably exhibit periods not much different from those of terrestrial circadian clocks. Indeed, a rhythm with a period slightly different from that of the Martian rotational period has been reported in the Viking Mars LR data.[34] (Additional studies are planned to determine whether the difference is statistically significant.[35]) On Earth, some organisms exhibit an entrained tidal rhythm of about 24.8 hours, the resultant of the Sun-moon gravitational vectors, and distinct from the diurnal cycle of 23.93 hours. High or low tide may entrain the endogenous "circatidal" (semi-tidal, i.e., 12.4-hour period) rhythms of inter-tidal, pool-dwelling organisms. Another periodic signal on Earth is lunar phase, which appears to entrain a circalunar rhythm of about 29.5 days (e.g., human menstrual cycle). Mars has two moons, Phobos and Deimos, with orbital periods of 0.319 and 1.262 days, respectively. Since these moons are relatively tiny, their effects on biological rhythms are unlikely, but possible. In the latter event, entrainment on one or both moons, or on the resultant of their gravitational force vectors, or, perhaps, their periodic appearances, could entrain metabolic events very differently from the pattern on Earth.

<u>Catastrophic Events</u>: Mars has, as has Earth, suffered catastrophic environmental changes. It is likely that the atmosphere and the oceans were sucked off Mars by violent collision(s) or near-collision(s) with objects from space. These events would have occurred suddenly, with more immediate and farther-reaching effects than the greatest threat to life Earth experienced, the accumulation of toxic oxygen produced by the rise of vegetation. The flourishing of species on Earth took place late in the planet's history, the Cambrian explosion of about 570 million years ago. This event was dependent on the evolutionary accomplishments preceding it. The ecological change on Mars was likely more sudden and drastic, and occurred early in the planet's history. Unlike terrestrial life, Martian life did not have the time to evolve gradually to cope with its increasing threat. This may have prevented a Cambrian period from occurring there. Thus, the Martian ecology today would be expected to be limited to simple organisms. Images transmitted from Mars orbiters and landers show no evidence of living macro forms (it is presumed that, even if the dark dunes near the Southern Pole prove to be biological, they will likely be agglomerations of single-celled organisms). That may explain the apparent absence of macro-organisms. However, since this abrupt change in environment occurred earlier in Mars' history than did all catastrophic events on Earth, except the accumulation of oxygen, Mars may have had adequate time subsequently to evolve complex organisms. However, the severe environment that persisted would likely have constrained that evolution, perhaps limiting it to the types of simple organisms found living in such environments on Earth.

## 3. IMPLICATIONS FOR MARTIAN ORGANISMS

Having stated what the author believes to be the key factors providing opportunities and constraints on Darwinian evolution, he will now speculate on the resultant characteristics of present life on Mars.

<u>Origin and Its Significance:</u> The first living cell on Mars could have originated *de novo* on that planet. However, unless there is a "biological imperative" driving the development of life, much as the "elemental imperative" must force the same periodic table whatever the source of atoms, it is unlikely that life would have originated independently on both Earth and Mars. Since we have no evidence for a biological imperative, the independent origin of life on the only two planets sampled would provide an unlikely 100% positive result. Because of their proximity, and in the light of increasing evidence[36] supporting the exchange and survival of microorganisms between Earth and Mars, it is more probable that life originated on one planet and then infected the other, or that the infection(s) came from some other source(s). Since the first presence of life on either planet, additional forms have likely arrived from space. Regardless of the source(s) of life, the opportunities and constraints provided by the Martian environment would have similarly focused the evolutionary paths of subsequent generations. Severe constraints were placed on Mars at an early point in its history, before much diversification could occur, thereby greatly limiting the varieties compared to the proliferation

that developed on Earth. Thus, Martian organisms are likely to be similar to present day terrestrial forms that occupy environmental niches similar to those on Mars.

Possibly having emerged from the conjectured[37] pre-biological formation and replication of RNA, later expanded and called "RNA world[38]," the earliest forms of living organisms identified on Earth date from approximately 3.5 gya, only about 1 billion years after the formation of the planet, barely allowing time for cooling of the surface to permit the existence of living forms. This may imply that life forms were arriving on Earth from space before then, and that, as soon as conditions allowed, they extended the biosphere to include Earth. Whether their origin occurred on Earth, Mars or elsewhere, evidence[39] suggests that the first organisms to inhabit Earth were anaerobic unicellular prokaryotes. It is, thus, presumed that these were the earliest, most elementary forms of life generated anywhere. There is some indication[40] that the first form of metabolism performed by these microorganisms depended upon electron cycling between sulfate and sulfide. The presence of larger amounts of sulfur on Mars than on Earth indicates that sulfur metabolism might have played, and might still play, an important role on Mars. It is stated[41] that the first organisms to emerge from the RNA world could "… make proteins and reproduce without the need of a plant." In any event, anaerobic photosynthesis was soon established thereafter, and synergy with heterotrophs quickly developed.

## 4. MARTIAN LIFE TODAY

It is speculated herein that extant Mars life evolved from microorganisms identical, or similar to, the early forms that have been identified on Earth. Applying the evolutionary opportunity and constraints on Mars indicates that Martian life would have developed slowly and within narrow metabolic confines, but having certain advantageous opportunities.

Minimally satisfying the criteria for the first living cells would be unicellular sulfate-reducing microorganisms, anaerobic phototrophs and heterotrophs. The organisms would have evolved to overcome the scarcity of liquid water by absorption of water vapor, utilization of inter-crystalline films of water, or the melting of ice by excretion of substances to lower its melting point, or by a physical process, possibly protein flexure. Martian biology might have evolved to include formation of vertical or horizontal strombolites, or mats, to obtain and transport liquid water from subsurface depths and to transport carbohydrates to the subsurface portion of the colony. Cyanobacteria on early Earth, and today, formed and form massive strombolites that likely developed to provide advantages of this nature. Stromatolites consisting of anaerobic phototrophs existed as long as 3.5 billion years ago. Stromatolites remain prevalent on Earth, in crusts covering many square miles[42]. They are good candidates for life on Mars today, perhaps somewhat evolved from the forms on primitive Earth.

In order to protect against deleterious UV rays, Martian organisms might have developed protective pigments as have many terrestrial organisms, utilized coatings of the fine Martian dust, or concentrated their growth in the photic zone beneath the first millimeter or so of the surface. Should endolithic organisms have arrived on Mars, they would have provided a ready platform for further evolutionary development to the more exacting environment of Mars including the UV flux.

Martian life has vastly more carbon easily available to it than does terrestrial life. This may have allowed phototrophs the opportunity to generate and utilize greater amounts of energy, perhaps, enough to permit significant improvement in mobility over the gliding capability of cyanobacteria and other motile mechanisms shown by phototrophic prokaryotes on Earth. The enhanced ability to move would be very useful for seeking water, minerals or substrates, and in adjusting depth diurnally for UV protection. The low gravity field of Mars would further enable mobility, and the winds would help in the dispersion of microorganisms and spores, all contributing to swift planet-wide propagation.

Except for high temperature zones, such as in or near magma, there are virtually no uninhabited environments on, beneath or above the surface of Earth. The evolutionary process has proven so efficient and adept here that the same pervasiveness of life should be expected on Mars. Essentially duplicate life detection results[43] obtained by the Viking LR at sites 4,000 miles apart are consistent with this view.

Viking Imaging System spectral analysis of the four visible and two near-IR channels of Viking lander images[44] of Mars identified areas ranging from yellow to olive to green. Greenish patches on some rocks showed the same visible and near-IR spectra as those of terrestrial lichen viewed under the Viking Imaging System. Known as "the pioneers of vegetation," lichens are the first, or among the first, forms of life to appear upon fresh rock surfaces, such as on Surtsey, where, after the newly formed island cooled, they appeared soon after or simultaneously with mosses[45]. Particularly in endolithic form, lichen are good candidates to be among the life forms on Mars.

## 5. CONCLUSIONS

Application of Darwinian opportunities and constraints in the context of present knowledge of Mars encourages speculation that:

1. Martian and Earth life forms are of common ancestry, therefore genetically similar, and share common metabolism and chirality.
2. Life on Mars is primarily, or exclusively, limited to simple, anaerobic, psychrophilic organisms.
3. Mars life obtains liquid water from diurnal melting of ice, thin films existing between ice crystals, by absorbing and condensing water vapor, and by actively melting ice.
4. Spore formers are prevalent.
5. Sulfur metabolism plays an important role on Mars.
6. Iron serves as an oxygen sink, and may be involved as a sink and source of electrons in metabolism, perhaps in combination with sulfur.
7. Both phototrophs and heterotrophs are present on Mars.
8. Martian life forms may be physically larger than their terrestrial counterparts.
9. Martian phototrophs may have evolved motor ability, including locomotion.
10. Martian microorganisms may form large mats, perhaps vertically as well as horizontally.
11. Endolithic microorganisms and endolithic lichen are part of the Martian ecology.
12. There is significant danger that planetary probes may infect Mars with microorganisms, and, while survival will be severely limited by present environmental conditions on Mars, species or strains new to the planet might be introduced, ultimately affecting the ecology.
13. Probably most Martian life forms could readily grow on Earth. Because of their common gene pool, they are likely to be benign. However, it is possible that adverse environmental and health effects could result from the introduction of Martian mutants, and from the introduction of unfamiliar species to discrete regional populations of humans, animals and plants. Any infection of Earth would probably be concentrated in or restricted to the frigid zones. Such infestations would absorb more solar energy, perhaps contributing to global warming.

## 6. SIGNIFICANCE AND PROMISE

Significance: General acceptance of the existence of any kind of life on Mars will answer a fundamental question, with implications for reshaping many of our concepts in science, society, politics and theology. A highly significant paradigm shift will have been made, one that will take mankind to a new level of understanding and exploring the universe, his place and, perhaps, his destiny in it. Should the above inductive speculation about the common origin of life on Earth and Mars prove correct, it will still leave open the question of whether our life is unique. However, should the chirality, or genetic information of Martian life indicate a separate origin from ours, that would imply the existence of many independently generated forms of life on many planets throughout the universe.

Promise: Once the problems of forward and back-contamination between the planets have been solved, studying the comparative biology of Mars and terrestrial life will enable scientists to wrest, in fairly short order, certain genetic advantages from the former to the benefit of the latter. Such benefits may include improvements to agriculture, animal husbandry, the biotechnology industry, and improved human health and longevity. Long-term prospects looking toward the utilization of Mars and other planets and objects in space will be stimulated, paving the way for exploration and the possibility of human colonization of extraterrestrial bodies.

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