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ABSTRACT

Presented is one of a series of National Aeronautics and Space Administration (NASA) facts about the exploration of Mars. In this publication, emphasis is placed on the sun's planetary system with note made that there is no one theory for the origin and subsequent evolution of the Solar System that is generally accepted. Ideas from many scientists are pointed out. The planatary atmospheres, climates, and the search being made for extra terrestrial life are discussed in this particular series. Photographs, diagramatic schemes and a table representing the evolution of living systems on Earth are included. Student projects are suggested as well as a reading list. (EB)

NASA Facts
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National Aeronautics and
Space Administration

NF-61/8-75

MARS AND EARTH

One of a series of NASA Facts about the exploration of Mars.

The Sun's Planetary System

It is important to be aware that there is no one theory for the origin and subsequent evolution of the Solar System that is generally accepted. All theories represent models which fit some of the facts observed today, but not all. Many scientists today consider that planets of the Solar System probably formed between four and five billion years ago; all about the same time, as material condensed from a primordial solar nebula. The Sun also formed from this same material. After the Sun had condensed, planets of different sizes and probably different compositions originated from concentrations of matter present at various distances from the Sun. Electric and magnetic fields of the original nebula could have forced these embryonic planets into orbits around the central Sun and spun them on their own axes.

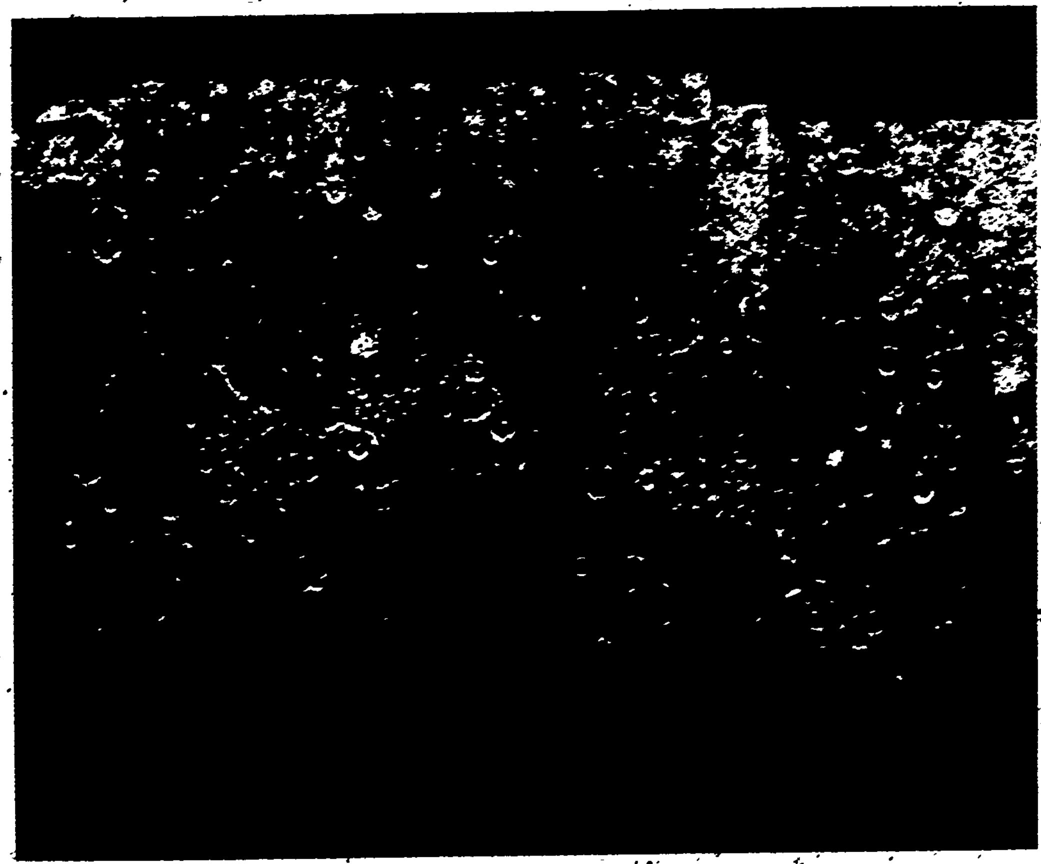

Figure 1. In the latest stages of planet building, some 4 billion years ago, the impact of mountain-sized bodies produced great impact basins similar to this on Mercury. Such basins are dust filled on Mars and have been all but obliterated on Earth.

Matter also condensed within the young Solar System in the form of mountain-sized chunks of rock. Some theories claim that these minor planets were concentrated in a belt between the large, outer planets and the small, inner planets. Other theories postulated that the concentration was beyond the outer planets. In the former case the asteroid belt would now represent today's remnants of this multitude of small bodies. In the latter case the planet Pluto might be the sole visible remnant of the outer ring of bodies.

Such planetesimals would be perturbed by the growing planets and sent into elliptical orbits that would cross the planetary orbits. They might form the nuclei of comets, too. It has been calculated that within a few million years any one of these bodies that crossed the orbits of planets would be either captured by a planet or hurled out of the Solar System. If captured, the planetesimal would crash into the planet's surface and gouge a huge hole, such as a crater or a major impact basin. (Figure 1).

The very large craters and impact basins on Mars, the Moon, Mercury, and Venus are thought to be the result of the impact of falling bodies during this second period of planetary accretion, as the process of falling together is termed. The Earth also probably had large craters and impact basins early in its history.

While the inner planets of the Solar System lost lighter elements, such as hydrogen and helium, because they were too hot to hold these gases due to their proximity to the Sun and their relatively weak gravities, the outer planets retained their hydrogen. Thus the planets of the Solar System, separated by the asteroid belt, consist of rocky inner planets, Mercury, Venus, Earth and Moon, and Mars, and fluid outer planets, Jupiter and Saturn, with compositions similar to that of the Sun, and Uranus and Neptune, which may be ice giants. Pluto is thought by some scientists to be a large example of an outer belt of asteroidal bodies from which comets may be originating today. In some respects, too, it behaves as a very distant satellite of Neptune.

There are striking differences among the five inner planets, and particularly between the Earth and the others. These differences are important to our understanding why the Earth is as it is today, and why the other planets are different despite their formation from common building blocks at about the same time.

Mercury is Moon-like in some respects, a cratered world with virtually no atmosphere, but displaying evidence of volcanic activity after its formation and bombardment molding, and also showing contraction around a very dense core. Mercury, like the Moon, rotates very slowly on its axis; three rotations for every two revolutions around the Sun. The Moon rotates once each revolution around the Earth. Mars and Earth rotate quickly in close to 24 hours. Venus has a unique backward rotation of 243 days.

Planetary Atmospheres

After the formation of the planetary bodies there appears to have been a period of planetary heating in which more dense material sank toward the center of each planet to form a core, while less dense material rose to form a crust. This is termed differentiation. The Moon and Mercury still show much of the ancient cratered surface on which there are some lava flows. Mercury exhibits compressive shrinkage around a cooling, iron-rich core.

Volcanic activities on the planetary bodies would release gases from their interiors; water vapor and carbon dioxide with traces of other gases. On Mercury and the Moon, these gases escaped into space; they were lost from Mercury because of high temperatures close to the Sun, from the Moon because of its weak gravity.

But on Venus, Earth, and Mars, the gases were retained, so that these planets still have atmospheres.

Today, however, these atmospheres are very different. Venus has an extremely dense atmosphere of carbon dioxide at the bottom of which the surface of the planet is hot enough for lead to melt (480°C; 900°F). On Mars the atmosphere is again predominantly carbon dioxide, but at a very low pressure, and the planet has a cold surface. On Earth the atmosphere is predominantly nitrogen with some oxygen and traces of carbon dioxide. Most of Earth's carbon dioxide has been bound with the rocks of the Earth's crust as carbonates because of the presence of much water. Both Venus and Mars seem very deficient in water compared with the Earth, which may be why their atmospheres are predominantly carbon dioxide.

Why are Earth, Mars and Venus so very different? Their distances from the Sun are not much different compared with the great distances of the outer planets. Could Earth become like Mars or Venus? How might this happen? These questions intrigue scientists today and they are important for other people too. Perhaps man's industrialization of the Earth, or a series of major volcanic eruptions, could sufficiently change Earth's atmosphere to push it toward the Mars or Venus state.

It is thus important to gather as much information as possible about the other planets to make sure that man's activities on Earth will not lead to a planetary catastrophe here.

Planetary Climates

At present scientists are concerned that the climate of the Earth is changing; growing generally colder. They believe that the Earth is still in an ice age that began about 1 million years ago, though not now at the severest part of the ice age. Although they do not know how quickly climatic changes occur, they do know from the record of fossils that several hundred million years ago Earth experienced a very warm period. These changes to world climate could result from variations in the radiation from the Sun if the Sun is a variable star, as well it might be.

The climate of a planet is governed by three major factors; the amount of radiation it receives from the Sun, the tilt of its axis of rotation, and the eccentricity of its orbit around the Sun. What a planet does with the radiation it receives from the Sun is also governed by the composition of its surface and its atmosphere. A reflective planet (high albedo) that sends the Sun's rays back into space will be cooler than a dark planet (low albedo) that absorbs the solar rays. And the atmosphere, too, governs this energy balance between solar radiation received and radiation sent back into space.

Satellites have measured that the Earth should reflect about 35 percent of the sunlight falling upon it. But the balance of the sunlight absorbed by the Earth would only raise its temperature to about —18°C (0°F). The oceans would freeze. Why then is the Earth so warm? The incoming sunlight is converted to infrared radiation by the Earth's surface, and because of the presence of carbon dioxide and water vapor in the Earth's atmosphere, the infrared radiation is trapped in the atmosphere. The atmosphere behaves like the windows of a greenhouse, it allows the solar radiation in, but does not let the heat energy out. The planet heats up like the inside of an automobile left in the sunlight on a cold day with all its windows rolled up. This is termed the "greenhouse effect."

Now if the temperature of the Earth should drop a few degrees, the amount of water vapor in the atmosphere would decrease because cold air cannot be as humid at hot air. With less water vapor in the air the greenhouse effect on Earth would be reduced, and the temperature would fall still more. In this way a slight change in the overall temperature of the Earth could precipitate a runaway effect to a glaciated planet. The opposite is also true; a slight rise in Earth's overall temperature could trigger a heating effect that would continue until the Earth became a hothouse planet.

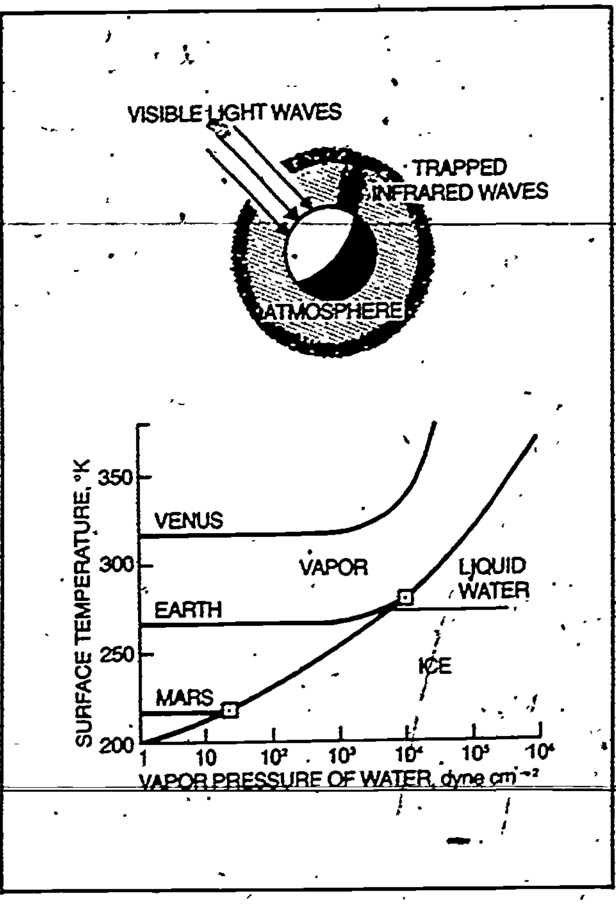

Figure 2. The greenhouse effect is illustrated for the three planets, Venus, Earth and Mars, assuming each went through a period when water and carbon dioxide vented from the crust into a primitive atmosphere. Because Venus was warm, being closer to the Sun, its atmosphere could hold much water vapor. The planet heated to the point at which oceans could not condense. On Earth the temperature was right for some water vapor to enter the atmosphere and most to condense into oceans. On Mars, the temperature was too cold, most water remained frozen and very little was able to enter the atmosphere.

Such changes might be brought about by a change in the tilt of the Earth's axis which would alter the effects of sunlight falling on the poles and the equator. They might also be brought about by particles suspended in the Earth's atmosphere which would affect the reflecting properties of the planet. A major volcanic eruption might thus change the Earth's climate drastically.

It is believed that Venus is an example of a planet on which the greenhouse effect has run away with itself (Figure 2). When the planet formed, its surface might have been warmer than

Earth because of Venus' proximity to the Sun. Thus there would be more water vapor in the atmosphere of Venus than in the atmosphere of Earth. Trapping solar radiation, the atmosphere of Venus would have become hotter and hotter until all its primitive oceans boiled off into the atmosphere and the carbon dioxide was not allowed to combine into carbonates in Venus' crust as happened on Earth. Over eons of time the oceans in the atmosphere of Venus were broken down by solar radiation into oxygen and hydrogen which escaped into space.

An alternative theory suggests that Venus accreted from materials of the solar nebula that did not contain water and, therefore, the planet did not possess any water when formed.

On Mars, by contrast, the primordial planet was colder than the Earth and never entered a hot phase. Rather, Mars was forced in the opposite direction. Water was permanently frozen in the martian crust, and even carbon dioxide froze into polar caps until an equilibrium, or balance, was reached between the amount of frozen carbon dioxide and the amount of the gas in the atmosphere. At the present temperature of Mars this

Figure 3. These sinuous river-like beds on Mars seem to imply past period of great water flows.

balance is reached with an atmospheric pressure of less than one hundredth that of the Earth's atmosphere, compared with Venus' surface pressure of nearly one hundred times that of Earth.

On Mars, slight changes to the overall temperature of the planet because of changing albedo, changing tilt of the planet's axis, or changing eccentricity of its orbit, could produce vast changes to its atmosphere. If the temperature on Mars rose just slightly, more carbon dioxide would vaporize from the polar caps and make the atmosphere denser. Then circulation from equator to the poles would be able to carry more solar heat to the poles and vaporize even more carbon dioxide. Thus, the temperature and the atmospheric pressure of Mars would continue to rise until all the carbon dioxide was in the atmosphere. Under such conditions, the pressure of the Martian atmosphere might be high enough for bodies of liquid water to be present in all low regions of Mars and for rivers to flow into mini-Martian oceans.

It is fascinating to see that the sinuous arroyos of Mars (Figure 3), which defy explanation except as resulting from running water sometime in the past, have so few craters on them that they can be dated as extremely young; possibly only 200 to 500 million years. And it is known that about that same time the Earth was suffering a hot spell, perhaps from an increase in solar radiation that warmed both planets at the same time. Now, with the Earth in an ice age, Mars, too, is in an ice age. The big question is; how long and how deep will the ice age become?

There are, however, other ways in which Mars can heat up and have water flow on its surface. Because of the gravitational influence of Jupiter the tilt of the Martian axis can change within a period of hundreds of thousands of years, and with a greater tilt to this axis the poles would be presented more to the Sun. The consequence would be a runaway heating effect. It has been calculated that the polar regions of Mars would need only one century of solar heating at 20 percent more than they receive today for the runaway heating effect to start. This could result from the Martian axis tilting only 5 degrees more than today, which is well within the calculated amount that could be produced by Jupiter's gravity.

Today, scientists are becoming concerned that the Earth's climate is not as stable as was once thought. Even very small changes to Earth's climate can have far-reaching consequences to the peoples of Earth since today we are so dependent upon intensive agriculture based on crops that are resistant to disease but have virtually no resistance to climatic changes. Thus, knowing what is happening on other worlds assumes increasing importance to understanding, controlling, and safeguarding our own world.

And this leads naturally to the major question; Why is there life on Earth? Is there life on other worlds, particularly on Mars?

Living Systems—The Search for Extraterrestrial Life

Life might be described as an unexplained force that somehow organizes inanimate matter into a living system that perceives, reacts to, and evolves to cope with changes to the physical environment that threaten to destroy its organization.

In 1953, a mixture of hydrogen, methane, ammonia, and water vapor—the kind of atmosphere that Earth might have had soon after it was formed—was treated in a laboratory (Figure 4). Scientists passed electrical discharges through the gas mixture and were surprised to find that the electrical energy changed some of the simple gases into more complex compounds of carbon, hydrogen, nitrogen, and oxygen; into molecules known as amino acids which are believed to be the essential building blocks for all living systems.

Today it is generally believed that natural processes such as lightning and radiation from the Sun can produce complex chemicals to form building blocks for living things. In fact, some of the complex chemicals are found in the space between the stars and on meteorites (the familiar 'falling stars'); small rocks that plunge into the Earth's atmosphere from space, the debris remaining from the formation of the Solar System.

At some point in the past, probably about 3½ billion years ago, something organized the complex carbon-based molecules on Earth into living systems which were then able to make copies of themselves—to reproduce. Life had been created. From then on, according to one theory, that of evolution, by slight changes to subsequent copies, biological evolution produced all living things on Earth, all using the same basic 21 amino acids as building blocks. At one stage, the theory continues, a special consciousness emerged that gave rise to Man himself, a living system that can contemplate not only itself but also the whole of the universe in space and time (Figure 5). By contrast, most religious theory views Man as the result of a unique creative event.

A big question is whether or not life originated on other planetary bodies as it did on Earth. We know from the Apollo program that it did not evolve on the Moon. There is no life there today, nor any trace of life having been there in the

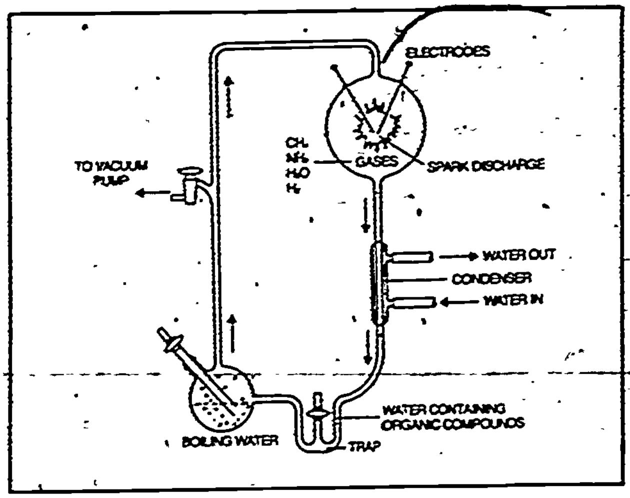

Figure 4. This is a simple diagram of the apparatus designed by Stanley Miller in 1956 to produce complex molecules from simple gases by the energy of an electric spark. This is believed to be one way in which life precursors may evolve in planetary atmospheres.

TIME	GEOLOGIC ERA	LIVING SYSTEMS EVOLVE	EARTH CHANGES
PRESENT		MAN (CONSCIOUSNESS)	ICE AGE (MOST RECENT)
	CENOZOIC		
	MESOZOIC	FIRST MAMMALS	
	PALEOZOIC	CREATURES WITH SPINES	CLOSE TO PRESENT DAY ATMOSPHERE
1000		FIRST MULTI-CELLED CREATURES	
2000			OXYGEN INCREASES
	PRE-CAMBRIAN		
3000			ATMOSPHERE ENRICHED WITH OXYGEN BY ALGAE
		FIRST MICROFOSSILS (ALGAE, BACTERIA)	ATMOSPHERE-WATER METHANE, AMMONIA AND POSSIBLY HYDROGEN
4000		EVOLUTION OF CARBON COMPOUNDS (THE BUILDING BLOCKS OF LIVING SYSTEMS)	A CRUST AND WATER OCEANS
	EARTH FORMATION	TOO HOT AND CHAOTIC FOR LIVING SYSTEMS	AN EARTH SPHERE FORMS
			PARTICLES GASES A FORMLESS VOID
5000			

Figure 5. The evolution of living systems on Earth. The question is whether or not a similar evolution has taken place on Mars, and if so, how far has it progressed?

past. Mercury, too, looks most inhospitable to life, as does Venus. Some of the outer planets are candidates for life such as Jupiter and large satellites. But within the inner Solar System only Mars seems to present a possibility of life besides the Earth.

In earlier centuries there was much speculation about life on Mars; linear markings, now known to be mainly an optical effect, were categorized as "canals" (channels) across the surface, and the evidence of an ancient civilization. The close-in photography by NASA's Mariner 9 shows no evidence of life on Mars, but it is important to realize that most space views of Earth show no evidence of life on that planet either!

One thing is certain; life as we know it on Earth can adapt to adverse conditions; it lives in hot

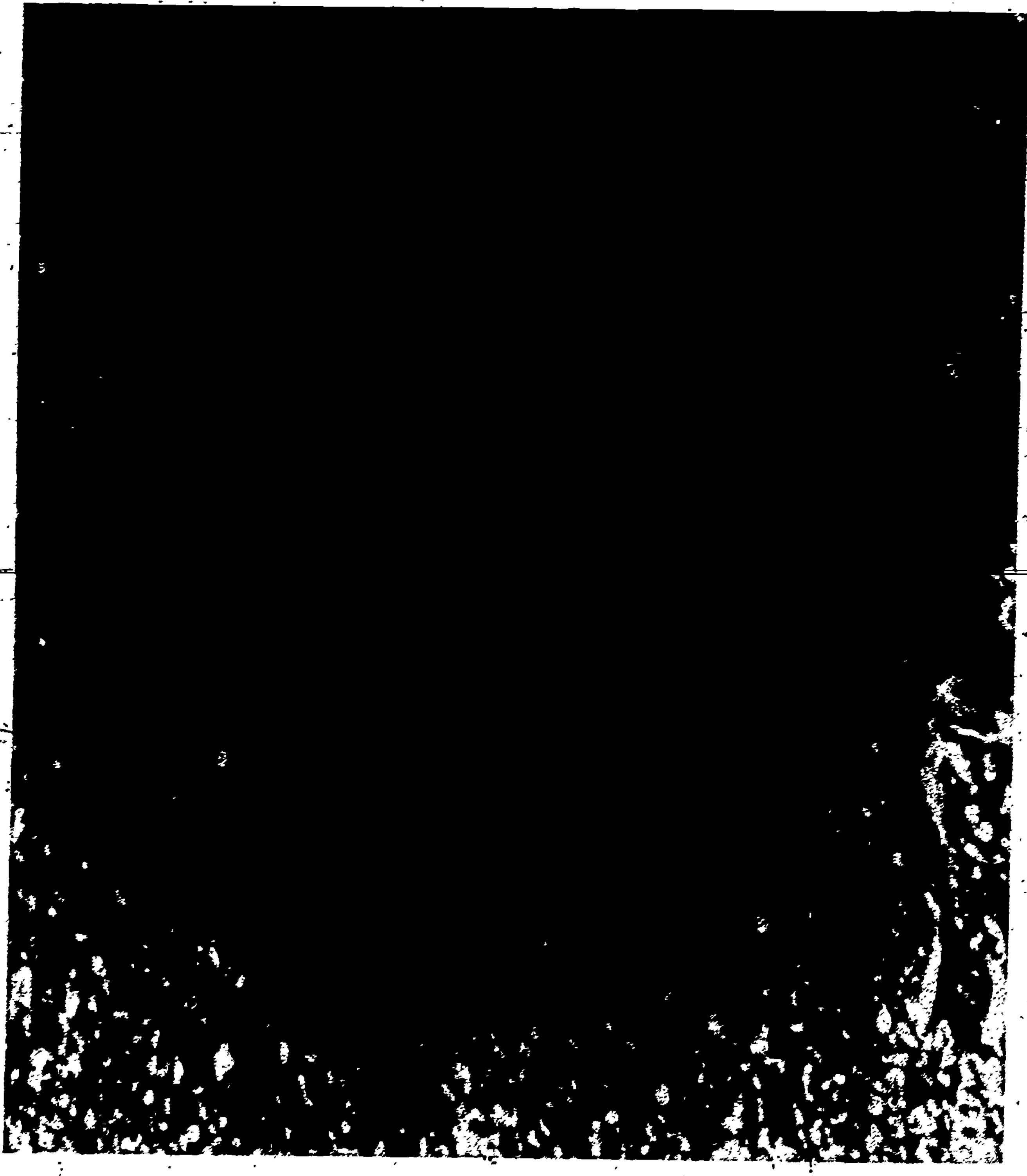

Figure 8. On Earth life adapts to difficult environments. Here a small flower blossoms after spring rain on the cinders of a volcanic crater in Death Valley, California.

springs and in Arctic ice, it lives in the depths of the oceans and the tops of the highest mountains, it lives in sulfuric acid and in the cooling water of nuclear reactors. Some algae even grow in salt pools and they explode and die if they are placed in fresh water. Flowers will blossom after rain on the cinder cones of desert volcanoes (Figure 6). Plants grow where there is never any rain; they extract their moisture from dew each night. Kangaroo rats do not drink. They make water by synthesizing it from sugar in their food.

If Martian life adapted to its environment as life on Earth did, it must today exist in a virtually waterless world, drier than the driest deserts of Earth. It must resist ultraviolet light (the rays that cause sunburn) stronger than on any mountaintop of Earth. It must resist raging dust storms and temperatures that dip to hundreds of degrees below zero each night.

Experiments in laboratories of Earth have shown that such adaptation is possible. Earth organisms have thrived under simulated Martian conditions. Only a few inches below the surface of Mars, an organism might be protected from solar ultraviolet, temperature extremes, dust storms, and be in touch with frozen water that it could tap by biological heating. It may, indeed, be an ice eater rather than a water drinker; a worm-like creature forever burrowing beneath the frozen soil. There are snow worms on Earth that eat snow algae. There are even bacteria on Earth that can extract water directly from salt crystals and this needs as much energy as extracting water as vapor from the Martian atmosphere.

Mars creatures might also protect their bodies as many Earth creatures do by growing hard outer cases or shells. And just as Earth creatures moved from the oceans to escape competition there, so Martian creatures might have evolved to live under the harsher conditions which prevail today on the planet's surface.

Also, in the past, Mars might have had plenty of water. Life on Mars might have life cycles geared to the pluvial periods of Mars when, thousands of years apart, there are times when the planet warms up. There are many examples on Earth of this form of life adaptation, though for much shorter periods. There are Earth creatures that hibernate for a single winter and others that remain dormant for long periods of drought in desert dry lakes. When, scores of years apart, these lakes fill with water for a short season, they are soon teeming with the previously dormant life revived by the water.

The search for life on Mars is perhaps one of the most fascinating activities of mankind in this day and age. If life is discovered on Mars it will be important to find out if it is based on the same amino acids as Earth life, or if there was a separate act of creation. It is also of great interest to find out if the life evolved only to the simplest of bacterial forms, or did it, as on Earth, evolve into more complex forms to meet competition with other living systems and to survive a changing environment.

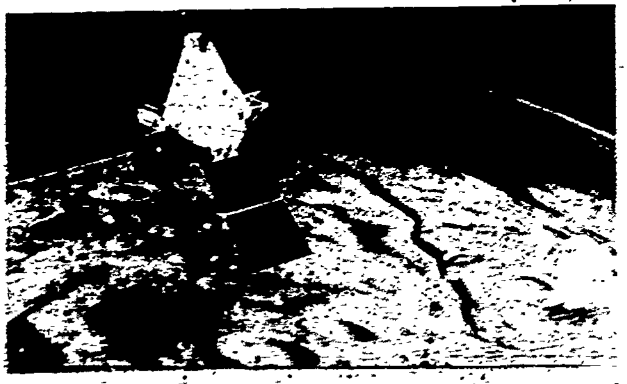

Figure 7. On July 4, 1976, an American spacecraft, Viking, will start to search for life on Mars. This artist's concept shows the orbiter high above the lander and its jettisoned parachute.

If there is no evidence of life on Mars, and such evidence will not be really conclusive until extensive searches have been made over large areas of the Martian surface, it will be even more important for people on Earth to preserve themselves and their planet because of their uniqueness. Mankind may have to be prepared to accept a greater destiny than learning to live in harmony on its planet of birth. It may have to accept the responsibility of spreading living systems throughout the Solar System and into the cosmos.

To search for life on Mars it is necessary to put a lander on the Martian surface (Figure 7). The United States has such a spacecraft—two in fact. If all goes according to plan the first will land on Mars on July 4, 1976, the bicentennial day; a fitting tribute to the pioneering and forward-looking spirit of the American people. This NASA project to land life-seeking spacecraft on Mars is called Viking. It is described in the next booklet of this series.

STUDENT INVOLVEMENT

Project One

Compare the planets Earth, Mars and Venus in terms of size, location in the Solar System, and physical characteristics. Prepare a table and sketches of these data for reference.

Project Two

Define the limits of conditions for life as we know it on Earth, and compare the extremes for different forms of life on our planet—plants, mammals, man; bacteria, algae, viruses—in terms of temperature, pressure, water, salinity of water. Are these limits greatest for energy-gathering life forms (photosynthesizers) or for eaters?

Project Three

Design an interplanetary spacecraft either as a group or individual project.

a) Classify the planets in a convenient scheme and identify three major problems in exploring them—atmosphere, radiation, temperature. What techniques can be used to explore the planets? Probes, orbiters, atmospheric probes, landers?

b) Define missions for each type of spacecraft in the exploration of Mars.

c) Imagine you are a Martian: define the type of spacecraft you might use to explore Earth and try to find out if there is life on Earth.

d) For both designs (i.e. to explore Mars and to explore Earth) give details of the power supply (electrical batteries, solar power, nuclear power), experiments (cameras, life-seeking devices, radiation and temperature measurers, meteorological instruments), and the configuration (shape of spacecraft, size, landing equipment, radio system).

e) Prepare a sketch of each spacecraft.

Project Four

Select a site for a lander on Earth and on Mars

a) Discuss how you would define life.

b) What types of instruments would you recommend to detect this life:

i) In oceans
ii) In dried-up water channels
iii) In dry ocean basins
iv) In deserts
v) On mountain tops
vi) On polar caps
vii) Elsewhere on the two planets?

c) What conclusions could you draw about life on Earth, given that you detected life at any two of the chosen sites?

d) Where would you select landing sites on Mars as most likely to show evidence of Martian life?

Project Five

Space-related drama, dance, or body movement activity. Imagine that you are a creature of another planet. Show how you move. First describe yourself and your environment, and then portray yourself.

Suggestions:

- Your planet may have:
  a) very little gravity
  b) crunching gravity
  c) a blinding sun so you must feel rather than see
- Your planet may be:
  a) all liquid
  b) all gaseous
  c) all solid surface
  d) combinations of these
- You may be:
  a) shaped like a ball
  b) equipped with many tentacles
  c) a single organism
  d) a group, like a colony of ants
  e) microscopically small
  f) gargantuan
  g) a parasite
  h) equipped with very different senses using; for example, touch instead of eyes, sound instead of touch, smell instead of taste, and the like.
  i) a symbiosis of machine and living system such as a biological brain in a mechanical body, or an extended computerized electronic brain (cerebrum cortex) coupled to a small biological cerebellum in a biological body.

Suggested Reading

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