Scientific logic for life on Mars

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ABSTRACT

Scientific findings and theoretical analysis over the past several years have increased the probability for extant life on Mars. Discoveries have revealed terrestrial organisms flourishing in environments thought hostile and barren of life. Experiments with extremophile organisms, including some of those newly discovered, have demonstrated their extraordinary and unanticipated hardiness, including under conditions comparable to, or approaching those on present-day Mars. Microorganisms subjected to extreme g forces survived shock as severe as meteoric impact. Calculations and experiments based on Viking data allow for water to be liquid on the surface of Mars for biologically significant periods. Direct observations of Mars by subsequent missions support this likelihood. These new developments provide a workable Panspermia model for the transport, survival and growth of terrestrial life on Mars. No insurmountable obstacles to their survival to the present have been demonstrated. Organisms transported to Mars from Earth and/or from other sources may have been responsible for the positive results returned from Mars by the Viking Labeled Release experiment in 1976. A simple robotic experiment can resolve the issue.

Keywords: Life on Mars, Panspermia, Viking Mission, Labeled Release Experiment, Extraterrestrial life, Astrobiology

1. INTRODUCTION

For countless centuries, man has wondered whether life came to Earth from distant sources beyond his ken. A repetitive theme in our earliest myths and writings, this poignant mystery has puzzled us since the dawn of reasoning. Perhaps the best modern answer to the puzzle was articulated by Arrhenius[1], whose theory, Panspermia, proposed that the seeds of life travel from planet to planet. His theory, however, quickly met with fundamental objections centering on the improbability of living organisms to withstand the rigors of interplanetary transport. These objections have survived until the present.

It is only since 1860, when Louis Pasteur[2] tried, and failed, to culture organisms from the Orgueil meteorite, that empirical investigation of this problem began. For the next 50 years, little scientific attention was paid to it, until Percival Lowell published[3] his famous, erroneous observations of Mars. His drawings of his telescopic views led to sustained excitement about the possibility of intelligent beings on Earth's nearest neighbor. Unfortunately, Lowell's brilliant deductive reasoning was applied to very poor quality data that he subjectively obtained through an inadequate telescope. His work maintained heightened public and scientific interest in the possibility of Martian life until 1964. Then, images of Mars taken by Mariner 4 revealed no trace of the straight lines of intelligently produced works Lowell reported on Mars. Instead, Mariner 4 saw an utterly dry desert. Hope for life on Mars was virtually abandoned.

The next life-seeking mission to reach Mars was NASA's Mariner 9, arriving in 1971. Mariner 9's orbital imagery resuscitated the possibility that Mars might harbor life. Images showed signs of ancient water flows, and a generally more hospitable Martian landscape. The first scientific indication that there might be life on Mars was sent back by Mariner 9's Infrared Interferometer Spectrometer (IRIS) [4], but was unrecognized for years. That evidence was in the analysis of the Martian atmosphere, 95.32 percent CO_2, with a CO content of only 0.07 percent. Based on earlier telescopic analysis, Hunten[5] had recognized that the large amount of CO_2 in the Martian atmosphere required some supporting reaction. With no ozone layer to absorb it, the ultraviolet light penetrating the Martian atmosphere would split that gas to liberate CO to become the dominant atmospheric constituent. To solve this inconsistency between his theory and Mariner 9's observation, Hunten theorized that the ultraviolet light also split water vapor molecules in the atmosphere to produce OH^- radicals that then combined to form H_2O_2. This compound completed the carbon cycle by oxidizing the CO back to CO_2. No mention was made of the possibility that, as on Earth, the CO_2 could be supplied by living organisms.

However, Hitchcock and Lovelock[6] had proposed that an imbalance, or dynamic disequilibrium, in the atmospheric constituents of a planet would indicate the presence of life. They used Earth as an example, citing the presence of CH_4 in its atmosphere. Earth's oxidizing atmosphere immediately turns CH_4 into CO_2. Unless it were being constantly replenished, there would be no trace of CH_4 in Earth's atmosphere. A knowledgeable observer on another planet, detecting CH_4 in our atmosphere, could thus conclude that life was present (in this case cows, Earth's principle source of CH_4). This finding by Mariner 9 was reported[7], possibly as being the first real clue to life on Mars. However, the possibility found no response among the scientific community, and was ignored thereafter. It was not until 1997 that all of the clues and observations on Mars and Earth reviewed together with the results of many pertinent experiments led to the first published[8] conclusion that Viking had detected microbial life on Mars.

An attempt is made herein to show that the conclusion that microbial life currently exists on Mars is supported by logic that, if from no other source, microorganisms exist on Mars transported from Earth. The doubts of Panspermia being operative, even from Earth to Mars, are herein assuaged by two lines of argument: quantitative testing of the principal rigors of travel between the two planets; and the discovery of microbial extremophiles thriving in environments previously thought inimicable to life, including those at temperatures and with liquid water limitations equal to those on Mars. Appropriate recent literature citations are used to support this model of Panspermia that could have infected Mars with terrestrial organisms surviving, in original, adapted or evolved form, to the present. An important ancillary asset of Panspermia with respect to life on Earth and Mars is the elimination of the need to invoke separate origins of life on the two planets.

Perhaps, the next generation of young students will wonder why it took so long for their predecessors to accept the fact that we are not alone. Those future students might even be taught that comparisons of evolutionary rates to the length of time Earth has been inhabited indicate that our life likely did not originate on our planet. Such studies will have been made by then.

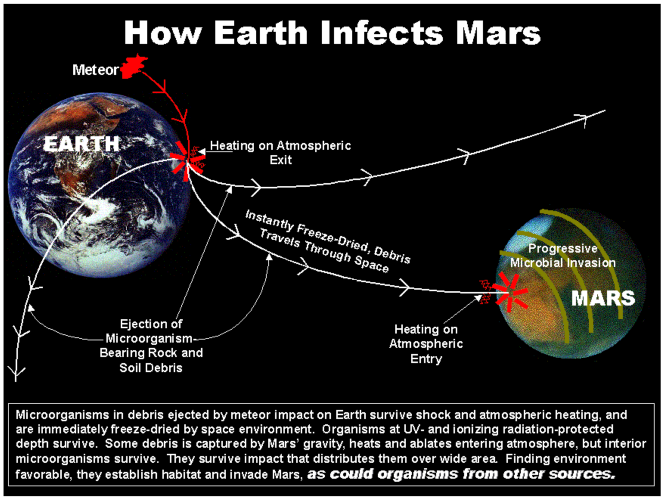
No longer merely on the wings of science-fiction, life's microscopic seed can now be accorded the ability to actually travel through space, planting itself to grow and to evolve to the extent possible in any sustaining habitat encountered. But, no matter what level of organization such transplants engender, the microbial form must remain. It is necessary to provide a fully operational ecology, that is, to recycle organic matter assembled into any larger organisms. This requirement for microorganisms as life's least common denominator also renders life always available for ejection into space to further distribute the expanding phenomenon of life. Our new knowledge may remove life's origin from Earth to some yet unknown site, or sites. This merely begs the issue of genesis. The ultimate question of how life began remains. Corollary questions are: Is the formation of life a cosmic imperative? If so, does it dictate only one basic form of life?

2. PANSPERMIA FROM EARTH TO MARS

Figure 1 depicts the model of Panspermia proposed herein. The necessary, and sufficient, links in the chain of events that could infect Mars with microorganisms from Earth are given in Table 1. Each of the links in the proposed chain of Panspermia is treated below, along with referenced support for its successful participation in the portage of viable microorganisms from Earth to Mars:

1. Microorganisms must be widely distributed about Earth, available to impact-ejection into space. Long regarded as a thin film covering most of the Earth and existing in all the seas, microorganisms easily meet this requirement. Moreover, rather than constituting a thin film, microorganisms are now known to inhabit a large, three-dimensional biosphere, extending from deep within the Earth, up to the surface and through most, if not all of the atmosphere. Thus, they would be in materials ejected by meteoric impact, or readily available for incorporation into such materials in the explosive process of their being formed into ejecta.

2. Meteoric impacts must be capable of ejecting rocks and earth into space. Calculations by Melosh[9] show that meteor strikes on a planet can send ejecta to a planet in another solar system. Clark[10] finds interplanetary transport of materials between Earth and Mars occurs not infrequently, but assigns only a small probability to the survival of any living material therein because of the sterilizing effect of ionizing radiation. In a recent analysis, Mileikowsky *et al.*[11] found that viable transfer of microbes, if they exist on Mars, is highly probable. Earth to Mars transfer was also found possible.



Microorganisms in debris ejected by meteor impact on Earth survive shock and atmospheric heating, and are immediately freeze-dried by space environment. Organisms at UV- and ionizing radiation-protected depth survive. Some debris is captured by Mars' gravity, heats and ablates entering atmosphere, but interior microorganisms survive. They survive impact that distributes them over wide area. Finding environment favorable, they establish habitat and invade Mars, ***as could organisms from other sources.***

Figure 1. How Earth Infects Mars

TABLE 1

ALL LINKS IN THE VITAL CHAIN CONNECTING MARS AND EARTH ARE NOW ESTABLISHED

1. Microorganisms are widely distributed on Earth.
2. Meteorites impacting Earth eject soil and rocks into space.
3. Microorganisms in the ejecta can survive the shock and temperature of impact.
4. Microorganisms in ejecta can survive heating through Earth's atmosphere.
5. Microbes can survive the temperature and vacuum of the space environment.
6. Microorganisms can survive the ionizing radiation of space.
7. Mars-infecting ejectus can approach Mars and be captured in its gravity well.
8. Microbes can survive the temperature of entering the Martian atmosphere.
9. Microbes can survive the shock and temperature of impact on Mars.
10. Terrestrial microorganisms can grow under Martian conditions.
11. Microorganisms are capable of adapting to or evolving to spread over wide regions of Mars.

Earth and Mars were hospitable over epochs that would have permitted infection of Mars by Earth microorganisms—*and from other sources.*

It is now more difficult to propose a sterile Mars than a live one.

Earth and Mars are part of the same biosphere.

3. Organisms in the ejecta must survive the mechanical shock and heating of meteoric impact. In addition to the above citations[9,10,11], Horneck *et al.*[12] found sufficient survival among *B. subtilis* spores subjected to intense shock to report that "…Bacterial spores may survive an impact-induced escape process in a scenario of interplanetary transfer of life." Roten[13] demonstrated the survival of bacteria and yeast after subjection to g forces in excess of those of planetary impact. Weiss *et al.*[14] reported that the temperature experienced in the interior of Martian meteorite ALH84001 did not exceed 40° C at any time during the journey.

4. The organisms must survive friction heating of the ejecta passing through the Earth's atmosphere. Reports cited in items 2 and 3 above support this requirement.

5. The organisms must survive the low temperature and vacuum of space over the time of interplanetary trip. In addition to Weiss *et al.*[14], a direct demonstration of the survival of terrestrial microorganisms under space conditions was reported[15] when they were recovered and cultured after nearly three years on the moon. Survival of microorganisms in the space environment is supported in the paper by Roten[13], and by Mileikowsky[16].

Perhaps most relevant with respect to low temperature and high vacuum is the fact that such lyophilization of microorganisms is the universally applied method for their indefinite preservation in viable form.

6. The organisms must survive their exposure to ionizing radiation in space. The extensive treatment of Clark already cited[10] includes a detailed evaluation of radiation exposure to rocks ejected from Mars to Earth. He finds that organisms within pebbles less than one cm in size would be sterilized by radiation in less than 10,000 years, and that a boulder would be required to protect interior microorganisms for a one-million year trip. From this, he argues that there is little probability of organisms surviving the trip. However, he cites evidence that, of the small number of Martian meteorites found on Earth, one arrived about 600,000 years after leaving Mars, and others after about 2.6 million years. Allowing for errors in measurements, in assumed parameters, and for the small sampling, the window of possibility sketched by Clark certainly remains open. Moreover, Weiss et al.[14] point out that travel times for Martian ejecta larger than 100g can be as little as 2 to 3 years. Including the radiation problem in his assessment, Melosh[9] found the probability of Panspermia between planets in different solar systems small but possible. The exposure time for possible trajectories between Earth and Mars are far less than those for interstellar travel, providing a significantly greater probability of survival. In the paper reported in 2 above, Mileikowsky *et al.* report that 5 billion rocks capable of bearing radiation-surviving microbes likely arrived on Earth from Mars over the past 4 billion years.

7. The Mars-infecting ejectus must approach Mars and be captured in its gravity well. Clark's and Mileikowsky's citations in 2 above support this link in the chain.

8. The organisms in the ejectus must survive the temperature of entry into the Martian atmosphere. This temperature will be less than the temperature experienced in the impact and exit through the Earth's atmosphere already treated in 3 above.

9. The organisms must survive the mechanical and thermal stresses of impact on the Martian surface. Again, these stresses will be less than those shown in 3 and 4 to be survivable upon leaving Earth.

10. Environmental conditions at the impact site must be amenable for growth of the organisms. Living populations of microorganisms have been found in active ecosystems in supercooled droplets in clouds above the Austrian Alps[17], deep within ancient permafrost[18], in very high salinity[19], in sub-freezing ice on the South Polar Cap[20], beneath a high Arctic glacier[21], and under simulated Martian conditions[22]. Even the deep trenches in the seas have been reported to be teeming with organisms surviving extreme heat, cold, enormous pressure and lightlessness. Indeed, life has recently been found to be so pervasive on Earth, including under conditions approaching those on Mars, that it has inspired life-related experiments on Beagle 2[23] (although no direct life detection experiments are known to be included). However, Pathfinder's finding[24], that the atmospheric temperature below one meter's height at the landing site diurnally rises into the 20's°C, extends the habitable zone further than previously thought.

11. Alien organisms arriving on Mars must be capable of adapting to, or evolving to spread over wide regions of the planet. As pointed out in 10 above, terrestrial organisms have demonstrated an astonishing ability to adapt to extreme environments approaching those on Mars. The evolutionary history of life on Earth fully supports the likelihood that, once deposited in a life-sustaining, if not optimal environment, terrestrial microorganisms would successfully adapt and/or mutate eventually to spread across wide areas of the Red Planet.

12. Earth and Mars must have been hospitable to life over epochs permitting infection of Mars by Earth organisms. Thus, conditions supporting life must have prevailed on Earth at the time of a meteor-produced ejection, and on Mars at the subsequent time of its arrival. It is now widely believed that life began on Earth about 3.5 billion years ago, and has existed here continuously since then. While most meteors impacted Earth during the eons following its formation, the impacts continued well into the time of life, continuing until the current era. Kerr[25] reports that a study of many spacecraft images of Mars supports a warm, wet Mars some 4 billion years ago. Evidence of liquid water on the surface of Mars in the current era was recently reported[26],[27], and recent analysis[28] of Viking data indicates extensive regions where liquid water is currently stable for months on end. Moreover, recent experiments[29] have demonstrated that ice melts into liquid water under present Martian conditions. ALH84001 is now reported to have magnetite crystals[30] in chains constituting evidence of biological origin[31]. There has been sufficient overlap of habitable environments to allow for viable ejecta from Earth to land on a receptive Mars. Indeed, it is contended[8] that such conditions exist on Mars today.

3. CONCLUSION

In his extensive treatment of the possibility of Panspermia operating from Mars to Earth, Clark[10] proposes a probability analysis indicating little likelihood of viable organisms surviving the trip from Mars to Earth. Similar to the links listed above, a series of barriers to Panspermia is proposed by Clark. He finds each probability less than one, such that the product of all produces a virtually nil overall probability that Martian life can arrive on Earth in viable form. Some of his barriers seem repetitive, and others might well be assigned a probability of 1, but were not. Clark concludes, without calculating, that the probability product renders the possibility of live transfer from Mars to Earth virtually nil. Nonetheless, the author carefully ends with the caveat, "The probabilistic model, though yet incomplete and with many uncertainties, already argues against any conclusion that Martian contamination of Earth's biosphere occurs pervasively (emphasis added)."

A very different conclusion results from the analysis proposed herein. Argument is made that each of the vital links in the chain of life connecting Earth and Mars has a probability of one. Today's knowledge makes it very difficult to conceive of a sterile Mars. Indeed, it now seems that Earth and Mars form one biosphere. This sheds new light on the results of the Viking LR experiment on Mars. Together with growing acceptance[32] of the fact that no chemical or physical experiment or theory has satisfactorily explained the extensive and consistent LR data, significant support is found for the conclusion[8] that it detected microbial life in the soil of Mars.

While the case for life on Mars has strengthened in recent years, many will require additional proof before accepting such a major change in paradigm. It has been proposed[8],[33] that this important confirmation can be obtained by a simple modification of a miniaturized version of the original LR experiment[34].

All of the multiple rationales attempting to explain the Mars LR results as chemical or physical in origin have now been effectively refuted, but their impact remains. A tried and true scientific axiom says: once a method to probe the unknown demonstrates utility, the exploratory tool should be refined to investigate the causes of the phenomenon discovered. Mars exploration might greatly benefit by elaborating on the demonstrated LR technique.

The simple modification of the LR instrument to settle the issue of life on Mars could do so in a manner acceptable to nearly all scientists. Called the "Chiral LR Experiment," the refinement separately applies the optical isomers of compounds the LR originally applied to the Martian soil. Other suitable compounds having optical isomers might be tested in parallel. For reason still unknown, life evolved with great preference for left-handed, or "L-"amino acids, and right-handed, or "D-" (for Dexter) carbohydrates in all of its metabolic functions. The enzymes that evolved to catalyze the otherwise energetically improbable biological reactions originally chose those forms. The successors to the first cell that arose handed down those preferences in perpetuity to their progeny, including you and me. Chemicals, on the other hand, cannot distinguish between D- and L- versions of the same compound, reacting equally with both forms. Thus, a positive metabolic response to one chiral isomer of a compound in exclusive or overwhelming preference to the other would unequivocally establish that the agent responding was alive. Moreover, should the preference be similar to that shown by Earth life, a relationship would be implied, enhancing the prospect that interplanetary propagation was operative. On the other hand, the most interesting result would be for the chiral preference to differ from that on Earth. This would be strong evidence for a form of life differing from our own at the fundamental biochemical level. This would present a case for multiple origins of life.

A strong, if not irrefutable scientific argument can be made for going back to Mars at the earliest opportunity with a slight, but important variation of this already demonstrated technique. Should the experiment confirm microbial life on Mars, future missions could apply further variations in nutrients, environmental controls and other elucidating factors to conduct comparative biological studies of Earth and Mars life for improved and beneficial knowledge of each. This mission would be consistent with NASA's announced highest priority, the search for life on Mars.

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