The Search for Life in the Solar System

Unit 8 of the astrobiology curriculum encompasses the search for life in the solar system. How can life, similar to Earth’s, be discovered on another planet in our own solar system? Based upon the premise that a living organism would need to be based on carbon—as is life on Earth—the detection of carbon on another planet would be necessary before that planet would be considered as a prospect for harboring life. So how can scientists detect carbon on another planet? If no in vitro sample is available, spectroscopic analysis can be utilized. Once carbon itself is detected, the search must continue for complex hydrocarbons. Certainly, one would assume that if hydrocarbons are not detected, there is no indication for the presence of life. This argument was critical for designing the Mars Viking Landers. However, before expanding upon the Mars program, which is the most interesting example of the searches for life in our solar system, we examine where else in our solar system there might be signs of life.

Many missions followed the initial Luna and Pioneer series of spacecraft. Of major import was the Surveyor series. This was the first attempt by humans to dig into the lunar surface itself, not just visually study the surface. The Surveyor surface sampler was the predecessor to the Martian sampler which was the first in situ attempt to detect life on another planet in our solar system (Levin, 1968).

On July 19, 1969, Neil Armstrong was the first man to walk on the surface of the Moon, despite current urban legend to the contrary. Armstrong’s Apollo 11 mission brought back many lunar surface samples. Upon the return of Apollo 11, the astronauts were quarantined to allay the
fears of certain scientists; there still might be some form of life on the Moon that might harm life on Earth. No sign of life on the lunar surface ever materialized, allowing future lunar missions to forego a quarantine process (Cooper, 1980; Levin, 1968).

Chronologically speaking, the expectation of life on the Moon was diminished long before the lunar landings began in 1969. In fact, by this date there were already other discoveries that dimmed the chances for life on a number of planets in our solar system.

**Investigating Planets Other Than Mars**

The first successful Venus flyby occurred in 1962 with the Mariner 2 spacecraft. The Soviet Venera spacecraft was to attempt a landing on the surface of Venus. Venus atmospheric conditions were already known to be hostile, although the degree of hostility was still to be determined. The first Venera spacecraft to descend to the surface was destroyed before reaching the surface by surrounding temperatures of 320 degrees Centigrade and atmospheric pressure of 27 times that at the Earth’s surface. In 1970, the Soviets finally landed a Venera spacecraft on the surface of Venus. There they found temperatures around 600 degrees Centigrade and atmospheric pressure about 90 times that at the surface of the Earth. No Soviet spacecraft was able to survive much more than an hour on the surface of Venus. Thus early in the space race, Venus lost all hope for humans as a place for finding life of any kind (Marov and Grinspoon, 1998).

The surface of Mercury was first examined closely by the American Mariner 10. Mercury is a planet of sharp contrasts. Its night side temperature was measured using a radiometer to be about 200 degrees
below zero Centigrade. The daytime temperatures on Mercury were measured at about 200 degrees Centigrade above zero. It was also known at that time that Mercury had essentially no atmosphere (Murray, 1973).

Pluto is the furthest of the planets and definitely least known. However, it is so distant from the Sun, that no one is arguing that life might exist in its domain because it is so cold.

The Jovian planets, Jupiter, Saturn, Uranus and Neptune, do not possess a rocky solid surface. However, some very exotic arguments have been offered for life being able to exist even on these gas giants. These arguments rely on the fact that the Jovian planets are home to carbon-based molecules, which theoretically could form even more complex organic molecules (Sagan, 1980).

Although none of the Jovian planets posses a rocky surface, some of their moons do have very interesting surfaces. In particular are the cases of Europa, a moon of Jupiter, and Titan, a moon of Saturn.

Europa, one of the moons of Jupiter discovered in 1610 by Galileo, is 671,000 kilometers from Jupiter. It has a diameter of 3130 kilometers and a density of 3 grams per cubic centimeter. Europa’s surface, as first photographed by the Voyager spacecraft, reveals a frozen tundra. The questions raised by scientists relate to the possibility of liquid water, beneath the frozen surface. Spectroscopy of the surface informs scientists that there is plenty of water ice tied up in the surface. As such, perhaps there is liquid water beneath the frozen surface, similar to a frozen lake on Earth. High resolution imagery from the Galileo spacecraft revealed cracks, ridges and ice rafts that are very reminiscent of similar structures on Earth, such as exists in the frozen Arctic Ocean. Scientists can imagine a
scenario, whereby, similar to the Arctic Ocean region on Earth, a vast ocean of water exists beneath the Europa frozen surface. In fact, there was a mission proposed to NASA to test this hypothesis. Unfortunately, it has not yet received funding for a future NASA launch.

Titan is the largest moon of Saturn, discovered by Christian Huygens in 1655. It is over 1.2 million kilometers from Saturn, and has a substantial diameter of 5150 kilometers. Its mean density is 1.88 grams per cubic centimeter. The surface of Titan has yet to be seen in the visible region of the electromagnetic spectrum, due to the atmosphere of Titan. In fact, Titan is unique of all the moons in the Solar System, as it has a dense atmosphere, consisting mostly of nitrogen. In January 2005, it is hoped that the surface of Titan will be revealed to humans with the aid of the probe named Huygens, delivered to Titan by the Cassini spacecraft. Spectroscopy has revealed the presence of hydrocarbons, but the phase of these is still unknown. Some hypothesize that there are lakes of hydrocarbons, such as ethane, on the surface of Titan. A book for the general public about Titan was published by Cambridge University Press by Ralph Lorenz and Jacqueline Mitton (2002).

Where else in our solar system might there be life? What about the asteroids? Some scientists have theorized that life on our planet could have been spawned by meteors that fell to Earth. Many years ago a controversial finding led scientists to believe that some carbonaceous chondrites are carriers of complex organic molecules, including amino acids, the building blocks of the proteins of life on Earth. Although this finding can be suggestive to some of our imaginative scientists, few believe that anything can develop beyond these molecules in space, especially under attack from
high energy electromagnetic radiation, and without a solvent like water (Hoyle and Wickramasinghe, 1978).

THE PLANET MARS

Humans have long felt that the best place to look for life in our solar system is the planet Mars. In fact, at the turn of the 20th century, near the period of the Lowell frenzy of canals, the French Academy of Sciences offered a reward of 100,000 francs for anyone coming forth with proof of life on another planet, or anywhere in space, excepting Mars. They felt that Mars would soon be proven to possess life, even including intelligent life (Abell, 1978; Wilson, 1980). In fact, in 1902, a book by Richard Proctor, a British astronomer, was posthumously published in the United States, titled Other Worlds than Ours. Proctor (1902) wrote the following about Mars:

The planet Mars, on the other hand, exhibits in the clearest manner the traces of adaptation to the wants of living beings such as we are acquainted with. Processes are at work out yonder in space which appear utterly useless, a real waste of Nature’s energies, unless, like their correlatives on earth, they subserve the wants of organized beings. (p. 100-101)

Just about every major observatory, at the beginning of the 1900s, had released hand paintings of Mars and some were even releasing photographs as astrophotography was up-and-coming. Anyone can examine these drawings and compare the different observers' sketches. Few scientists could agree on the formations on the planet's surface, except for the obvious features of the polar ice caps, and light and dark regions. What is of importance to this study is the fact that even these showed a Mars
with a varied surface possessing darker and lighter areas, as well as those polar caps.

Making a comparison to Earth, one finds Mars is smaller, with a diameter of 6794 kilometers compared to Earth’s 12756 kilometers. The total surface area of Mars is only 28 percent of the Earth’s. Interestingly, this percentage is equivalent to the entire land surface area of the Earth that is above sea level (Wilson, 1987).

Another key characteristic is mass, which is linked to the density of the planets under consideration. Mars has a density of 3.9 grams per cubic centimeter. Earth’s density is 5.5 grams per cubic centimeter. The total mass of Mars is only 10.7 percent of the mass of Earth (Wilson, 1987).

Another key parameter is the study of heat balance of a planet. Mars is approximately 228 million kilometers from the Sun, about 1.52 AU, or more than 50 percent further from the Sun than our own Earth, which, being at 1 AU, is about 150 million kilometers from the Sun (Wilson, 1987).

When comparing the radiation absorbed by the Sun facing side of a planet and the amount radiated into space by the dark side, one parameter that helps in the understanding of the heat balance of the planet is the rotation rate, i.e. the length of a day. The Earth day is some 86,400 seconds in length. The length of a typical Martian day is approximately 88,640 seconds long, only about 2 percent different (Wilson, 1987).

Another factor influencing the thermal balance of a planet is of course the obliquity of the planet which causes the seasons in the northern and southern hemispheres to be opposite of one another. The Earth’s obliquity is about 23.5 degrees, while Mars possesses an obliquity of about
25 degrees. Again, fate has decreed some very similar numbers in this realm (Wilson, 1987).

Utilizing Kepler's laws and the distance of Mars from the Sun, the solar orbital period for Mars can be calculated in Earth days and one finds the Martian year is about 687 Earth days long.

Another important physical characteristic of Mars, relevant to any study of the heat balance of the planet, is the fact that the Martian orbit is more elliptical than Earth's orbit. The eccentricity of the Earth's orbit is 0.017, while Mars comes with an eccentricity of orbit of 0.093, over 5 times that of Earth's (Wilson, 1987).

The eccentricity causes the planet Mars to be as near to the Sun as 1.38 AU at perihelion and as far from it as 1.66 AU at aphelion. The amount of radiation received near perihelion is about 40 percent larger than the amount of radiation received from the Sun at aphelion. This combined with the obliquity of the planet produces a relatively long, cool northern summer and a short, hot southern summer. The precession of its perihelion produces important climatic changes on Mars (Wilson, 1987).

The first successful Mars flyby mission was Mariner 4, whose closest approach came on July 15, 1965. In 1969 the United States launched two successful craft to Mars. Mariner 6 was launched in February and Mariner 7 in March. In the summer—July for Mariner 6 and August for Mariner 7—both craft made their closest approach to Mars at a distance of approximately 3400 kilometers. Each craft contained not only narrow- and wide-angle cameras, but also an infrared radiometer, infrared spectrometer and an ultra-violet spectrometer. The temperature, pressure and
atmospheric constituents were analyzed. The pictures were not spectacular, and this Mars mission was disappointing to many (Eschleman, 1969).

The year 1969 also saw two unsuccessful attempts by the Russians to rendezvous with Mars. These failures were repeated nearly two decades later, when probes sent to rendezvous with the Martian moon Phobos failed to complete their mission. In 1971 The Russians had Mars 2 and Mars 3, both equipped with lander modules but neither successful in their attempts. The Americans had Mariner 9 that had the unfortunate circumstance to reach Mars during a global dust storm. The storm eventually subsided and the mission was enough of a success so as to provide pictures for choosing a site for landing the upcoming Viking missions (Murray, 1973).

The Viking missions were first approved in December of 1968 for a 1973 launch. In May of 1969, Martin Marietta received a contract for $250 million to build the landers while the mother craft was put together by the Caltech Jet Propulsion Laboratory using the same technology as Mariners 8 and 9 (Soffen, 1977).

As is typical, the launch date was postponed due to Congressional funding cutbacks. Viking 1 was scheduled to be launched on August 11, 1975 but was postponed due to a malfunction. While fashioning repairs for the spacecraft, the twin unit was substituted and so Viking 2 became Viking 1 and vice versa.

Finally, on August 20, 1975 the first Viking craft was successfully launched, followed by the second on September 9, 1975. Each Viking orbiter consisted of a television camera system, an atmospheric water detector and an infrared thermal mapper. Each lander was also equipped with a television camera system, gas chromatograph mass spectrometer, x-ray fluorescence
spectrometer, seismometer, biology lab, weather station and the vital sampler arm. Each spacecraft also conveyed with its aeroshell a retarding potential analyzer and an upper-atmosphere mass spectrometer (Snyder, 1977).

Although Viking 1 did arrive at its Martian destination by June 19, 1976 the attempt to gain beneficial pictures to aid in the choice of a landing site for the lander caused a delay in the landing beyond its Independence Day rendezvous. Using the latest pictures from the Viking Orbiter, the western slopes of Chryse Planitia were selected for the landing (Greeley et al., 1977).

On July 20, 1976, seven years after man had taken his first steps on the moon, the Viking lander successfully descended upon the soil of Mars. Immediately after successful touchdown, the lander had instructions for taking pictures with its camera. There was concern that the lander might sink into the soil, and so a picture was taken immediately upon impact (Snyder, 1977).

Viking cameras were not cameras in the conventional sense. Each consisted of a nodding mirror and a rotating turret which caused the images to be reflected down to the photodiode, which built up a picture as a series of pixels from each scan of the mirror and rotation of the turret. This technique had been criticized for its inability to detect any moving objects, because some felt it possible that there might be macroscopic creatures on the planet.

The first instrument recording results on its sample was the x-ray fluorescence spectrometer, which determined the inorganic composition of the soil sample. Its results determined that the Martian material was
composed of between 15-30 percent silicon, 12-16 percent iron, 3-8 percent calcium and 2-7 percent aluminum (Clark et al., 1977; Toulmin et al., 1977).

Recordings from the gas chromatograph mass spectrometer (GCMS) gave an indication of carbon dioxide and a little water but no organic compounds. This marked the beginning of a controversy, because this negative result conflicted with results from the biology experiments that were indicative, to some, of the existence of microbial life (Biemann et al., 1977; Horowitz, Hobby, and Hubbard, 1977; Levin and Straat, 1977; Oyama and Bordahl, 1977). This controversy continues to this day.

The biology laboratory, packed into approximately a single cubic foot of volume on the Lander, consisted of a pyrolytic release experiment, a labeled release experiment and a gas exchange experiment.

The labeled release experiment was headed by Levin. The basis for his experiment was that if micro-organisms were present they would use the available nutrient broth and metabolize organic compounds. The organics in the broth were tagged with carbon 14 (Adelman, 1986; Levin and Straat, 1976; Levin and Straat, 1977).

Horowitz headed the pyrolytic release experiment. His experiment was also based on the ability of an organism to metabolize, but he was looking for the ability of an organism to take carbon dioxide and produce some product for its own use, a reversal of the process sought by Levin's experiment. The soil sample was placed in the test chamber for five days and incubated with or without the presence of light. If the soil had somehow fixed or metabolized the carbon dioxide that was tagged with carbon-14, then after the chamber had been evacuated, the sample would be
pyrolyzed and carbon would be detected within it from the labeled gas (Horowitz, Hobby and Hubbard, 1976; Horowitz, Hobby and Hubbard, 1977).

Oyama headed the gas exchange experiment. It also looked for evidence of metabolism by recording changes in the gaseous environment of the sample. First the sample was introduced into the chamber and the chamber’s atmosphere sampled and analyzed. After a period of incubation, the gas would be re-examined and any differences between its analysis as compared to the initial analysis would be noted and viewed as a sign of activity (Oyama and Bordahl, 1977).

Initially, all three biology experiments registered results indicative of some very active samples. If these results were obtained here on earth there would be no doubt that organisms were responsible, but was that the case for the Martian samples? There was immediate doubt of the biological results because the GCMS had failed to detect any organics within the soil sample (Horowitz, Hobby and Hubbard, 1977).

Theories dealing with superoxides, peroxides and superperoxides were offered which attempted to explain the results of the biological experiments. Soon, there was only one stubborn holdout for the possibility that these still might indicate the existence of life on Mars, and that was Levin (Adelman, 1986; Horowitz, Hobby and Hubbard, 1976; Levin and Straat, 1976).

The first close-ups of the Martian atmosphere were provided by the Mariner series of spacecraft. When Mariner 9 began orbiting the planet, the atmospheric scientists effectively had the cameras to themselves because of the presence of a global dust storm that prevented observing the Martian surface (Leovy, 1988).