The search for evidence of life on Mars is a highly interdisciplinary enterprise which extends beyond the traditional life sciences. Mars conceivably had a pervasive ancient biosphere which may have persisted even to the present, but only in subsurface environments. Understanding the history of Mars’ global environment, including its inventory of volatile elements, is a crucial part of the search strategy. Those deposits (minerals, sediments, etc.) which could have and retained a record of earlier biological activity must be identified and examined.

While the importance of seeking another biosphere has not diminished during the years since the Viking mission, the strategy for Mars exploration certainly has been modified by later discoveries. The Viking mission itself demonstrated that the present-day surface environment of Mars is hostile to life as we know it. Thus, to search effectively for life on Mars, be it extant or extinct, we now must greatly improve our understanding of Mars the planet. Such an understanding will help us broaden our search beyond the Viking lander sites, both back in time to earlier epochs and elsewhere to other sites and beneath the surface. Exobiology involves much more than simply a search for extant life beyond Earth. It addresses the prospect of long-extinct biospheres and also the chemistry, organic and otherwise, which either led to life or which occurred on rocky planets that remained lifeless. Even a Mars without a biosphere would reveal much about life. How better to understand the origin and impact of a biosphere than to compare Earth with another similar but lifeless planet?

Still, several relatively recent discoveries offer encouragement that a Martian biosphere indeed might have existed. The ancient Martian surface was extensively sculptured by volcanism and the activity of liquid water. Such observations invoke impressions of an ancient martian atmosphere and environment that resembled ancient Earth more than present-day Mars. Since Viking, we have learned that our own biosphere began prior to 3.5 billion years ago, during an early period when our solar system apparently was sustaining clement conditions on at least two of its planets. Also, we have found that microorganisms can survive, even flourish, in environments more extreme in temperature and water availability than had been previously recognized. The common ancestor of life on Earth probably was adapted to elevated temperatures, raising the possibility that hydrothermal systems played a central role in sustaining our early biosphere. If a biosphere ever arose on Mars, at least some of its constituents probably dwelled in the subsurface. Even today, conditions on Mars and Earth become more similar with increasing depth beneath their surfaces. For example, under the martian permafrost, the geothermal gradient very likely maintains liquid water in environments which resemble aquifers on Earth. Indigenous bacteria have recently been recovered from deep aquifers on Earth. Liquid groundwater very likely persisted throughout Mars’ history. Thus, martian biota, if they ever existed, indeed might have survived in subsurface environments.
MARS EXOBIOLOGY PRINCIPLES: Des Marais et al.

Given that life indeed seems possible at some time in Mars' history, can a realistic search strategy be proposed? Will such a strategy reap significant scientific rewards, even if life never arose on Mars? The key approach for future missions will be to understand the history of the Martian environment and its endowment of volatile elements. We must examine the surviving repositories of information about the environment and its volatiles. Global inventories of key volatile elements (e.g., C, N, S and H) can be assessed from atmospheric constituents (including the rare gases), from subsurface volatiles, and from the mineralogy of rocks and soils. Our exobiological interest in the martian environment focusses most directly upon the history of activity of liquid water, an ingredient essential for life. We are drawn to those environments which simultaneously provided the water, nutrients and energy, as well as the means for sustaining the synthesis of organic compounds. Hydrothermal systems meet these requirements and thus seem particularly relevant. Indeed, thermal activity within the parent bodies of carbonaceous meteorites played a role both in the aqueous alteration of these meteorites and in the synthesis of organic matter.

We also must apply a key lesson learned from studies of our own early biosphere, which is that the record of early life is only as good as the fidelity of its preservation in suitable rocks and minerals. Thus, we should also locate those rocks and minerals (cherts, carbonates, phosphates, evaporites, etc.) which formed in aqueous environments and which trapped and effectively preserved remnants from those environments. Searching for these key repositories offers several benefits. First, the search will simultaneously provide a broader picture of the early environment, a valuable perspective even if martian life never arose. Second, such a search can indeed proceed as part of the Mars Surveyor Program with its series of orbiters and landers. Prospective localities include springs, lakebeds, cemented regolith, and "grab bag" sites which offer an assortment of rock debris derived from aqueous environments. Third, locating such deposits also contributes to our search for evidence of extant life on Mars. For example, if life exists in the martian subsurface, it might have left clues in the mineral deposits of recently active springs. In addition, evidence of life might be found as trace gases in the atmosphere or as organic constituents which were cold-trapped in ice deposits at the poles or in ground ice.

The most effective exobiology strategy recognizes that, because life is a product of its interactions with the environment that nurtures it, the features of this environment will help us to recognize and understand the characteristics of life itself. Thus we must understand the history of Mars and its environment before we can expect to discover evidence of a biosphere. The need to explore the dimensions of both time and space make site selection a crucial part of the strategy, both for orbital and for landed missions. Progress in exobiology depends upon the degree to which the diverse planetary science disciplines can coordinate a balanced, effective strategy for the exploration of Mars.