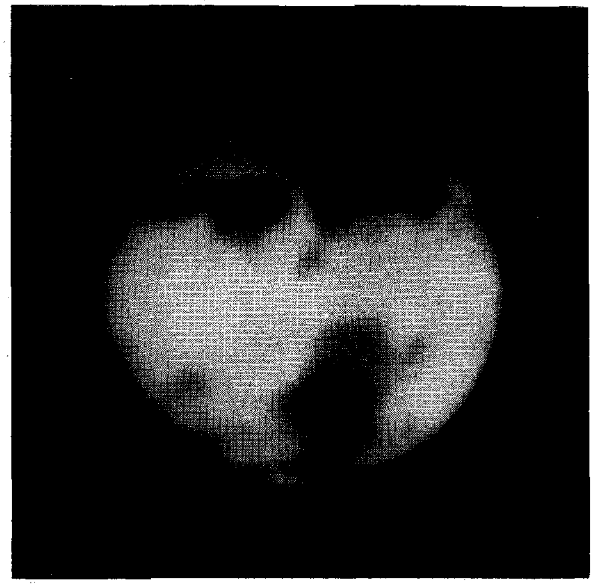
A biologist examines the direct evidence that life does exist on Mars—and comes to an intriguing conclusion.



by FRANK SALISBURY

THE INHABITANTS OF MARS

ARE THERE MARTIANS? Are there entities on the planet Mars which, according to our standards, possess life? Certainly, of all the objects which an asstronomer may directly observe with his telescope, Mars is the only one with an environment even remotely enough related to our own to possess life at all as we know it. Mercury is as hot as a furnace on one side and as cold as space on the other. Venus has no water, and its surface is probably subjected to constant sand blasting. The planets beyond Mars are frozen wastes with atmospheres containing large amounts of astringent gases such as ammonia and methane. Most of the satellites of the solar system planets have no atmospheres (nor does Mercury), and beyond the solar system the suns the astronomer sees appear only as points of light, and planets which might support life can only be inferred.

If there are Martians, what are they like? Are they extremely small and simple, comparable to earthly bacteria, algae or lichens? Or do they possess reflective intelligence, comparable to that of man? Certainly, the only way to obtain answers to such questions would be to build a rocket ship and fly to Mars. Since this isn't being done at present, everyone is left to his own speculations.

Speculation can be lots of fun, both to read and to indulge in. As a framework for logical speculation about the possibilities and characteristics of Martian life, one should have all the known facts regarding the Martian environment. But first, to see whether or not any speculation at all is warranted, let us examine the direct evidence that life *does* exist on Mars.

The direct evidence for life on Mars is easily seen even with a small telescope. When it is winter in the southern hemisphere of Mars, the planet appears as a reddish disc with a brilliant white polar cap covering the south pole (the top pole, as the inverted image appears in the telescope). Some rather faint brownish markings extend irregularly from the polar cap to, and slightly beyond, the Martian equator. As spring arrives in the Martian southern hemisphere, the polar cap begins to recede, and the brownish areas begin to become bluish-green, and finally, in summer, after the polar cap has completely disappeared, these areas are quite green. In the fall the areas become brown again, and the cap begins to appear. The colors involved in these changes are strongly reminiscent of the changes seen in earthly vegetation as the seasons succeed one another. The colored areas are not static from year to year, but change in both size and shape. Observation in the summer of 1954 revealed a fairly large area which had not previously been seen.

In the spring the markings first become green in the area nearest to the polar cap, and the greening then progresses away from the pole and toward the equator, rather than from the equator toward the pole as on earth. This striking fact implies that the melting of the polar cap is a direct cause of the change of color in the markings, rather than merely coincident with it, both phenomena being the result of the general increase in temperature.

All of the above features have been photographed, and their reality is accepted by everyone. Of a more controversial nature, however, are the so-called Martian canals. Since 1877, when the Italian observer, Giovanni Schiaparelli, published a map of Mars showing the planet covered by a network of fine lines (which he called *canali*, probably for want of a better term), many observers have confirmed his observation and many others, equally well trained, have denied that such markings exist.

Professor Percival Lowell has been, perhaps, the greatest champion of the canals. To detect the canals, it is said that the "seeing" must be exactly right; that is, that the air above the observatory must be perfectly clear and still. To obtain these conditions, Lowell established the Lowell Observatory in Arizona, around the turn of the century. After many years of patient observation by him and his co-workers, a map was published showing 700 canals on the surface of Mars. Many of the canals were double lines, and often at the intersection of two such sets of canals there would be a small green area, which Lowell called an oasis.

Lowell gradually developed an extensive hypothesis relating the canals to intelligent life. The oases were said to be Martian cities, surrounded by farms, and the canals, which varied in width from a few to many miles, were actually farms located along Martian waterways extending from the polar cap to the equator and beyond. Lowell reported that the canals, as well as the other areas, became green in the spring, starting at the pole and working toward the equator.

The problem of the canals

Few people nowadays agree with the theories of Lowell. Although the canals have been seen by many people and some of the major ones seem to be present on some of the best photographs of the planet, no one claims to have seen all 700 described by Lowell. Fairly plausible explanations have been advanced to account for them on some basis other than that of intelligent life. Some consider them to be optical illusions. Others suggest that they mark boundaries between unlike areas. Certainly the problem of the canals is far from solved. Perhaps the strongest evidence against the sort of civilization proposed by Lowell is found in the description of the Martian environment given below.

Whatever the significance of the canals, the facts concerning the green areas are well established and are very difficult to interpret under any other hypothesis except that they represent life—probably vegetation. No one has been able to think of a chemical which would change color, as do the green areas, with slight increases in relative humidity. Dean B. McLaughlin, astronomy professor at the University of Michigan, suggests that the areas consist of volcanic dust, which is green because of the lack of oxygen, and are blown around and made more visible each spring as the Martian winds increase. (Shades of the March Winds!)

This would account for the changes in size and shape, and windrows of volcanic dust might account for the canals; but why should the areas turn brown in the fall, and why should the greening progress from the poles towards the equator in the spring? Furthermore, astronomers often see clouds of yellow dust from the red and yellow deserts blowing across the face of the planet. If the green areas consist of green volcanic dust, why isn't it seen blowing across the planet and why hasn't the yellow dust covered the green areas? The best hypothesis still seems to be that the green areas consist of Martian vegetation, able to "grow through" the yellow dust which is often deposited upon it.

Life like ours?

Could the Martian environment support a type of life akin to our own? The Martian soil probably would be suitable. Dr. Gerald P. Kuiper of the University of Chicago concludes from spectral studies that the red deserts consist of igneous rock, possibly felsitic, or something similar. (The red color was long thought to be due to large amounts of iron oxide, but Kuiper's studies failed to bear this out.) This rock, as well as most other related materials, would be a perfectly suitable substrate for plant growth.

The atmosphere, however, is much more critical than the soil for life as we know it. The polar caps are almost certainly ice (rather than frozen carbon dioxide—dry ice—as has been suggested), although they may be only a few millimeters thick. Clouds are occasionally seen in the atmosphere, and they have the spectral characteristics typical of earthly clouds consisting of minute particles of ice. Indeed, the thin haze which covers the planet almost all of the time may consist of fine ice crystals, which would give the Martian sky a brilliant white appearance—making the sun almost invisible. As the morning twilight zone crosses the planet, a narrow white line can be observed which disappears as soon as it is in the direct rays of the sun. This is probably frost on the surface of the planet.

All of these facts indicate that water must be present, but, so far, no vapor has been detected in the Martian atmosphere. Because of the large amounts of water in our own atmosphere, the problem of observing water in the atmosphere of Mars is very difficult. None the less, our methods are sensitive enough to show clearly that the atmosphere of Mars, by our standards, is very dry. So dry indeed, that liquid water must exist, if at all, only in areas immediately adjacent to melting ice crystals.

Carbon dioxide does occur in the atmosphere of Mars. There is probably about twice as much above the surface of Mars as there is above the surface of the earth at sea level. Oxygen, on the other hand, has never been detected in the Martian atmosphere. Once more, we are limited by the methods available, but the most optimistic upper limit set by astronomers for the amount of oxygen present is still far too low to support animal life as we know it on earth. This one fact throws into very serious doubt all the inferences of Lowell about intelligent animal life.

The total amount of atmosphere on Mars can be roughly estimated, and carbon dioxide, the only gas so far detected, is not present in nearly large enough quantities to account for the total amount of gas. Argon must be present, as it is produced in fairly large amounts from the radioactive decay of an isotope of potassium. The principal gas is thought to be nitrogen, but no method is known by which this assumption could be directly tested. A fair estimate of the composition of the Martian atmosphere would be: 0.3% CO_2, 4.0% A, and about 96% N_2. The atmospheric pressure is probably equal to about .10 to .20 atmospheres as measured on earth.

The average maximum temperature on Mars seems to be from 0° C. to about 16° C. In the green areas, near the equator and in the Martian summer, the temperature may reach 30° C. in the middle of the day. The night temperature may drop as low as —100° C., and is always very much below freezing.

A factor of great importance in consideration of life on Mars is the ultra-violet radiation which strikes the surface of the planet. The ice-crystal haze and the carbon dioxide and nitrogen of the atmosphere allow most of the ultra-violet light from the sun to reach the surface. On earth the ozone layer of the upper atmosphere is the primary agent which filters out this ultra-violet radiation, but ozone has not been found on Mars.

The Martian environment

Thus the Martian environment can be summed up as follows: The atmosphere contains considerable carbon dioxide (0.3% compared to 0.03% in our atmosphere) and nitrogen, but very little water or oxygen. The temperature has a great daily variation from far below zero to somewhat above freezing. Because of low atmospheric pressure, a dry atmosphere, and a normally frigid temperature, water does not commonly exist as a liquid, but only as a solid or a gas. Ultra-violet radiation strikes the surface almost with undiminished intensity. There are seasonal variations in climate and rather frequent storms of yellow dust. Mars is an extremely cold, extremely dry desert.

Nothing exactly comparable to this environment occurs on earth. Of course our atmosphere differs greatly in composition from that of Mars, and only small amounts of radiation strike the earth. Even temperature and moisture conditions are not duplicated on earth. On earth, where it is very dry, it is also very hot, and where it is very cold, it is also very wet, at least for part of the year. Yet in spite of the striking differences between the environments of the two planets, conditions on Mars more nearly approach conditions on earth than do the conditions found on any of the other planets.

Could earthly vegetation survive in an environment like that of Mars? On Mars most of the familiar plants would perish immediately. Astronomers, however, have considered the possibility that lichens might survive the Martian climate. Lichens are a sort of symbolic "double plant," consisting of an alga (which photosynthesizes) and a fungus, which seems to help in water storage) with their cells in intimate contact. They are the little green, brown, or reddish patches seen on rocks. They are found in the coldest, driest, and highest places on earth. Assuming that Martian plants contain less than half as much water as plants on earth, and taking into account the total amount of water on Mars, it has been estimated that Martian plants, from their area on the planet and their water content alone, could be at most a fraction of a millimeter high. The patches of lichens seen on rocks are often less than a millimeter thick. The infra-red reflection spectrum of the green areas on Mars is nearly the same as the infra-red reflection spectrum of earthly lichens. The spectrum, however, is lacking in detail in both cases, probably because of lack of water, and certainly no definite conclusions can be drawn from such data.

Martian plants

In the opinion of this author, there are two striking differences between lichens as we know them on earth and the green areas of Mars. First, the completeness of cover of the grass areas is hard to reconcile with the lichen growth habit. For an area to appear green, the cover must be very nearly complete, as in our forests. In our deserts, a distant hill may appear barren, although a fair percentage (perhaps 30 percent) of its area may be covered by plants. There are lichens in the desert, but their detection requires careful examination; they are never a conspicuous part of the landscape. In the far north they do form a complete cover, but during at least a part of the year they have a super-abundant supply of liquid water, a circumstance far different from conditions on Mars.

Second, the rate of change of size, shape, and color of the Martian green areas is many times greater than would be expected if these areas consisted of lichens like those found on earth. The thin, flat type of earthly lichens (those which fit the calculated size range of Martian plants) is extremely slow-growing. Erosion can be estimated from the line of lichens on a rock above the soil level, for the lichens may extend their area only a fraction of an inch in a century. Of course some earthly lichens grow more rapidly than this, but they occur only in moist places, as on the trees of a rain forest or on the soggy tundra of the north. Lichens do change color as their moisture content changes (becoming brown in summer as they dry), but it would seem unlikely that the slight change in relative humidity which seems to cause the color changes on Mars would be sufficient to bring about such a color change in earthly lichens.

On earth, the continuance of life is absolutely dependent upon oxygen. There are organisms that are able to live in the absence of oxygen, but if all life on earth consisted of such organisms, the processes of decay could never be complete. Dead organisms would pile up until essential nutrients such as carbon were no longer available but were all contained in these dead remains, and then life would stop. Decay is an oxidation reaction, and although various stages of it take place in the absence of oxygen, oxygen must ultimately be present or the process will come to a halt. Thus it is highly short-sighted to suggest that Martian plants live by an anaerobic metabolism. Most plants on earth, including lichens, require oxygen, as do virtually all animals.

Dr. Hubertus Strughold, head of the department of Space Medicine at Randolph Field, Texas, in a recent book, *The Green and Red Planet,* suggests that the key to this problem is the "internal atmosphere" found within the plant body. Oxygen produced in photosynthesis would be trapped in the inner spaces and used in respiration. It is, however, rather difficult to imagine how an internal atmosphere could contain one gas (oxygen) without allowing its escape and yet allow another gas to enter (carbon dioxide). Certainly the plants on earth from which this model was taken have no such mechanism. Nor does the "internal atmosphere hypothesis" explain how the decay organisms might obtain oxygen.

Perhaps the most serious problem of all concerns the ultra-violet light striking the surface of Mars. This type of radiation, at such high intensty, would probably be fatal to most things living on earth, at least after an extended period of time.

Lichens could be subjected to an artificial Martian environment in the laboratory to see if they could survive the rigors of Mars. It would seem, however, to the present author, that even in the absence of such tests, we might be quite certain that earthly lichens transplanted to Mars could not produce the effects described above. Indeed, they would probably not survive for long.

A new type of life?

The conclusion of this discussion, then, is that earthly vegetation—even lichens—could not survive the Martian climate, let alone flourish and expand in the manner described by many careful observers such as Lowell. Certainly the oft-painted picture of Martian lichens struggling for existence on a dying planet does not seem to convey a true representation of the Martian green areas.

Hence, since speculation is free, we may be justified in postulating an entirely new type of life. We might assume, in our Martian biochemistry, that nitrogen instead of oxygen plays the active role in energy transfer. Various soil bacteria on earth oxidize nitrogen from ammonia to nitrite and then to nitrate, and derive energy from so doing. Martian biochemistry would certainly involve the many compounds of carbon, as does our biochemistry, for there is ample carbon in the atmosphere (CO_2). Martian photosynthesis might use red and blue absorbing pigments (which appear green, as does chlorophyll), but it might involve the formation of carbon-nitrogen bonds as well as carbon-carbon bonds. The medium of reaction might be water, as it is on earth, or it might be some other compound which remains liquid at much lower temperatures (a sort of protoplasmic anti-freeze—synthesized by the "plants" themselves).

The fact that the areas become green in the Martian spring nearest to the melting polar cap indicates that water is of distinct importance to the Martian vegetation, but it may act in a limiting way as a growth regulator rather than as a primary solvent. In our oceans, when some disturbance in the current brings water from depths, the concentration of critical elements such as phosphorus and nitrogen may be increased, and the result is a rapid growth of the sea flora and fauna. Perhaps, in an analogous manner, the slight increase in relative humidity of the Martian atmosphere, caused by melting (or subliming) of the polar cap, provides the few molecules of water required by the Martian vegetation to flourish in the Martian spring.

Perhaps the compounds involved in Martian biochemistry are relatively stable to ultra-violet radiation, or they are protected by screening pigments on the surface of the organisms. Indeed, important reactions may occur through absorption of ultra-violet radiation, such as the production on earth of vitamin D from certain sterols.

No precedents

Our knowledge of biochemistry rests upon the study of earthly enzymes produced under earthly conditions, and hence there are no real precedents known to us for a synthesis of a new biochemistry. One might consider a biochemistry with the oxidation and reduction of sulfur as its basis, or perhaps manganese is responsible for certain phases of energy transfer in Martian protoplasm. On earth this element is lethal in doses larger than trace amounts, but such trace amounts are essential for life!

The idea of water as a growth regulator rather than a primary solvent has some rather interesting implications. The calculation of the size of Martian plants based on their water content would no longer be valid. Plants much larger than one millimeter might be found, and animal-like organisms having locomotion would not be out of the question. They might obtain "vitamin H_2O" from the plants! Even intelligence is conceivable, and Lowell's canals could have some of the significance which he tried to attach to them.

Whatever sort of life exists on Mars, it must have an ecology. There must be numerous like and unlike individuals, struggling for existence with each other and with their environment. The complete cover would certainly seem to indicate this. Probably all ecological niches are filled and natural selection operates in full force.

Seasonal and secular cycles in the Martian vegetation may be observed from earth. A biochemist studying the inhabitants of Mars would also study their life cycles, and a bio-geochemist would study elemental cycles. If carbon and nitrogen are fixed in photosynthesis, some other processes must ultimately free them to the atmosphere. Again it is tempting to think of animal-like forms occupying a position between the autotrophic "plants" which are able to live on minerals from soil and atmosphere and the organisms of decay which finally release these minerals from the Martian biosphere. On earth food chains become very complex. How complex are they on Mars?

Plant succession must be a Martian phenomenon as well as an earthly one. Some forms must be more adept at surviving on the undisturbed Martian red deserts than others. Indeed, the deserts may be sparsely covered with vegetation, as our own deserts are. Some of these forms may, by their reaction upon the environment, modify conditions so that other species are able to move in. The invaders then probably crowd out the pioneers, as they do on earth. Eventually a climax is reached in which no other Martian species is able to compete with the existing ones, and the resulting environment is quite different from the original bare red desert. The color and insulating quality of the climax vegetation result in significantly higher temperatures. A soil has formed in equilibrium with the climate of the region. When disasters such as severe yellow dust storms wipe out a climax population, a secondary succession must take place.

Species distribution is probably correlated with latitude, topography, etc. Plant (or animal) communities probably result from the control of certain dominants and the association of species having common environmental requirements.

And what effect would intelligence have upon all this?

It is intriguing to a biologist to think of life on Mars. Would the ecological and physiological principles worked out on earth today apply there? An earthly biologist likes to think of things such as plant succession, photosynthesis, and natural selection as fundamental principles of life. Yet they have only been studied under one general set of conditions, those of earth, and their universal nature can only be inferred. It would be a most striking evidence that they are indeed of a fundamental nature if such principles were found to apply to the inhabitants of Mars as well as to the inhabitants of earth. Astronomer, geologist, chemist, and physicist would all like to test their theories on another world, but what could surpass the enthusiasm of the biologist if he were given a chance to examine the inhabitants of the red planet in their native habitat?