What Does Space Flight Teach Us?

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It is marvellous that today information from more than five million kilometers out in space can be recorded on a piece of ticker tape 50 kilometers long. In just eight times that distance our nearest neighbor, Venus, can be contacted. One of the disappointments is already apparent in recent measurements of cosmic radiation, especially of solar plasma. At certain altitudes this radiation presents formidable hazards to a space traveler so that his route must be limited to very specific orbits. As a result we shall have to rely on unmanned flights for progress in the years immediately ahead. The most dramatic breakthroughs are expected in the category of interplanetary matter, either in clarification of the panspermy hypothesis or in the direction of space chemistry. These advances, along with anticipated analysis of a lunar dust sample, will bring us closer to solving the mystery of biological origins on earth. Space medicine, naturally, occupies the most prominent place in cosmobiological research today. In the next few years it will yield valuable information for future manned space flights.

BEFORE CONSIDERING THE TITLE question in detail we shall first attempt to systematize the entire realm of biological investigation related to astronautics.

By definition we tend to think of life today in terms of biological forms already familiar to us on earth. We call this "terrestrial" life, classified according to location, *geobiology* ἡ γῆ = the earth). And to designate life processes which occur in the cosmos outside the earth, we propose the simple, unambiguous term, *cosmobiology*. Leading authors in the field today, J. Lederberg[10-12] and H. Strughold,[16] have used "exobiology" and "astrobiology" extensively in the literature.

"Exobiology" (extraterrestrial biology) refers to the outermost fringe of the earth's atmosphere, continuing out into space. This is the so-called exosphere, which begins presumably at 600-800 km. Here conditions are practically equivalent to those of true outer space. "Astrobiology," as suggested by Strughold, would pertain to spheres of influence belonging to individual stars.

Though topography was selected previously, other factors, in direct antithesis, might just as well have formed the basis for our classification. It is possible, in other words, to categorize cosmology in its entirety as follows:

(1) The influence of the entire cosmos on *terrestrial* life (cosmobiology in its narrowest sense);

(2) Biological conditions to which the space traveler is exposed (space medicine);

(3) Exploration of the possibilities of life on other celestial bodies and in intervening space.

In reference to (1) we should note that the concept of cosmology was first formulated more than thirty years ago by J. Faure, who wanted to express statistically the influence of solar activity on man. If solar effects can also be considered cosmic then life on earth could actually be termed astrobiology of the sun (heliobiology). More recently cosmology has broadened in meaning to include research on the influence of cosmic radiation on earthbound life and other related, but previously neglected, areas.

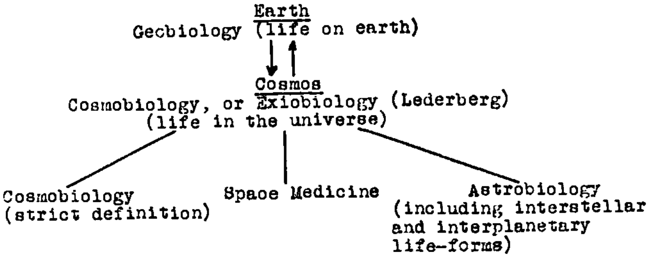

Fig. 1.

It would be of great benefit if international congresses would undertake to discuss and agree upon a definitive, systematic terminology. In view of the rapid progress in astronautics the need for precise definitions is acutely felt not only in existing areas of research but also in those which are certain to emerge.

GEOBIOLOGY

It is widely accepted today that all life-forms on earth have certain universal characteristics, whether they be primitive, one-celled organisms or more highly developed representatives of both the plant and animal worlds. Among these are the chain molecules of nucleic acids. Nucleic acids are essential for heredity and evolution. They are composed of many parts—about 2500 chain links in the simplest viruses, as compared to five million in bacteria and a thousand times more in the human cell. Whether nucleic acids were the very *first* genes is questionable because they are so complex and because they have reached a state of perfection which indicates an interval of chemical evolution, rather than a single stroke of "masterpiece" creation.

Theories Concerning the Origin of Life on Earth

Louis Pasteur (1822-1895) was first to discredit the

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[1] This manuscript was translated from German by J. McLean and T. Boubel.

belief that simple microorganisms arose spontaneously from inorganic material. By sterilizing culture media and isolating them from further contact with bacteria he demonstrated the biological law, "Every cell develops from another cell."

Pasteur's work, however, still does not explain how life originated. We recognize that bacteria, in spite of their minute size, are extremely complex organisms. The first living unit must have been appreciably simpler than present-day bacteria.

It is entirely possible that at the beginning of evolution something like a prebiotic intermediary stage bridged the gap between living and "lifeless" inorganic substances.

Not long ago Miller and Urey[13] created extremely simple amino acids by means of electric discharges in gas mixtures of ammonia (NH_3), water (H_2O) and methane (CH_4).

Their results agree with the concept that the earth's original atmosphere must have had a reduced composition (hydrogen compounds), which later became secondary to an oxydized atmosphere (oxygen compounds). Terrestrial life-forms are comprised mainly of hydrogen (H), carbon (C), oxygen (O), and nitrogen (N) atoms. The next logical step will be to consider what elements are found in interstellar space. This information is summarized in Table I, which shows the preponderance of lighter elements. Hydrogen (H) and helium (He), by far the most frequent elements, are followed by carbon, oxygen and nitrogen. The original condensation of free atoms to form interstellar dust and eventually the stellar mass itself must result in the molecular clustering of H, C, O and N. In other words much of the solid mass of the universe must consist, or at one time did consist, of extremely complex macromolecules (organic nature).

TABLE I (from van de Hulst)
Chemical Composition of Interstellar Dust Particles

Chemical compound	Per Cent by Weight
H_2O	42
NH_3	16
CH_4	15
Fe	13
SiH_4	6
H_2S	5
Mg	3
others (Ti, CN, radicals)	<1
	100

Even if the experiments of Miller and Urey[13] do account for the origin of simple amino acids we are still far from understanding the all-important nucleic acids. At this point, Nobel Prize winner Kornberg, seeking to learn how nucleic acid reproduces inside the cell, set out to synthesize a giant molecule in a test tube. For this, however, he needed the basic elements, the separate links of the chain. The particular nucleic acid Kornberg used in his experiments contained four different elements differing only in their bases (guanine, adenine, cytosine or thymine). Kornberg mixed these individual elements (nucleosides), added extracts of bacteria and the individual elements did in truth become the important giant chain molecule. Kornberg then succeeded in isolating the enzyme responsible for this synthesis. The remarkable fact is that the enzyme united the individual elements only when complete nucleic acid was simultaneously present in the mixture, as if it were the pattern for the desired combination.

The following components must be present in order for this unnatural biological synthesis to occur:

(1) Individual elements (which are already complex molecules);

(2) A pattern by which the synthesis should occur;

(3) A complex enzyme.

Even though these processes are well understood today mystery still continues to surround the origin of the three components just cited. This question will be discussed later under the panspermy hypothesis, as it is directly implicated in the transition from lifeless to living nature.

COSMOBIOLOGY (EARLY CONCEPT)

In the 1930's, long before the heyday of "satellites," cosmobiology was simply the study of cosmic influences on terrestrial life.

It is a known fact that light and heat from the sun are basic conditions for the continuation of life on earth.

Just as solar activity (solar flares) influences biology, atmospheric conditions are probably also affected in an indirect way. Today the chemical changes caused by ultraviolet radiation are well known. Windaus, for example, discovered that ergosterol is converted into Vitamin D_2 by UV radiation.

All types of rays of many different wavelengths have produced mutations throughout geological history—heat, UV, roentgen, Ra gamma, even cosmic radiation at extremely low wavelengths. We forsee many new developments in this area. (See Reference 7.)

SPACE MEDICINE

Since space medicine has ranked foremost in importance until now it has naturally won greater attention than any other area. Hubertus Strughold, Chief Scientist, Aerospace Medical Division, Brooks Air Force Base, Texas, actually created this branch of research, which deals with all aspects of manned space flight. The big question mark is, of course, whether man can survive in space at all. So many complex problems come to light when one begins to comprehend all that is involved in sustaining a human life in space and protecting it from danger.

In space man finds himself in an environment, including atmospheric conditions, extremely hostile to life. Travel through this vacuum requires a completely sealed "cabin," a small "manmade earth," in other words, with an artificial atmosphere enclosed in a protective shell.

This tiny, isolated island in the great beyond also spells great psychological problems.

Space travel is not the only venture beset with almost insurmountable difficulties. Even more perplexing problems surround the biotechnical know-how required to maintain life on another celestial body, in view of its basically different physical environment. We should be aware that utterly strange flora and fauna can have beneficial as well as harmful consequences. Microorganisms, to cite one example, could cause diseases heretofore unknown.

Throughout most of the flight the space vehicle will behave like any other object in space governed by fixed laws. Man, as a bioorganism accustomed to living under conditions of 1 g, will experience many times this force during space flight.

Before leaving the context of this survey I would like to touch briefly on the problem of oxygen requirements. The naive belief that man can survive by taking along enough bottles of pressurized oxygen offers no solution. Perhaps a new inroad lies in Strughold's[16] fascinating experiments, in which oxygen is produced by cultures of certain algae. The plants, in turn, live on expired carbon dioxide. These experiments have been performed successfully for years on thousands of mice and constitute a brighter outlook on the oxygen problem.

ASTROBIOLOGY

This concept originated with H. Strughold. It refers to investigation of the possible existence of life on other planets. Since life can hardly exist on fixed stars themselves by astrobiology (astro = star) is meant the entire sphere of influence of a star, including its planets. An example is our sun, which is also a star. Heliobiology (helio = sun) might be termed a special case of astrobiology. Life on the known planets would then be influenced more or less by the sun, which is very probably true.

The following three possibilities define our present understanding of extraterrestrial life:

(1) The life is lower than even our simplest organisms—so-called prebiotic levels;

(2) The forms of life are the same or nearly the same as ours on earth;

(3) They are totally different from life as we know it.[8]

The second alternative arises from the possibility that completely independent biological systems originated with an identical chemical composition. Thus, the earth's system would be, so to say, universal.

The hypothesis of *panspermy*, defended by Nobel Prize winner Svante Arrhenius (1859-1927), would lead to the same conclusions. Arrhenius assumed that spores of the most primitive organisms in cosmic dust particles are continually being scattered throughout space. Life-forms on other inhabited planets, he reasoned, must therefore be similar to those on earth. The hypothesis was vigorously attacked from many sides. Although some of the arguments are easily refuted the importance of the controversy lies in its thought-provoking nature and in the enormous significance it has held for cosmobiology.

Fritz[8] writes that with any of the three alternatives the researcher will be dealing with strange forms of life. The flora and fauna will be arranged in an entirely different hierarchy, perhaps with many extinct species still enjoying their prime on earth. Unique evolutionary tendencies will be apparent and the investigator will encounter peculiar combinations of attributes and life-forms not existing in the wildest imagination of any earthbound biologist.

We shall now turn to our closest neighbors in space —the moon, Venus and Mars—to determine to what extent conditions on these bodies are favorable to life.

Moon

We know that the moon has no atmosphere comparable to the earth's. However, if recent observations of shooting stars near the lunar surface are verified there is a slight possibility that an extremely thin atmosphere might exist on the moon. To date all evidence supporting the lack of an earthlike atmosphere mentions nothing about conditions in the countless cracks and depressions in the lunar crust, where the presence of minute residual traces of oxygen and water vapor is not entirely impossible.

While meteoritic dust particles are changed almost beyond recognition during their journey through the earth's atmosphere, on the moon they can be found among possible mineral deposits or in sheltered cracks on the lunar surface. The steady accumulation of cosmic dust over the past millions of years ranks foremost among such topics of interest. Perhaps man will be able to collect much of this material, called *astroplankton* by Haldane. A study of lunar dust presents two highly interesting challenges for the biologist: it enables us to estimate the prebiotic synthesis of organic compounds and creates an opportunity, perhaps, for randomly sampling the distribution of living spores, as described in the panspermy hypothesis. This would comprise at least one answer to the question of what space flight teaches us.

Special precautions should play an important part in the plans of any of these scientific expeditions. If bacteria are carried by spaceship to another planet, for instance, we might be mistakenly led to believe that the same forms of life also exist on that planet. We shall discuss the problem of mutual contamination in greater detail later.

Venus

Even an insufferably hot surface temperature does not rule out the possibility that a moderate temperature zone may exist above or below this plane. Of all the planets Venus is our closest neighbor, being "only" about 40 million kilometers away. The fact that Venus is nearly the same size as the earth would favor similarity in other physical characteristics as well.

It is extremely difficult to observe Venus directly because the planet is shrouded in an opaque cloud or fog. Some investigators believe conditions on Venus to be dry. Other observers, however, maintain that the canopy consists of massive clouds of water vapor and ice crystals. If this were the case Venus would be a moist planet. In 1956 radio waves were received from

Venus in the eleven-meter band for the first time. They were observed to occur in very short and somewhat longer impulses, suggesting thunderstorm-like activity in the clouds of Venus.

As for the *chemical* composition of the Venusian atmosphere spectral analyses to date have revealed the presence of carbon dioxide (1933) and nitrogen (1954). So far there has been no definite confirmation of those gases which are so essential for life, oxygen and water vapor.

In 1953 the Dutch scientist, J. Houtgast, obtained evidence of a strong magnetic field on Venus. Latest reports indicate that attempts to contact our sister planet by radar have been successful. Moreover, a radar echo, although extremely faint, was received in return.

These promising results provide impetus for continuing to research the possibilities of exploring Venus by radar. This technique has a decided advantage in that radio waves do penetrate clouds and fog, enabling us to receive an echo from the actual surface of the planet.

We hope that this novel approach will strike Venus "more favorably" than has been the case to date and ultimately persuade her to lift her veil a little.

Mars

There is a good chance that life exists on the planet Mars. With the aid of the 200-inch telescope at Mount Palomar we have been able to detect unmistakable color changes. These greenish-gray color shifts can be observed during the Martian winter and summer in the northern and southern hemispheres of the planet. Some investigators believe they are caused by a kind of primitive vegetation, consisting perhaps of mosses, lichens and/or algae.

That the color changes are related to changes of season on Mars is also demonstrated by the shift in position noted in the white polar caps. We must be careful not to conceive of life on Mars in terms of our earthbound concept of "vegetation" for the latter is probably far too restrictive. Highly interesting evidence of the existence on Mars of carbohydrates, which are so compatible with life, has also been found.

OPPORTUNITIES FOR TESTING ASTROBIOLOGICAL HYPOTHESES

Theoretical Considerations

Undoubtedly there are suns other than our own around which planets also revolve. These stars are extremely faint and difficult to see, let alone photograph, because they are so distant. Probably only a small fraction of the planets satisfy those conditions absolutely necessary for life, including a constant source of radiation, moderate temperatures, water and proper atmospheric conditions.

Today it is assumed that billions of galaxies exist in that part of the universe known to man, with hundreds of billions of stars in each galaxy. Science is probing deeper and deeper into space but still no end is in sight. Modern telescopes can penetrate up to two billion light-years. Some now being perfected in the United States hopefully will reach as far as thirty billion light-years to help determine whether or not the universe is in truth a closed system of finite dimensions. About ten per cent of approximately one hundred trillion stars are similar to our sun (so-called G-stars).

According to the latest theory our sun and other stars were formed when interstellar dust and gas clouds contracted in a gravitational field. Matter remaining outside the revolving sun became planets.

Our sun is now rotating very slowly (one revolution every 25 days). Astronomer O. Struve speculates that part of the original solar rotational energy was absorbed by the planets. From this we might assume that slow rotation is an indication that the star is accompanied by a set of planets. Since there might be billions of stars in the Milky Way which rotate slowly we are led to believe that an inordinately large number of planets exist in our galaxy *alone*. Some investigators, however, hold just the opposite view, maintaining that there are very few inhabited planets like our earth. This position rests upon the principle that nature must be extremely wasteful in the selection of very specific events as, for example, fertilization of eggs and seed distribution in the plant and animal worlds. It follows that among billions of planets in the universe there could be only one "permitted" and selected earth.

Let us now turn to the actual testing of possible hypotheses in (1) interplanetary space, (2) analytic studies of meteorites and (3) Project Ozma.

(1) Interplanetary Space

Through instruments carried aloft by balloon and in satellites we are currently learning much about "planetary chemistry" and biology. Space probes in the neighborhood of so-called "targets" will also yield valuable information preparatory to actual landing on a celestial body.

In addition to these research methods we should consider what kinds of long-distance observation would establish the existence of life on earth. In other words by perfecting techniques with weather satellites in outer space we can utilize the same methods during earth-watching as we would in observing Mars. What picture would the earth present from far out in space, with its deserts, oceans and inhabited areas? How would a Martian, for instance, conclude that the earth is inhabited?

Microbiology, before any other discipline, is in a better position to deal with the life question. Microorganisms will sooner be found in a small area than larger biological forms. Microorganisms must precede large forms in development but we are not willing to assume that bacteria living today are necessarily very primitive.

The earth is well endowed with both types of organisms, as we know. While the larger forms occupy only a very small part of the earth's entire surface we would expect to find evidence of microscopic life in every drop of water, in every soil or air sample. Microbiological tests have distinct advantages but a very careful plan of investigation and special research techniques are required to evaluate them properly. Collecting and transporting these samples until they can be observed under the microscope, cytochemical procedures and the danger of contamination are all special problems.

Microorganisms can be distinguished from mineral particles by observation under UV light at 2600-2800 Å. This corresponds to selectivity for nucleic acids and proteins. The simplest tests to carry out are atmospheric dust and surface sampling by means of automatic devices or after a landing. High-altitude samples of cosmic dust are now being collected on a moving tape consisting of strips of transparent paper. After exposure the tape is rolled up and sealed inside a special airtight container.

It is easy to imagine that there must be some planets on which no life of any kind exists. Even a "sterile" planet is probably of unique interest to the biologist, as it may enlighten us on chemical developments preceding the prebiotic stage.

(2) Analytic Studies of Meteorites

Reports by M. Calvin and S. K. Vaughn[4] have recently aroused much interest. In essence the authors found complex organic compounds in meteorites similar to compounds associated with biological beginnings on earth. Presumably this organic material is extraterrestrial in origin. Calvin and Vaughn believe, furthermore, that prebiotic forms from other bodies in space are definitely involved here. In their words, "Tests show that the same evolutionary processes which occurred on earth have also taken place elsewhere. We are by no means unique."

(3) Project Ozma

Project Ozma, actually a "space probe" aimed at fixed stars outside our solar system, is the responsibility of a brand new research branch presently operating from the radio observatory at Green Bank, West Va. Its purpose is to ascertain whether any radio contact can be made with whatever life-forms may exist on planets in other solar systems. The receiving station at Green Bank consists of a radiotelescope with a 26-meter diameter. This location was chosen because it offers relative isolation from disturbances caused by normal radio communication on earth. To keep these disturbances as minimal as possible a frequency near 1420 mc (21-cm wavelength) was used. In the event regular impulses are received they might possibly be traced eventually to intelligent creatures.

Selectivity

Stars within a circumference of about 12 light-years qualify for inclusion in this study. Only one quarter of these stars, however, are similar to our sun. By cosmic chronology the fixed stars in this category may no longer be very young and consequently not very hot but they may still be able to give off sufficient radiation. Double stars are not eligible because planetary orbits can only be stable at very great distances from these suns, where conditions of intense cold would be prohibitive. Nineteen stars lie within this twelve light-year perimeter. Only about five of these, however, fulfill the above conditions to some degree, among them the following three, in particular:

(τ) Cetus in the constellation Whale
(ε) Eridanus in the constellation Eridanus (river)
(ε) Indus in the constellation Indus (Indian)

The first two, which can be seen by the naked eye, are 3.6th magnitude stars eleven light-years away (about 100 billion km). The reason for not selecting fixed stars much closer to earth (α Centaurus, for example, which is only four light-years away) is that signals near the plane of the Milky Way are too often blocked by increased noise from this dense stellar grouping. As part of Project Ozma, ten hours daily for two or three days at a time are spent listening to the above-mentioned stars. If an unusual signal from outer space is ever received it would probably appear as a peculiar peak in the vibrating curves formed from natural cosmic noise.

The chances of achieving immediate success are naturally very poor. According to O. Struve we may very well have missed signals from creatures in outer space by minutes, days, centuries or even geological eras. The radiotelescope, he points out, has been developed only during the last twenty-five years.

Cocconi[6] concludes, "The probability of success is difficult to estimate but if we never search it is zero."

H. C. Urey's opinion is that "in some world unknown to man other intelligent beings may be discussing the possibility of life on other planets. The greatest feat we can imagine today is communication with them."

In the systematic outline presented above classification was attempted along the lines of physical location. Since astronautics is largely based on changes in location we can select the earth as our reference point and develop a *geocentric* outlook. Everything transported from the earth to another body in space would fall under the category, ἔξοίK = *emigration.* This term would also pertain to introducing our forms of life into a different, extraterrestrial environment. μετοιK = *immigration* would refer to the importation of other living organisms to earth.

We must first determine whether life exists on other planets and, if so, whether there is any resemblance between its metabolism and that of terrestrial organisms. If bacteria from earth are introduced to another planet by spaceship they might, under certain circumstances, influence or even kill microorganisms indigenous to the planet. The importation of microbes on a seemingly barren planet or on one inhabited by far less adaptable forms could set off a population explosion among the microscopic newcomers.

It will therefore be mandatory to decontaminate all material before leaving earth. Under the auspices of the National Academy of Science (U.S.A.) and the International Council of Scientific Unions a special commission was organized to handle all of these problems.

Space travel also affords us an opportunity to introduce microorganisms from other planets to earth. As long as there are no definite clues as to the form extraterrestrial life may take we are unwilling to pessimistically speak of "drastic danger" from new diseases on earth. Strict adherence to basic decontamination procedures should greatly reduce the risk of this danger.

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