Do the Mariner 9 results increase the possibility that life exists on Mars? Yes, says Carl Sagan— but Bruce Murray disagrees *(p. 10)*.

Is There Life on Earth?

by Carl Sagan

If the inhabitants of Mars set out to do preliminary exploration of Earth, what would they have to do to detect life here?

There are three spacecraft in orbit around Mars. We know that at least one of these—Mariner 9—is taking superb data. For the first time, the planet is being exposed to a detailed and rigorous scientific scrutiny.

Despite widely advertised opinions that Mars is lifeless, Mariner 9 has discovered surface conditions that significantly improve the chances of life there. The planet is revealed to be geologically young and active, shielded at least in places from ultraviolet radiation by atmospheric dust, and possessing enigmatic, sinuous, dendritic features which look for all the world like terrestrial river beds.

In view of the current closeup reconnaissance of Mars and the many questions about the possibility of life on other planets, it is of some interest to reconsider the appearance of our own planet as seen from space. If the inhabitants of Mars set out to do preliminary exploration of the planet Earth, what would they have to do to detect life here?

They could, for example, characterize the terrestrial environment. Ground-based telescopic observations would reveal temperatures, atmospheric pressures and composition, the presence of liquid water, frost caps, and the bright and dark markings which outline the continents and oceans. On the heels of these observations would be speculation about whether the terrestrial environment was suitable for life. There would be arguments that the great excess of oxygen in the Earth's atmosphere surely excludes the possibility of life because all organic compounds would be completely oxidized to carbon dioxide and water. There would probably be arguments that the temperatures on Earth were much too warm by Martian standards.

But other Martian scientists would object, and argue that such a view was much too chauvinistic and that perhaps life can be constructed on slightly different principles—inhabiting somewhat different regimes of temperature, pressure, and composition. The most bizarre hypothesis would be that terrestrial organisms breathe the well-known poison gas, molecular oxygen.

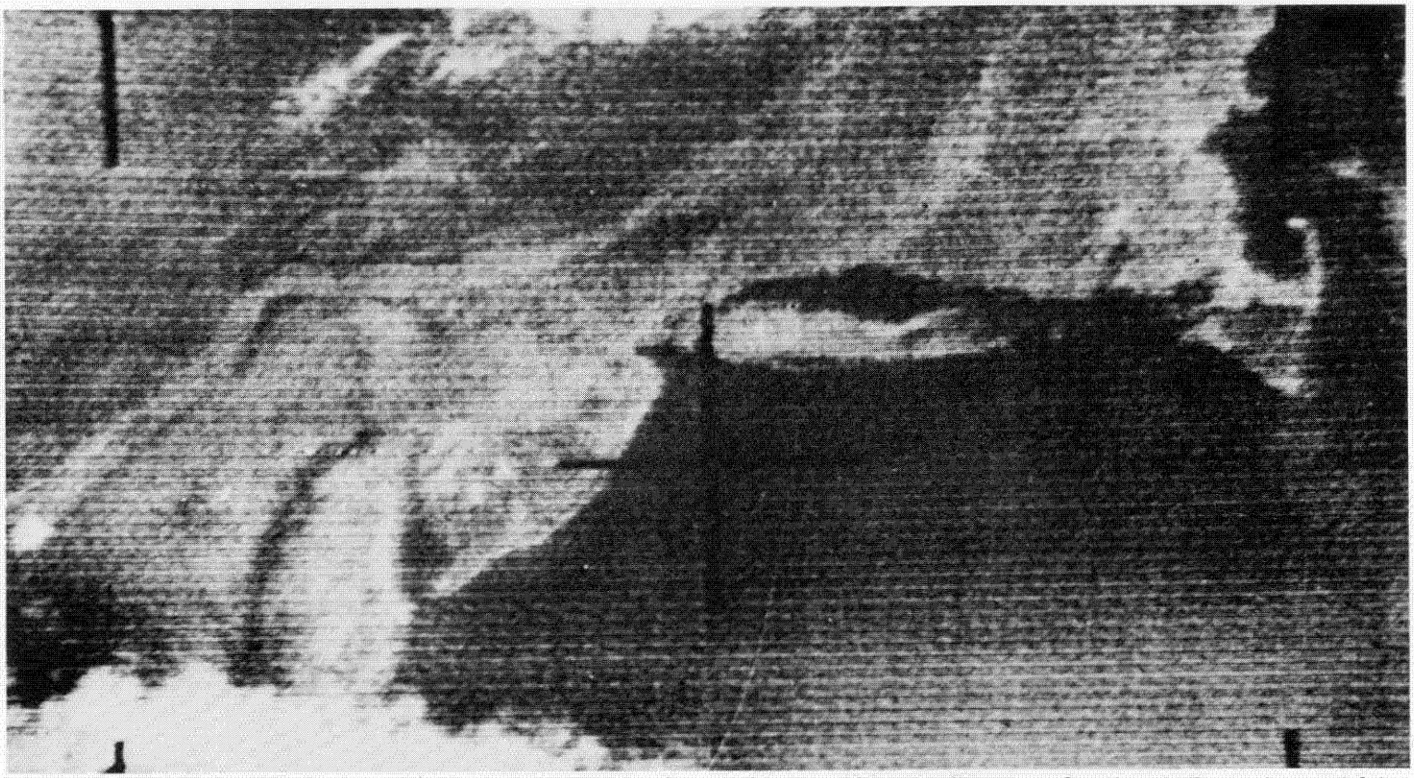
I believe that such debates would, there as here, be inconclusive. What is needed is more data.

One very simple search method for intelligent life (which, indeed, would take all the fun out of the game) is to point a small radio telescope at the Earth at the appropriate frequency. When the North American continent turns toward Mars, there would be a blast of radio emission that would knock the observer off his feet. Prolonged scrutiny would probably reveal a minimally intelligent content to the television signals, and a low form of life on Earth would thereby be discovered.

But this method works only if the Martians observe during the precise epoch in terrestrial history after radio was discovered, but before the widespread introduction of cable TV and other methods of economical usage of communications power. They would have to be observing during one or two hundred years out of the several billion in which life has existed on Earth.

Another approach would be to put radio astronomical searches aside and assume a Martian photographic search in daylight for life on Earth. With a small telescope, scientists on Mars would certainly see the Earth go through phases just as we see the Moon and Venus do. But not much about the Earth would be discernible. With larger telescopes more detail would appear. The wispy white changing features would be revealed as an atmospheric phenomenon, clouds—but of unspecified composition. Once the temperature structure of the atmosphere was determined, it would be clear that these were water clouds and not carbon dioxide clouds or dust clouds.

Beneath the clouds are brownish continents which would probably be called bright areas. The more bluish or blackish areas would at first be called dark areas. But then



Tiros photograph of the eastern seaboard of the United States reveals no visible sign of life—intelligent or otherwise—in Boston (upper right), New York City, or Washington. The effective resolution is a few kilometers.

it would be noticed that these dark areas would occasionally exhibit a bright glint of specular reflection, and the existence of oceans would eventually be revealed. The rotation and obliquity—the deviation from the plane of the ecliptic—of the Earth would be determined. But at this sort of resolution it would not be possible to detect life.

At occasional times of exceptional clarity—when the thin Martian atmosphere was free from dust—scientists using a large telescope on Mars could achieve a resolution of about one kilometer on the Earth. With such a resolution, it would be possible to detect features of fair contrast if they were larger than one kilometer in extent. But features smaller than one kilometer, even if of high contrast to their surroundings, would not be visible.

Would this be enough to detect life?

The Tiros and Nimbus weather satellites photographed the Earth at one-kilometer resolution, and we examined several thousand of these pictures. We found the photographs to be biologically uninteresting. No sign of major engineering works or of the largest metropolises could be found. It has been argued that, for reasons of economy and geometry, technical civilizations tend to construct rectilinear features that have a markedly artificial appearance. But the number of such features visible at one-kilometer resolution is very few. Only about one in a thousand of the Tiros and Nimbus photographs showed evidence of rectilinear geometry on the Earth. And most of these features were natural, rather than man-made—as peninsulas, seif sand dunes, sand bars, and possible jet stream clouds.

At one-kilometer resolution there is no sign of life—intelligent or otherwise—in Washington, Boston, New York City, Moscow, Peking, Melbourne, Berlin, Paris, London, or any other major population center.

Although we believe we have severely reworked the surface of the Earth and have made a profound influence on our planet, we are in a fundamental way still undetectable at a resolution of one kilometer.

Better resolution could be obtained by a space-vehicle reconnaissance of the Earth. Just as we are able with Mariner 9 to examine Mars at 100-meter resolution, our hypothetical Martian scientists might perform spacecraft observations of the Earth at the same resolution.

Would they detect life?

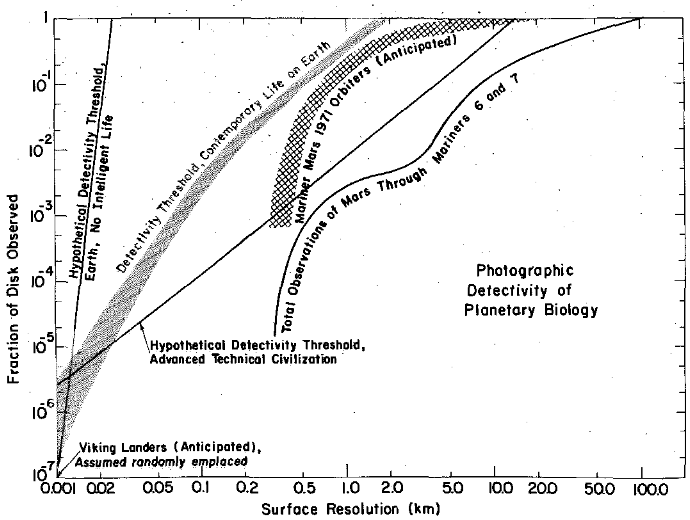
We have closely examined 1,800 selected high-resolution color photographs of the Earth obtained by astronauts aboard the Apollo and Gemini flights. Most of these photographs are at approximately 100-meter resolution. Our sample applied to cloud-free areas. Since the Earth is on the average about 50 percent cloud-covered, this corresponds to an effective non-selective inspection of 3,600 photographs of the same resolution. Dozens of rectilinear or highly geometrized features were uncovered. Of these, 60 have been classified as geological and 20 as meteorological in origin.

Some phenomena, such as dunes, are undeniably rectilinear, but are not of biological origin. Other phenomena, such as coral atolls, are undeniably of biological origin, but would almost certainly not be so identified on the basis of their geometry, without further knowledge of terrestrial biology. Some river basins have a remarkably striking geometry as seen from space, as do some cloud features. Likewise sandbars and craters have striking similarities but are not indicative of life on Earth.

A sizable number of the photographs—57—are so regularly geometrized as to defy non-biological explanations. With the knowledge about the Earth's features that we have (but an extraterrestrial explorer surely would not have) these pictures break down as follows: roads, 29; canals, 5; agricultural geometrizing of the environment, 15; jet contrails, 4; industrial pollution, particularly smokestack plumes, 4. Some cities, laced with extensive highways, such as Dallas-Fort Worth, are easily detectable. Other cities of large size (Cairo, for example) are much less detectable. Perhaps the most striking signs of intelligent life on Earth are the checkerboard patterns of agricultural and urban territoriality.

The conclusion is that with a fair number of photographs at a resolution of 100 meters or better it is very easy to detect intelligent life on Earth. At resolutions worse than

A portion of an Apollo 6 photograph of a typical populated region of the planet Earth—at a resolution of about one-tenth of a kilometer—reveals a fine checkerboard pattern which is the result of the human passion for order, geometry, and territoriality.



In this diagram, three thresholds for the detection of life on Earth—one actual and two hypothetical—are compared with past, present, and future observations of Mars. A previous analysis of photographs of the Earth with similar resolution to photographs of Mars indicates that Mariner 9 will almost surely rule out the possibility of civilization—but not of life—on Mars.

one kilometer, it becomes difficult to impossible.

Human beings have been around for only a few million years, and human beings capable of reworking the Earth to this extent have been around for only a few thousand years. A Martian exploration vehicle coming to Earth in any previous epoch would not have uncovered any of the artifacts we have just described because they have only recently arisen. Yet, for something like four billion years there has been life on the planet Earth.

What about detecting life that does not rework its environment as human beings do?

At one- to ten-meter resolutions it becomes possible to detect large plants (especially trees) and animals. Because of their top-heavy geometry, the biological origins of cows, for example, would be rapidly deduced. A cow is remarkaby unstable dynamically, which is a good sign that it is a cow and not a rock. Life forms, in general, are characterized by such disequilibrium phenomena—chemical, physical, dynamic, and otherwise. Although I do not think it is possible to predict in any detail what the manifestations of life on any other planet would be, it is clear they would be characterized by strong departures from equilibrium—departures we would search for in the biological exploration of another planet.

Because there are so many more plants and animals than technological reworkings of the Earth's surface, the photographic detection problem becomes much easier as our resolution becomes much better than 10 meters. This is shown clearly in the diagram at the left, which indicates what fraction of the Earth's surface must be observed at a given resolution to detect life.

At what point in our exploration of Mars could *we* detect a biology even as rich and diverse as our own? As the diagram at the left shows, all the observations of Mars made by mankind through Mariners 6 and 7 would not have detected even a civilization much more advanced than ours.

Mariner 9 offers the first good chance of testing (and probably putting to rest) the persistent speculation about the existence of intelligent beings on Mars. But it is unlikely to have any direct bearing on the most fundamental issues—whether Mars can be a habitat for simpler forms of life. In my view this question remains entirely open—at least until landing missions of the Viking-class journey to Mars in 1976.

Carl Sagan, professor of astronomy and director of the Laboratory for Planetary Studies at Cornell University, is currently a visiting associate in planetary science at Caltech, and a co-investigator on the Mariner 9 television team. "Is There Life on Earth?" is based on a talk given to the Caltech Women's Club on January 13, and on the paper "A Search for Life on Earth at 100 Meter Resolution," published in the December 1971 issue of Icarus. *A further discussion of the detection of life on Earth can be found in Sagan's book* Planetary Exploration: The Condon Lectures. *University of Oregon Press, 1970.*