THE EXOBIOLOGICAL EXPLORATION OF MARS

J.F.Kerridge, UCSD/NASA HQ; M.H.Carr, USGS; B.C.Clark, Martin Marietta; D.J.DesMarais, D.L. DeVincenzi, J.D.Farmer, NASA Ames; J.M.Hayes, Indiana U.; H.Holland, Harvard U.; B.M.Jakosky, U.Colorado; G.F.Joyce, Scripps Clinic; H.P.Klein, Santa Clara U.; A.H.Knoll, Harvard U.; G.D.McDonald, Cornell U.; C.P.McKay, NASA Ames; M.A.Meyer, NASA HQ; K.H.Nealson, U.Wisconsin; E.L.Shock, Washington U.; & D.M.Ward, Montana State U.

Whether or not life emerged on Mars remains an issue of profound scientific and philosophical importance, bearing on the origin of life on Earth and the distribution of life in the universe. Addressing that issue will require a sequence of increasingly finely focused experiments. Currently planned missions should satisfy most early requirements of that sequence, and adoption of recommended modifications would not impair achievement of traditional planetary-science goals.

Although theoretical considerations suggest that prebiotic chemical evolution could commonly lead to the origin of life, we still know of only one planet on which life has emerged. Consequently, the conditions necessary and sufficient for life to originate are poorly constrained. The geologic record suggests that the environments of Mars and Earth were quite similar prior to about 3.5Gyr ago, when life was emerging on Earth [1]. In particular, there is abundant evidence for liquid water on the martian surface at that time. Because liquid water is essential for all known biology, and life arose so rapidly on Earth once conditions became clement, the emergence of life on both planets is scarcely less plausible than emergence on only one. Consequently, a determination of how far Mars proceeded along the path towards life would be of fundamental significance, by greatly improving our definition of the "window of opportunity" within which life could originate. It is important to note that this remains true whether or not evidence is found for present or former life on Mars.

It follows that we can divide the scientific issues involved in the exobiological exploration of Mars into three general categories: (1) To what extent did prebiotic chemical evolution proceed on Mars? (2) If chemical evolution occurred, did it lead to synthesis of replicating molecules, i.e., life, which subsequently became extinct? (3) If replicating systems arose on Mars, do they persist anywhere on Mars today? Although these three lines of inquiry frequently involve quite different analytical approaches, particularly in the search for extant life, the broad mission requirements of all three are quite similar, leading to a sequence of five explorational phases capable of accomplishing all presently defined exobiological objectives [2].

The first explorational phase consists of global reconnaissance. In this phase, all three elements of the strategy focus on the role of water, past or present, and on the identification of potentially fruitful sites for landed missions. Thus, global information on the distribution of water (either solid, liquid, chemically combined or physically adsorbed), global mapping of pertinent mineralogical/lithological regimes, thermal mapping, and high-resolution imaging of the martian surface are requisites for this phase of the strategy.

Phase two of the strategy involves landed missions providing *in situ* descriptions of promising sites identified during phase 1. All aspects of the strategy converge on the need for broad-based geochemical and mineralogical characterization, culminating in elemental, molecular and isotopic analysis of the biogenic elements in a variety of microenvironments at specific sites, including analysis of volatile species. Of particular importance early in this phase is elucidating the extent to which the presence of Mars surface oxidant(s) influences the distribution of organic matter, either living or nonliving [3]. Another key target of this phase would be assessment of the needs for future *in situ* missions which would deploy critical experiments focused on specific questions within the three categories described above. During this phase of exploration, mobility over the martian surface would be necessary.

Phase three consists of deployment of such exobiologically focused experiments. In the case of chemical evolution, the goal would be a detailed characterization of any population of organic compounds on Mars. For the issue of extinct life, the task would be a search for biomarkers and for morphological evidence of formerly living organisms. Similar approaches would be involved in the search for extant life; in the event that extant life seemed plausible, experiments to test for metabolism in living systems, similar to those of

Viking, but based on a knowledge of conditions and resources at specific sites, would also be needed.

The fourth phase, involving robotic return of selected martian samples to Earth, would greatly improve characterization of the organic inventory at specific martian locations, and furthermore would be essential for verification of any *in situ* evidence for extinct or extant life obtained in phase three.

Finally, the fifth phase would involve human missions and would lead to establishment of a detailed geological context for any exobiologically significant observations made previously. Also, human presence would aid in the detection of "oases" capable of promoting or supporting life, that may have been missed during robotic exploration.

Although the later explorational phases tend to fall outside of the current planning horizon, missions planned for the 1996 and 1998 launch opportunities make a promising start towards implementing the earlier explorational phases outlined above. However, we have identified certain areas in which we make the following recommendations, based on the requirements of explorational exobiology:

(1) We believe that it is essential that a gamma-ray/neutron spectrometer be flown on the 1998 Mars Surveyor mission, in order to provide information on the global distribution of near-surface water.

(2) We recommend development aimed at improving the spatial resolution of orbital IR spectrometry to the point where it would be capable of detecting small-scale surface mineral deposits, such as those characteristic of individual hydrothermal vents or springs. Near-term deployment of this instrument would be required because of the important role it would play in site selection for subsequent missions.

(3) We recommend immediate development of a mineral-identification capability for the earliest landed missions. This would likely take the form of a miniaturized near-to-mid-IR spectrometer plus a combined x-ray-diffraction/x-ray-fluorescence unit.

(4) We recommend design, construction, and near-term deployment of techniques capable of acquiring samples from locations protected from the currently harsh surface conditions on Mars. Such techniques would include a drill capable of acquiring a core several m in depth from the martian regolith, and a device capable of extracting a solid sample from beneath the surface of a martian rock..

(5) We recommend development of a number of analytical approaches that will be capable of detecting, and then providing detailed information about, any volatile phases, particularly organic compounds, that might be present, possibly sequestered within stable mineral phases, on or near the martian surface.

(6) We recommend continued support of several lines of basic R & A which provide much of the intellectual underpinning to the Mars missions.

It should be emphasised that the exobiological evolution of Mars, no matter how truncated it may have been, represents an integral part of martian history. Furthermore, the observational objectives, i.e., instrumentation and target selection, of exobiology overlap to a considerable extent those of geology, geochemistry and climatology on Mars. Consequently, the exploration of Mars is best viewed as a joint endeavor in which both exobiology and the disciplines of traditional planetary science work together with interests and approaches that have much in common.

The exobiological exploration of Mars will involve a logically designed sequence of missions, each of which will focus on defining ever more closely where and how biosignatures may be found. Although one can never rule out a chance discovery, this quest should not be approached as one that will yield to a single, expeditious mission. (In fact, the proposed strategy lends itself particularly well to the use of a series of relatively small, inexpensive spacecraft, rather than a single flagship-class mission.) The search for life on Mars will take time and commitment, but the reward could be a discovery of inestimable importance, not just to science, but to humanity as a whole.

[1] McKay C.P. & Stoker C.R. (1989) Rev.Geophys. 27, 189; [2] Klein H.P. & DeVincenzi D.L. (1994) Adv.Space Res., in press. [3] Klein H.P. (1979) Rev.Geophys. 17, 1655.