Mars:The Living Planet" by Barry E. DiGregorio

Chapter Nine¾Life After Viking: The Evidence Mounts
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Barry DiGregorio first interviewed me by phone in 1993 for an article about life on Mars. I quickly detected his fascination with the subject. Obviously, he wasn't just writing another freelance, earn-a-living piece. When his story was published in *Final Frontier* in June, 1993, his intense interest in what many have declared to be mankind's most intriguing question—are we alone?—became even more evident. The article, in the form of a Q&A interview, was cogently designed by Barry to call attention to the findings of the Labeled Release experiment on Mars, which he felt had been given short shrift by most of the Viking scientists and had not been adequately disclosed to the public. Barry stayed in touch with me over the next three years, telling me in 1996 of his project to write this book. He informed me that my encounter with Mars through the LR experiment aboard NASA'S 1976 Viking Mission would play a prominent role in his book. Barry interviewed me frequently, gathering material for the book and requesting various reprints of scientific publications on Mars written by me and my colleagues. When he came to meet me in person, his interest in the Red Planet and its attendant scientific issues constantly shone through.

However, I already had come to appreciate his dedication to Mars and his desire to settle the life issue. About a year before he started this book, Barry asked my advice when he was preparing his proposal to the Hubble Space Science Institute. Barry proposed to view Mars through the Hubble Space Telescope, the world's most powerful, and, using the highly sensitive Goddard High Resolution Spectrograph, look for hydrogen peroxide in the atmosphere and on the surface of the planet. Unfortunately, the scientific rationale for Barry's experiment was not deemed sufficient by the reviewers for its selection. Barry missed his chance to participate in what pre-Viking NASA had stated could be "the most important experiment in the history of science," the search for life on Mars.

But why look for hydrogen peroxide on Mars? In one of the classic quirks of science, the very data from the LR life-detection test had been seized by other scientists to contend that the LR had detected not life, but chemicals. They concluded that the LR experiment produced "no evidence for life," but that it did establish the presence of chemical oxidants on the surface of Mars. It did not seem to matter that the LR had been approved as a life-detection test by four NASA-appointed science panels and that the experiment never had produced a false positive result from chemicals encountered in the many Earth soils tested. On Mars, putative chemicals seemed easier to invoke than did life.

The chemistry advocates constructed various theories, beginning with the "raining" of hydrogen peroxide from the Martian atmosphere onto the planet's surface. They contended, and still contend, that the hydrogen peroxide destroyed any organic matter, including life. This oxidant, they explained, either remained in the soil or, depending on the specific theory, complexed with one or more minerals in the soil to form strong oxidants that mimicked life in the LR experiment. The hydrogen peroxide theory also was proposed to account for the "absence" of organic matter in the soil of Mars as reported by the Viking Gas Chromatograph Mass Spectrometer (GCMS). However, as I explain later, there is no evidence for hydrogen peroxide on Mars. Moreover, there is evidence for life existing in an Earth environment in which hydrogen peroxide levels exceed those the chemistry advocates predict for Mars! Other theories to attribute the Mars LR result to non-biological reactions suffer from similar fundamental problems.

Dr. Patricia Straat, my Viking LR Co-Experimenter, and I initially stated and subsequently maintained that our LR data "are consistent with a biological answer." After continuing analysis of the data, and years of additional laboratory testing, I strengthened my conclusion. In 1986, in a talk at the National Academy of Sciences celebrating the tenth anniversary of Viking, I said that "more probably than not" the LR had detected microbial life in the soil of Mars. This produced near-pandemonium among the scientific audience. At the reception, which followed the talks, prominent Viking scientists accused me of having disgraced myself and science. Now, as you will be the first to learn, the facts force me to go a step beyond my 1986 statement.

About a year prior to NASA's announcement of the startling new evidence of biological fossils in the SNC meteorites believed to come from Mars, Barry called me to say he was going to write this book. He then paid me a visit to discuss it. During our conversation, he revealed that the LR experiment and I were going to be featured in his book. This placed me in a dilemma. Since I often have been misquoted by those anxious to attribute to me more than I have said, I feared that the careful line I have trod since Viking might be compromised if I paid no attention to the evolving manuscript. Technical errors might inadvertently creep into text written b even the most well-intentioned non-scientist. The other horn of the dilemma was that, if I did review the work, I would be deemed liable for any opinions or implications that some scientists might think beyond the pale. Having spoken with Barry, I knew his enthusiasm would be difficult to diminish, nor should I attempt to interfere with his views as author. After wrestling with the problem, I offered to review the chapters with the understanding that my factual corrections about the Viking LR experiment and related matters would be respected, but that I would have no other control over Barry's literary license, including his evaluation of the LR experiment and its scientists.

I think Barry has done a fine job in bringing together many discrete aspects of Mars and synthesizing them into a fascinating story about our neighbor's capacity to harbor life. His research of the literature has brought forth new insights. I find his snow algae discussion particularly interesting and, perhaps, very insightful. I have enjoyed reviewing his work and hope that I helped with the accuracy of the explanations of some of the scientific issues. This book is a popular version of the broad sweep of history surrounding the enigma of Mars, which has cloaked itself more with each attempt to penetrate its mysteries. Using my records to aid my memory, I have tried to keep the *Viking* story straight while, at the same time, realizing that Barry is writing for the general reader and is not attempting a scholarly work. Accordingly, while making some suggestions that I thought would allow scientists to enjoy the book rather than complain of scientific errors, I have resisted my impulses to make it conform to a style more suited for peer-reviewed journals. My disclaimer, however, is that I limit my responsibility for strict accuracy to those parts about *Viking* and its experiments relevant to the search for life, and other pertinent scientific findings discussed in this chapter. I hope the book might promote the fair hearing that the Mars LR data has never received.

After reading Barry's account of my long travail, some will wonder why I "persist" in avid pursuit of the life-on-Mars issue after twenty years; why I do not concede the issue and just go away. It is not a matter of my persisting, the data are what persist. An objective scientist, I cannot change my mind for expedience or comfort.

Viking Revisited

In my 1986 talk at the National Academy of Sciences' tenth anniversary of *Viking* I presented all the available evidence bearing on the LR results. I concluded my analysis with the statement that "more likely than not, the LR discovered life on Mars." Following the publication of news about the first Martian meteorite (ALH 84001) evidence, I told a calling reporter that, were the analyses confirmed, I would change my conclusion to "most likely." When the second meteorite (EETA 79001) results were announced, upon inquiry by another reporter, I said (again, presuming the report valid) "almost certainly."

Now, ten years after my 1986 analysis, I think new events and knowledge require another evaluation. In so doing, I will try to address each aspect bearing on the Mars LR data and other relevant data.

I. The LR Results

In all, nine LR tests were conducted on Mars at two landing sites 4,000 miles apart. All nine supported the finding of living microorganisms. Positive responses, similar to those obtained from Earth soils, were obtained at each location. Heating at 160 degrees Celsius for three hours destroyed the agent. When Viking scientists re-thought that control measure and proposed 50 degrees Celsius as the temperature to distinguish between chemistry and biology, two attempts were made from Earth to direct the instrument to achieve that temperature. One achieved 46 degrees Celsius, which produced a 70-percent reduction in the LR response, satisfying the new and more stringent agreed-upon discriminator. The other such test brought the soil to 51 degrees Celsius, resulting in more than a 90-percent reduction in the response. Terrestrial organisms show such narrow temperature discrimination. Fecal coliforms, for example, are distinguished from other strains in the coliform species by surviving incubation at 44 degrees Celsius whereas the other coliforms, normally cultured at 35 degrees Celsius, do not.

Alas, faced with the new results, the chemistry proponents, still constituting the majority, simply reneged on their agreement that a major diminution in response from soil heated to 50 degrees Celsius constituted evidence that the unheated response had been biologic. They remained immutable even when LR tests on previously active soil samples stored two and three months in the dark sample distributor box at 7 to 10 degrees Celsius produced no response! Microorganisms taken from their natural environment, deprived of their diurnal cycles, might have died.

As stated earlier, another non-biological theory was quickly struck down. It claimed that ultraviolet light hitting the Martian surface "activated" it to cause a physical reaction, releasing gas from within the LR compounds. Again, we resorted to directing *Viking* from the Earth. Commands were sent by which, just at dawn, the *Viking* arm stealthily moved a rock and snatched a sample from beneath it before daylight could "activate" it. This sample, protected from light for eons, produced a positive response within the range of the other positives!

There was only one result of the Mars LR experiment that could be interpreted against biology. The experiment called for a second dose of the radioactive solution to be squirted onto active soil samples after the responses from the first doses had plateaued. Were life present, a sharp increase in the evolution of gas was expected. Instead, when the second dose was added, 20 percent of the gas that had already been evolved disappeared from the space above the sample, reabsorbed into the soil below! The gas slowly re-evolved over about a month. Chemistry buffs contended that this showed that the active chemical in the soil had been used up by the first dose and that the freshly moistened soil had re-absorbed the gas. Had a second pulse of gas evolved, they probably would have said that the first dose of LR compounds had been exhausted by the chemicals in the soil and that the second dose merely supplied fresh reagent to restart the reaction. In an LR test we later performed on lichen in our laboratory, we got a positive response but, with excessive wetting, observed a large re-absorption of the gas evolved. Excess moisture is known to kill these symbiotic organisms. The wetting of an alkaline soil (such as the Martian soil was indicated to be by *Viking* analysis) results in absorption of carbon dioxide. We demonstrated this reaction, achieving the same 20 percent reabsorption of gas, in our laboratory LR instrument. Might the same explanation apply to the result on Mars, especially when lichen offer a model for possible Martian life forms?

2. The GEx Results

The GEx experiment had two stages: first, the "chicken soup" nutrient was uncovered and only the water vapor emanating from it was allowed to contact the soil in the test cell; in the second stage, the soil was wetted with the soup to promote metabolism by any organisms present. The water vapor stage produced a large burst of oxygen from the Martian soil. Even though no light shone on the soil during the experiment, the result was held out as possible evidence of microbial photosynthesis. When the soil was wetted with the GEx liquid medium, carbon dioxide was rapidly absorbed from the atmosphere into the soil but no additional oxygen evolved. When a duplicate sample of the soil was heated as a control and then tested, it still produced the large pulse of oxygen upon humidification. The GEx Experimenter and the Biology Team concluded that GEx had produced no indication of life, but of some chemical oxidant in the soil that reacted with water vapor to yield oxygen. The possibility that oxygen adsorbed on the soil (from the sparse amount in the Martian atmosphere) was released by the GEx vapor also was raised, but discounted because of the large amount of oxygen released in GEx.

3. The PR Results

The PR experiment produces and counts two signals, or "peaks." The first is from the radioactive carbon monoxide and carbon dioxide which had been adsorbed onto soil particles in the test cell. These adsorbed gases are released from the soil by modest heating. The second peak comes from gases released on further heating of the soil to combustion temperature. This signal indicates the burning of organic matter formed during the test. If found, the second peak is the evidence for life.

When the PR'S turn came, it produced a very small second peak response, so small that, in Earth tests, it would have been discounted as "noise" by Dr. Horowitz and his Co-Experimenters. 'Vet this was the big test on Mars, and Horowitz wanted to explore every possibility that he might have detected life. He had the PR instrument recount the faint signal for a full day to demonstrate that it was statistically significant above the background noise. He published this and called the response "startling." However, he cautioned that 'a biological interpretation of the results is unlikely in view of the thermostability of the reaction." The heated control gave the same results as the test sample. After suggesting several non-biological reasons for the results, Horowitz, nonetheless, stated that "it remains to be seen whether any of the proposed mechanisms can account for the intriguing observations," thereby leaving the door to life open.

While the PR signal was above the background level, it was far short of being significant in indicating life. Indeed, tests of the PR on Earth, both before and after the test on Mars, showed even higher responses from control tests with sterilized soils, despite the presence of the UV filter that had been installed to prevent false positives. Apparently, the PR's UV filter did not completely fulfill its mission of removing the rays that caused photo-chemical production of organic matter from Martian atmospheric gases. Thus, the PR experiment gave no evidence for life. Nonetheless, the PR was a very important experiment which, until now, has not been given due credit. It confirmed on Mars that—as in the PR tests on Earth—organic matter is formed in the sunlit atmosphere and, even under the continuous shining of the UV light, accumulates in the soil where the Viking GCMS should have found it! Had these gases not been incorporated into organic matter, they would have been blown out of the test cell during the first peak heating cycle.

4. The GCMS Results

The LR group held its breath while the GCMS went through its motions. And, because of mechanical and design problems, it had to perform sample acquisition twice before Klaus Biemann felt the instrument had obtained a sample. As stated, the Viking scientists all felt certain that there were organic compounds on Mars. Thus the mission of the GCMS was not to *detect* them, but to *identify* them. Our LR group hoped that compounds implicating life would be found. When the analysis was finished, the results astonished everyone. No trace of Martian organic compounds was found!

However, the GCMS had problems which raise questions about the validity of its findings. It could not detect some organic matter of biologic origin in soils only sparsely populated with microorganisms. Mechanical problems on Mars resulted in difficulty in obtaining soil samples. The mechanical difficulty was exacerbated by the fact that the instrument had no "tell tale" to signal the receipt of a sample. The only evidence for samples was the observation that the sampling arm had scraped a small ditch in the soil to obtain the sample. However, there was no way to tell whether that sample made its way through the distribution box, which received it, and then into the tiny ovens of the GCMS. And, if it did, the amounts that entered the ovens were uncertain. It finally was decided that the GCMS had obtained samples because of the amounts of water and carbon dioxide that evolved during the heating of the samples. However, carbon dioxide constitutes 95 percent of the Martian atmosphere, and that atmosphere daily reaches 100 percent relative humidity. Since frost was deposited on the surface daily, it also might have been deposited into the oven and sampling train of the GCMS, along with any carbon dioxide that had dissolved in the water vapor. To what extent these possible deposits might have figured in the GCMS results, particularly if no sample of soil had been obtained, is unknown.

Nonetheless, the GCMS' unexpected result forced a dilemma on NASA and its community of scientists: how could any thought of life be entertained in the absence of organic matter? The easy and cautious way out was apparent. The LR had detected inorganic chemical(s), not life. Once set, that stage has never been changed.

5. Simulations of the LR Results

In the twenty years since *Viking* many attempts have been made in various laboratories to duplicate the LR Mars results by nonbiological means. Our own laboratory spent three years in this effort. Hydrogen peroxide, superoxides, metalloperoxides, peroxide complexes, UV light, and ionizing radiation were tested against Mars analog soils prepared by NASA based on *Viking* analyses of Martian soil, various clays, minerals, and other surrogate soil substrates. We applied a wide range of environmental conditions to the test procedure. LR radioactive solution and its single components were applied to the samples in a Viking-type LR instrument. A wide range of control regimens was used. Under extreme conditions unrealistic for Mars we were able to force positive results. However, no simulation of the Mars LR data could be produced in any of our experiments or those of others when materials and conditions known to obtain on Mars were used. We have published on all of our efforts and on those of others that have been published or otherwise come to our attention. A plausible reproduction of the Mars LR data by nonbiological means remains to be demonstrated.

6. Imaging

Frustrated at the lack of progress in gaining acceptance of the LR results, in 1977 I went to JPL and examined all 10,000 *Viking Lander* images then in the JPL files. The JPL Viking Imaging System staff helped me by producing the digitized images in "Radcam," which means true color calibration. The first thing I noticed was that Mars was not "uniformly orange-red" as stated in NASA press releases. just as was shown in the first color image released, and then promptly withdrawn, by NASA, the landscape appeared very familiar, very Arizona-like. Generally reddish brown to brown, the landscape contained areas of ochre, yellow, and olive. Most surprising to me were olive to yellow-green to greenish colored areas on many of the rocks.

One night I made the discovery that, on some of the rocks, these colored areas appeared to show changes in pattern and coloration from Martian year to year. I thought it was the second time I had discovered life on Mars! I was so excited that I left JPL and drove up Angels Crest Highway to park and study the night sky until my high wore off.

Analysis of the six channels of digital information comprising each Viking image—red, blue, green, and three near-infra red frequencies—showed these spots on the rocks to be the greenest objects in the entire field of view. Thinking that the spots might look like lichen, on one trip I brought some rocks bearing patches of lichen from Maryland to JPL. I placed the rocks in the *Viking 1* simulated landing site. The JPL Viking Imaging System Team took images of the rocks through the Viking Lander Camera Imaging System. The pictures were taken under the simulated Martian light bathing the scene. They were processed in an identical manner to those obtained on Mars. The digital spectroscopic analysis showed that the lichen on the rocks were the greenest objects in view. Furthermore, the digital values of the color, hue, and saturation were very close to those for the greenish spots on the Mars rocks. Publication of this information in a technical paper had the reverse of the action I anticipated. Instead of supporting the LR biological interpretation, the publication was viewed as a desperate, non-scientific ploy. First, it was widely denied that any greenish coloration showed on the photographs! Next, I was chastised for supposedly intimating that there were lichen on Mars by claiming to have found green areas.

While working on the images at JPL, I called their attention to one of the Viking scientists. He subsequently wrote and published a report on the finding of greenish colored soil and markings on the rocks on Mars. Wary of the sinkhole that awaited biological references to Mars, he made no mention, among the many possible origins he cited for the coloration, of any biological possibility. He even was careful not to reference our earlier paper, nor credit my having called his attention to the colored spots and areas. However, it only has been since publication of his report that the presence of green spots on Martian rocks has become accepted. Recent renderings of the Martian landscape, once again, look very much like Arizona—as demonstrated by the carefully prepared image serving as the cover on the book *Mars,* published in 1992.

7. Liquid Water

The perceived lack of liquid water on the surface of Mars has led many scientists to conclude that life could not be sustained there and, therefore, the LR results must be ascribed to chemistry. "Water is life" has become a popular rallying call of the chemical protagonists. I do not believe the answer to be as simple as that didacticism. As with so many other questions put to Mars, it does not give a straightforward answer with respect to liquid water. The "triple point" for water is 6.1 millibars (mb) of atmospheric pressure. If the total atmospheric pressure exceeds 6.1 mb, water may exist in any of its three forms: solid, liquid, or vapor, depending on its temperature. However, if the total atmospheric pressure is below 6.1 mb, water cannot exist as a liquid. Atmospheric pressure on Mars varies between approximately 6 and 10 mb. Thus, at times when 6.1 mb are exceeded, should the temperature rise sufficiently to melt the abundant ice, liquid water would result. Temperatures of the sampling arms in contact with the soil were recorded at both Viking landing sites. The temperatures of the arms rose as the Sun rose to and a little beyond its zenith. The temperatures of the arm at the Viking 2 site reached 273 degrees Kelvin (0 degrees Celsius, the melting point of water) and stayed there for a while. That means that liquid water was present under the arms. When water transitions from solid to liquid, just before it melts, extra heat (the heat of fusion) is required before the temperature can continue to rise. This pause in the temperature rise is what Viking recorded—proof of liquid water. It is true that the metal sampling arms absorbed and stored more heat from the Sun than the soil would otherwise. However, it is quite likely that dark rocks, and perhaps dark soil, at the sites of both Landers act the same way. They could supply liquid water to microorganisms if only for a brief period daily. Mars microorganisms may well have adapted to garner needed water in this fashion. Furthermore, a new book *(Water On Mars,* M. Carr, 1996) reports that the *Viking Orbiters* found surface temperatures reaching 298 degrees Kelvin at the summer solstice at 1 P.M. local time in the southern hemisphere, with atmospheric pressures at both Viking sites exceeding the triple point for the 700 consecutive Martian days of measurement. Viking also reported temperatures exceeding 273 degrees Kelvin (98 degrees Fahrenheit) in the northern hemisphere where both Vikings landed.

At the other extreme is the possibility that Martian organisms may be able to obtain their water from the atmosphere, as has been reported for some lichen on Earth. While the Martian atmosphere is only about one percent of ours, both Viking sites showed high relative humidities, reaching 100 percent nightly. Even if the water vapor were in the form of tiny ice crystals, these would deposit on the organisms. The organisms might have learned to store energy from the Sun to melt the crystals and absorb the liquid, or, as many Earth microorganisms do to prevent freezing, Martian organisms might make antifreeze. Finally, ice crystals have been shown to participate in chemical reactions, such as in the atmospheric destruction of ozone by chlorofluorohydrocarbons (CFC), which is responsible for our ozone hole. It is believed that one end of an ice crystal in a cloud remains solid while the end in contact with the ozone and CFC behaves like a quasi-liquid and permits the "aqueous" reaction to take place. This process may be used by microorganisms on Mars (and, perhaps, on Earth, too!).

In sum, there is evidence for liquid water on Mars. In addition, Martian organisms may be able to absorb water vapor, or may have evolved to make liquid water from ice or to take advantage of ice's ability to provide an aqueous environment for reactions. Our knowledge of the water issue—on Earth or Mars—is too uncertain to be used as an absolute barrier to life on Mars.

8. The Martian Meteorites

When meteorite ALH 84001, believed to have come from Mars, was found to contain fossils indicating life, the news startled the world. Once again, the question of life on Mars became front-page news. Analysis indicated the meteorite to be approximately 3.5 billion years old, formed about one billion years after the planet Mars coalesced. By then the planet had had time to cool and become environmentally conducive to life. Liquid water is believed to have been abundant on Mars at that time. This history closely paralleled that of Earth, which is believed to have given rise to living organisms within the first billion years of its formation. Since the meteorite had left Mars before the serious environmental changes inimicable to life occurred, it was presumed that the life present three and one-half billion years ago had since become extinct. This scenario greatly stimulated the concept of searching for microbial fossils on Mars rather than extant life.

But Mars was not done with teasing humans. Hard on the heels of SNC ALH 84001, the analysis of another meteorite presumed from Mars, SNC EETA 79001, produced an even greater shock. This meteorite not only confirmed the biological organic evidence of the earlier one, but was estimated to be less than 600,000 years old! In terms of the planetary history of Mars, this was modern times, well after the drastic environmental changes on Mars which had been widely advertised as proof that the Viking LR could not have detected life. This news led the chemical theorists to conclude that Mars may have life today but, if so, it must be hidden in very rare "oases" deep beneath the surface of the planet in pools of liquid water heated by volcanic activity and kept from subliming into vapor by the overlying strata.

No one has offered to explain how the meteor that impacted Mars to launch EETA 79001 on its long journey to Earth found a precious oasis! Nor have the oasis proponents addressed a recent study which finds that material ejected from a planet by meteoric impact comes from near the surface not from the depths proposed for such oases.... And the leaders of the fossil search press on with no (announced) thought that might link the recent findings to the LR results! Darwin must be spinning in his grave at the thought that the modern descendants of his discipline believe that life existing on Mars during its recent era would not have survived to the present. However, they do not deny that early Earth life was faced with a much more desperate situation. When oxygen first appeared, produced by photosynthetic organisms, this gas was intensely toxic to all other life forms. However, life managed to convert that adversity to advantage.

9. Expansion of the Life Envelope

While the direct investigation of life on Mars has been at a standstill for the twenty years since *Viking,* knowledge about life on Earth has increased to an astonishing degree. Microorganisms, large anchored tubular worms, and fish, all previously unknown, have been found living in deep ocean trenches in lightless waters at temperatures of several hundred degrees Celsius and under pressures of thousands of pounds per square inch. Microorganisms frozen deep below the surface for millions of years have been resuscitated instantly when brought to the surface. Microorganisms have been found growing in cooling waters irradiated by nuclear reactors. A new kind of microorganism, capable of living on rock and water, has been found in deep sunless pools. Indeed, the "thin film of life" has been expanded to become a three-dimensional continuum. Obeying Darwin's principle of evolution, life on Earth has occupied virtually every environmental niche, many with extreme conditions exceeding those on the "hostile" Red Planet. Why should we expect life on Mars to have done less?

10. Panspermia

Perhaps the most important accomplishment of the analysis of the two life-bearing meteorites is their proof of the theory of Panspermia advanced by Svante Arrhenius in the nineteenth century. This Nobel Laureate in chemistry envisioned that life traveled through space, inoculating planet after planet. Whether the two SNC meteorites come from Mars, or not, matters little in this case. What matters most is that they do bear evidence of biology from someplace other than Earth! This finding defeats the ultimate argument of those opposing acceptance of the LR data—that the origin of life is such a complex process, still not nearly understood, that to suppose it happened on Mars is the most far-fetched explanation of the LR data possible.

"Ockham's razor," the fourteenth-century philosopher's admonition to seek no further than the simplest explanation—long cited by the pro-chemist group against the LR's having detected life—now cuts the other way! The meteorites show that we no longer have to assume that life on Mars arose there! Life, at least microorganisms, can ride the Cosmos. The way to preserve microorganisms indefinitely (no time limit is yet known, but it exceeds millions of years) is to freeze them. In the laboratory we freeze and dry them. They are readily resuscitated when placed back into an environment favorable to them. Space travel provides the best freeze-dry process available! So, microorganisms, once formed somewhere, can hitch rides for millions of years! Of course, while freeing up the LR data, this new information merely pushes back the problem of how life began somewhere.

II. L'Envoi!

Between 1976 and 1986, Pat Straat and I contended in published papers and oral statements that a biological interpretation of the LR results was possible. By 1986, our studies and our review of work done by others led to the statement that "more probably than not, the LR experiment on Mars discovered life." Much new information has been gleaned since then, on Mars and Earth, which requires a new assessment.

Each of the reasons supporting a non—biological interpretation of the LR Mars data has now been shown deficient. The demonstrated success of the LR in detecting microorganisms during its extensive test program with its record of no false positives can no longer be denied. New evidence, together with the review of the old, leaves the biological interpretation standing alone. The scientific process forces me to my new conclusion: the Viking LR experiment detected living microorganisms in the soil of Mars.

The conclusion that the Viking LR results and all available relevant evidence point to the existence of microorganisms in the soil of Mars raises the question of what type of microorganisms they might be, Several possibilities are evident. The LR data, the Viking images of greenish patches on the rocks, the Viking imaging system analysis of terrestrial lichen, and the known hardiness of lichen (these "pioneers of vegetation" are the first organisms to appear on newly formed bare rock, such as when Surtsey rose from the sea and cooled) make lichen a good candidate. Species on Earth are reported to survive on water obtained in vapor form, to endure Mars-like cold, and to grow on, even inside, rocks. The discovery and analysis of the Martian meteorites, if confirmed, would make it extremely likely that Earth and Mars have exchanged material frequently. As stated, space conditions are very good for the preservation of any microorganisms inside the ejecta. Since lichen are present within rocks on Earth, they, but not only they, make a good candidate for interplanetary travel. If present on Mars, lichen may be widely distributed over the planet's surface and might have been in the LR sample. The two symbiotic components of lichen are algae and fungi. They might also be widely distributed as individual species, as might a great variety of other species. It seems unlikely to me that any microbial forms would be confined to discrete "oases." Just as on Earth, life on Mars probably adapted to all of the environmental niches. As pointed out earlier, those niches on Mars are much less severe than on Earth. Even if that unlikely scenario of discrete oases were true, those oases might still have supplied living organisms to the LR. Organisms from the oases would have been extruded to the surface repetitively over time, perhaps by frost-heaving or by volcanic eruption, and would have become lyophilized (freeze-dried) by the climate. Thus preserved indefinitely, they would have been blown by the wind and eventually distributed over the surface of the planet. Such dormant organisms might have instantly begun to metabolize when given the LR's favorable environment and food. I think this hypothesis possible, but less likely than the hypothesis that life has adapted to all Martian ecological niches. In any event, the existence of life on Mars would make it likely that the LR soil would have contained a viable sample.

I believe confirmation of my new conclusion will come with additional life-detection missions to Mars, unfortunately not currently within NASA'S plans. However, the possibility does exist that the refined cameras on *Pathfinder;* scheduled to land on Mars on July 4, 1997, may surprise us with images we readily recognize as colonies of lichen or other microorganisms. I anxiously await more Patch Rocks.

Religion, Philosophy. Society, and Science

Science's first steps, taken in mankind's fledgling society, were largely controlled by religion. Centuries of effort by truly persistent scientists, some at the cost of their lives, have still not completely freed science from the bonds of religion. However, as science grows in scope, magnitude, and importance to our everyday lives, new shackles have been forming around it, forged by politics and government. Over the past half-century, science has been transformed from a discipline engaged in by lone, gifted investigators to a major enterprise requiring elaborate facilities, equipment, and teams of researchers. Big Science requires big budgets. Funding for basic science, which promises no immediate financial return, is largely supplied by government or large philanthropic agencies. They rely upon peer review to select projects for funding. As happens within any large organization, leaders emerge to dominate policy. The scientists, like anyone in a supplicant situation, realize the desirability of maintaining favor to maintain funding. They are prone to direct their efforts to areas determined as priorities by the funding sources. They often tune their public pronouncements to the current policies of their supporters. To do otherwise may be to incur displeasure at the source, which, even though unintentional, could adversely affect funding. For example, once, when I was principal investigator on a government contract, the government contract officer paid me a usual visit to discuss progress. After some talk, he asked me to change the direction of my research to follow one of his ideas. I did not think it worth deviating from my proposed course of work and told him so. He then began to insist. I then said that I appreciated his input, but that I thought it best to stick to the plan that his agency had approved. Then I made the mistake of adding, "After all, I am the principal investigator and your agency is paving me to use my best judgment in pursuing this project." When annual funding time came around, I was told that my project would not he continued. I never was funded by that agency again.

I think that once NASA announced that the LR had produced "no evidence" for life, the scientists in the agency, outside scientists supported by the agency, and those looking to the agency for future funding took their cue. Consciously or even without overt intent, they coalesced behind the official opinion—even to the extent of using that patently inappropriate phrase "no evidence" to describe the LR'S findings. The unlikely alternative is to believe that a large number of scientists do not know the definition of the word "evidence"!

In a December 12, 1996, CNN Headline News story on NASA'S new "Origins" theme following a NASA-sponsored meeting between scientists and theologians, Vice President Gore and NASA Administrator Goldin were shown in a discussion. The Vice President and the Administrator were speculating on the impact that would be felt if life were discovered on Mars. Administrator Goldin commented that"... many Americans ... believe in God. Different manifestation. Taxpayer dollars are involved.. . .“ It thus seems evident that religious considerations influence NASA programs.

'What role religion, philosophy, and sociological implications play in the acceptance of extraterrestrial life is difficult to assess, but I believe they do play a significant role. All three of these paradigms for seeking enlightenment would be seriously affected by the discovery of life beyond the Earth, which will have to be assimilated into the culture. We may face considerable resistance before that assimilation is accomplished. Apparently, the NASA Administrator believes the same.

The Next Steps

Before the analysis of the two Martian meteorites, NASA had laid out a ten-year plan for the continued exploration of Mars. None of these missions, some ten spacecraft in all, launched in pairs at two-year intervals, is scheduled to contain a life-detection experiment. Apparently, NASA still believes that *Viking* proved that there is no life on Mars, or else it doesn't want to discover life on Mars—vet. Despite President Clinton's stating that the number-one priority for NASA is to determine whether or not there is life on Mars, a statement echoed by the NASA Administrator, no change in plans has been announced.

Amidst all this renewal of the issue of life on Mars, NASA has announced that it will seek the "earliest possible mission, perhaps as early as the year 2001," to return a sample of Mars soil to Earth for detailed study. I believe this would subject our planet and its life forms to an undue hazard. A more cautious progression might be to send robotic missions to Mars in 1998 to settle the life issue and determine something about any life found. Then any samples for detailed study by human scientists should be returned, not to Earth, but to a laboratory established for the purpose either on the Moon or on the Space Laboratory. In that way the Earth would be protected until we were certain that there was no hazard in returning a sample to Earth.

As early as 1975, Biospherics completed a detailed report under NASA contract entitled "Technology for Return of Planetary Samples." A major problem in protecting the scientific integrity of the sample was pointed out but has yet to be addressed by NASA. Some means of protecting the sample against changes during the long return trip must be developed. A complex environmental chamber will have to be developed to maintain Martian atmospheric gas pressure and composition, Martian ambient temperature cycling, Martian diurnal lighting, water content in each of the phases occurring on Mars, pH, redox, and other still-undetermined parameters necessary to keep the sample pristine for its examination. AND, to preserve the sample to be able to examine it for living organisms, a whole life-support system must be provided and operated throughout the trip. Otherwise, any microorganisms present would likely use up some vital resource and be seriously impaired or DOA, thereby confusing the whole life issue. The report strongly recommends initial biohazard assessment and the development of suitable control technology. As stated above, the report urges that the sample not be returned directly to Earth, but to an off-Earth laboratory to determine any health or environmental threat.

The famous image returned to Earth from the Apollo Mission shows us how tiny and frail our planet is. We should protect it.

Future Experiments

A general rule for scientific investigations is that when a new technique begins to get answers, that technique is expanded to further the line of inquiry. The next experiments into the question of life on Mars, therefore, should begin with the LR technology. It readily lends itself to expansion. It not only can confirm the *Viking* results, but also can learn more about the life detected. This can readily be done by, first, separating its offerings of the left-handed and right-handed molecules, then varying the numbers and kinds of compounds to learn more about the metabolism of the life forms found. Environmental conditions can be controlled. Thus, the responses at different temperatures, relative humidities, amounts of water, atmospheric gases, and the like can he determined. An Automated Microbial Metabolism Laboratory (AMML), which Biospherics designed, built, and tested for NASA in the seventies, uses the extreme sensitivity of the radioisotope technique to look at the involvement of life-essential elements other than carbon, such as phosphorus, sulfur, and hydrogen, in the metabolism of microorganisms. We also proposed that, upon successful response to the LR probe, a subsequent mission test for the presence of adenosine triphosphate (ATP) in the cellular material detected. A robotic instrument to do this was built. Since ATP is the universal compound through which terrestrial life obtains its energy, this test would constitute a good comparison of Mars life to Earth life. New technologies, such as polymerase chain reaction (PCR) and nucleic acid mapping, will permit any traces of nucleic acids to be amplified to the point where they can be mapped for comparative studies.

In order to meet the deserved urgency and priority placed upon the search for life on Mars by President Clinton and Administrator Goldin, I suggest the following approaches for new missions:

1. The TEGA experiment in *Surveyor* '98 be modified as I proposed to include life-detection capability.
2. The Hubble Telescope should be used to survey the surface of Mars for evidence of seasonal geographic changes in patterns and coloration. These should be correlated with surface temperature and atmospheric moisture content to investigate and, if found, elucidate the reported wave of darkening.
3. A new LR experiment and instrument should be sent to Mars on the earliest possible mission. This should include the suggested changes described in this chapter plus new ones that a study of this opportunity will undoubtedly develop.
4. The ATP and AMML tests should be incorporated into an updated automated instrument.
5. New techniques such as PCR, nucleic acid analysis, and high-resolution imaging should be developed, instrumented, and flown.
6. Follow-on experiments to determine the nature of any life found, its variety, and its environmental limits should be designed and flown.
7. Return sample missions should deposit samples on the Moon or aboard the Space Laboratory for detailed examinations. Before such samples are sent to Earth, complete assurance of their safety should be established.

Postscript

Many of the references supporting statements I have made in this chapter are listed in the Reference section of this book. I have not cluttered the chapter with individual citations. However, a formal scientific paper supporting my new conclusion about life on Mars is under preparation. I have been invited to present the paper at a symposium on "Instrumentation, Methods and Missions for the Investigation of Extraterrestrial Microorganisms" at the Annual Meeting of the International Society for Optical Engineering, scheduled for San Diego for late July to early August, 1997. I will update my story to try to convince my fellow scientists of the new conclusion I have reached. I hope I can, but if not, I will continue to take consolation in knowing that scientific progress is not a democratic process, and I will keep trying to turn the tide. Like the Ancient Mariner, I cannot resist telling the fascinating story about life on Mars.

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I am especially pleased to acknowledge the professional contributions of my son Ron, who accompanied me at JPL during the Viking Mission, having freshly graduated from high school. Now a Ph.D. physicist at MIT's Lincoln Laboratory, it was he who supported my contention that the Viking data demonstrated the presence of liquid water on the surface of Mars. He also was the first to cite Rayleigh scattering (commonly taught in college physics courses to explain why the sky is blue) to refute the red sky arbitrarily assigned to Mars by NASA, and he applied his capability with computers to help me in studying the colored patches on the rocks.

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I also want to thank the Biospherics Board of Directors for its patience in allowing me to participate, long after funding had ceased, in my "hobby" at the expense of more conventional and profitable things expected of a company president.

It is always fitting and proper to acknowledge family support. In this case, it's more than a perfunctory obligation. My wife, Karen (who also helped in editing this chapter), my sons, Ron and Henry, and my daughter, Carol (who also contributed to this editing), have lived with my daily struggles with Mars for more than two decades!

My ultimate thanks, however, despite the complaints I voice in this chapter and elsewhere, go to NASA, which provided me with the most exciting scientific adventure I could ever imagine, one that I believe is not over yet! Among the NASA officials I feel mostly indebted to are Drs. Freeman Quimby, Orr Reynolds (deceased), and Richard Young (recently deceased), who, as sequential early directors of the Exobiology program, enthusiastically supported my efforts.