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Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ON THE POSSIBILITY OF EXTRATERRESTRIAL LIFE

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The search for extraterrestrial life, the prime objective of space biology, has begun. Project Ozma was an attempt to detect signals from other intelligent beings located in other parts of the universe. The search is directed toward Mars at present. The findings there will probably help decide in what part of the universe the next search will be conducted.

Indications are that life must exist somewhere in the universe other than on our planet. It is thought that we may have the answer to this question of extraterrestrial life by the beginning of the twenty-first century.

ADVISER'S APPROVAL L. Herbert Bruneau

ON THE POSSIBILITY OF EXTRATERRESTRIAL LIFE

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ON THE POSSIBILITY OF EXTRATERRESTRIAL LIFE

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INTRODUCTION

The minds of men have often been haunted by great problems. Man has been able to solve many of these, others continue to haunt him. One of the great problems which continues to haunt man is the distribution of life within the universe. It is probable that man has, since his realization that other planets exist, continuously asked the question, "Does extraterrestrial life exist?"

Some two thousand years ago Lucretius, a poet, wrote about life beyond the earth in a poem that appeared in his work, De Rerum Natura (Of the Nature of Things). He wrote:

> "...And if the very same laws of nature hold
> Which have the power to cast the seeds of things
> Together in their several places, then
> As here they are together thrown, perforce
> Thou must confess that other worlds exist
> In other realms of space and divers tribes
> Of human kind and breeds of savage beasts."

Thus the question of extraterrestrial life is not a recent one; nevertheless, we still seek its answer.

In attempting to solve another of the great problems confronting mankind, the origin of life on the Earth, one hypothesis, that is known as Panspermia, presupposes the existence of life elsewhere in the universe. According to this hypothesis, life on the Earth came from life in the universe by the migration of spores through space from one planet to another. These spores were assumed to have been carried by dust particles of meteorites from distant parts of the universe. This hypothesis has been rejected because the extremes of heat and cold, as well as the deadly radiation to which these spores would have been subjected are beyond what life as we know it can tolerate.

J. B. S. Haldane has suggested rather passively that life may have been disseminated by intelligent beings from other stellar systems.[1] It would be rather foolish, given another century of productive science and technology, to deny that man could possess this capability.

If one is to examine the possibility of extraterrestrial life, he is compelled to investigate the origin of life on the Earth. The theory that life arose due to the conditions that existed on the primitive Earth has been given impetus by the work of such men as Alexander I. Oparin, J. B. S. Haldane, Stanley Miller, Sidney W. Fox, Cyril Ponnamperuma, and numerous other investigators. Assuming life originated on the Earth in this manner, our knowledge of the universe,which has been gained from astronomical observations, should give us a number of clues as to where we should look for extraterrestrial life.

Studying the generally accepted theory of the origin of our galaxy with the subsequent formation of the Sun and its solar system will aid man in deciding where he should search. This understanding will give him an idea of what means are at his disposal and what new means he must produce to carry out his search for extraterrestrial life. It will indicate what precautions he must take to insure that he does not contaminate the object of his search with terrestrial life. These problems will require careful study and planning.

Man has made some decisions concerning the search already. He has decided to make Mars the first object of his search. He has begun to design and construct instruments that he will eventually use to accomplish his goal. The search for extraterrestrial life, the prime objective of space biology, has begun. We hope and feel that this will be accomplished by the beginning of the twenty-first century.

CHAPTER I

THE ORIGIN OF THE EARTH

The universe, according to astronomical evidence, appears to have evolved through a series of successive stages in which each successive stage was connected with the one preceding it. We can understand a single stage only in the light of what is known of its predecessor. There is general agreement among astronomers that stars are formed from local condensations of clouds of gas and cosmic dust which are found in many parts of the universe. The pressure of radiation is believed to initiate the concentration of dust. Two dust particles screen each other, to some extent, from radiation. This results in the radiation pressure being least along the line which joins the particles. The particles are slowly propelled toward each other by this self-accelerating process. Eventually enough particles concentrate and condense to form a star. It may be that planets and other heavenly bodies are formed in a similar manner.

The oldest stars are found in the central regions of a galaxy. They form part of what is known as a globular stellar group. The younger stars for the most part belong to the disc system of the galaxy. The youngest stars are found in the immediate neighborhood of the spiral branches of the galaxy. It appears that in our own galaxy the origin of the oldest stars occurred between 12.0-20.0 X 10^9 years ago.[2] These stars consisted almost exclusively of hydrogen. Our Sun was formed from a mixture of light and heavy elements. The heavy elements are thought to have resulted from a powerful outburst of material from the center of our galaxy between 5.3-6.0 X 10^9 years ago.

The origin of our Sun and the planets of the solar system were formed out of ready-made protoplanetary material which contained all the elements of the periodic table. This occurred approximately 5.0 X 10^9 years ago. The formation of the Earth with its present mass and composition resulted some 4.5 X 10^9 years ago from a continuing evolution which was due to its internal energy. This continued evolution led to the separation of the mass into the nucleus, the mantle, and the crust which formed 4.0 X 10^9 years ago. The oldest minerals known on the Earth were formed 3.6 X 10^9 years ago. This was followed by the formation of the oceans which occurred between 3.0-3.5 X 10^9 years ago. The formation of the Earth's secondary reducing atmosphere occurred about the same time. The most important milestone in the Earth's development was the formation of its surface of a crust, an atmosphere, and a hydrosphere.

The existence of a fully reducing atmosphere is placed between 1.8-2.0 X 10^9 years ago. Through a continuous gradual change an oxygen-containing atmosphere with its present composition was formed 1.0 X 10^9 years ago. These changes were necessary for life to originate in the manner it is assumed to have arisen. The table on the following page summarizes these events.

The origin of the chemical elements necessary to form the compounds which are involved in all living organisms occurred over a considerable period of time. Hydrogen is considered to be the most primordial chemical element in the universe.[3] All of the other elements were ultimately formed from hydrogen. Nuclear-fusion of hydrogen results in the formation of helium. The helium burning process produces carbon. This is followed by the carbon-nitrogen cycle which produces nitrogen.

An alpha-particle capture process leads to the formation of oxygen. The heavy elements which are involved in living organisms as we have previously mentioned were formed by a powerful outburst of material from the center of our galaxy. Since our solar system was formed within a cloud of gas and cosmic dust which contained all the elements of the periodic table, the elements necessary for life were contained in the mass of the Earth.

TABLE I

CHRONOLOGY OF ASTRONOMICAL AND GEOLOGICAL EVOLUTION

Event	Time (10^9 years ago)
Origin of the oldest star in our galaxy	12.0-20.0
Origin of the heavy elements	5.3- 6.0
Origin of the Sun and solar system	5.0
Formation of the Earth with its present mass and composition	4.5
Differentiation of the materials on Earth, formation of the crust	4.0
Age of the oldest minerals known	3.6
Age of the oceans	3.0- 3.5
Age of the secondary reducing atmosphere	3.0- 3.5
End of a fully reducing atmosphere	1.8- 2.0
Formation of an oxygen-containing atmosphere with its present composition	1.0

As the Earth formed, it increased in mass and its gravitational forces increased. This resulted in compressing the particles closer and closer together and causing the temperature of the Earth to rise. After the Earth reached its greatest mass, it eventually began to cool and continued to do so for millions of years. The heating and cooling caused the formation of many chemical materials. The heavier materials were forced toward the center of the Earth while the lighter ones formed the outer portions. As the cooling continued, the surface of the Earth began to solidify.

Because of its size, the Earth exerted enough gravitational force to hold part of the gases that surrounded it. This produced an atmosphere which was very different from our present atmosphere. This early atmosphere is believed to have been formed of hydrogen and the hydrogenous compounds; ammonia, methane, and water. The basic ingredients necessary for life are contained in these gases.

Meteorites, and especially carbonaceous chondrites, have continued to "feed" the Earth with organic substances throughout its existence. The quantity of hydrocarbons arriving on the Earth in this manner may be comparable with the quantity of these substances which were formed endogenously on the Earth's surface.

With the presence of all the necessary elements for life on the Earth, and particularly the composition of the early atmosphere, the stage was set for the evolution of life.

CHAPTER II

THE ORIGIN OF TERRESTRIAL LIFE

Stanley Miller demonstrated in 1953 the significance of an atmosphere of hydrogen, methane, ammonia, and water.[4] He allowed electric sparks to strike continuously for several days into a mixture of these gases. This produced a violent miniature thunderstorm such as could have occurred on a much larger scale more than four billion years ago here on the Earth. From his miniature ocean, Miller was able to identify a number of organic compounds such as amino acids, which are the building blocks of all living matter. This experiment demonstrated that the building blocks of living matter could have been formed by this means and that a living organism was not required for their synthesis.

Other investigators have used ultraviolet radiations as the energy source to produce amino acids from similar or modified mixtures of hydrogenous compounds.[5]

From Oparin's hypothesis, and the work of numerous investigators, we have made various assumptions concerning the origin of life on the Earth.

The energy from the ultraviolet rays of the Sun, from lightning, perhaps from erupting volcanoes, acted upon the gases of the primitive atmosphere to produce such substances as amino acids and sugars. These compounds rained down into the primitive oceans forming a thin, hot soup. As time passed, the molecules of these compounds grouped together to form larger molecules and clusters or aggregates of molecules.

The primitive atmosphere was also undergoing change. The bonds of the water molecules were being broken by the rays of ultraviolet light. This process released the gases of hydrogen and oxygen. Most of the hydrogen escaped into space, leaving the heavier oxygen behind. Ammonia and methane were also being broken up in a similar manner permitting the hydrogen to escape but retaining the heavier nitrogen.

Sidney W. Fox, in his experiment, demonstrated how the amino acids formed on the primitive Earth may have bonded together to form more complicated molecules very similar to proteins.[6] The conditions he imagined could have existed on the primitive Earth.

Films of polymerized organic substances formed on the surface of the oceans. R. J. Goldacre has shown that wind can break with such a film and that the film particles will curl themselves up into primitive individual systems. Isolated from their environment these systems take the form of droplets of liquid enclosed in a surface film. The formation of these systems, or coacervates, may occur spontaneously under certain conditions of temperature, pressure, acidity, etc., which occur very commonly in water.

Some of the coacervates became stable and developed the capacity to interact with their surrounding medium. These coacervates were capable of maintaining themselves in a stationary condition and were able to use the chemical-bond energy of organic molecules to increase their volume and weight. This enabled them to maintain, develop and improve their molecular organization. Oparin refers to such coacervates as protobionts.[2] The protobionts could exist for long periods of time. They were able to grow by a series of chemical transformations.

As time passed the protobionts improved and became able to increase the number of reactions taking place and to form longer chains. These chains branched and joined to form polypeptides of a variety of protein-like substances. This gave the progeny of the protobionts an advantage in that they possessed a more efficient means of synthesizing the polypeptides, during their growth, which produced the same catalytically favorable collection of amino acids.

The protobionts underwent further progressive evolution in which the polynucleotides played an extremely important part. Polynucleotides differ from other polymers in that the two polynucleotide chains can combine to form a double helix only when they are complimentary. One purine or pyrimidine base in one chain combines by means of hydrogen bonds with a particular but not identical base in the other chain. Adenine combines with thymine or uridine while guanine combines only with cytosine. This mechanism arose in the prolonged evolution of living systems.

The structure of the protein-like polypeptides and polynucleotides became more ordered and better adapted to the functions which they performed in extending and multiplying the biological systems. The protobionts which were capable of using an orderly sequence of reactions and using adenotriphosphate in releasing energy from organic molecules were called heterotrophs. The heterotrophs began to use energy to transport materials through the surrounding film or membrane.

Eventually the nucleic acids established control over all the basic processes in these organisms and they became the successful forms of early life. These organisms grew until they reached a limiting size, growth then ceased. Some of these organisms evolved means of duplicating themselves by dividing to form two like organisms, the others eventually died. Natural selection resulted in these organisms becoming more numerous.

Duplication or reproduction by this means is under the control of the nucleic acids. Normally the nucleic acids duplicated themselves accurately, but occasionally the coded messages in them changed causing a modification of a cell process or of the cell structure, a mutation.

Cells grouped together to form colonies. In time some of these cells became specialized. This led to interdependence among the cells. The formation of more complex organisms eventually resulted giving rise, through the processes of evolution and natural selection, to the plants and animals of today.

The beginning was very slow, but as time passed the tempo became faster. It took over 500 million years for the organic world of today to develop. Half of this period was necessary for plants to cover the dry land. Amphibians began to crawl out on the land but remained dependent on the water. Terrestrial animals developed more rapidly. It took about 100 million years for the reptiles to establish their supremacy. Some 35 million years passed before the reptiles were succeeded by the reign of the birds and beasts. Man has been here for only a short period of time.

Studying the processes involved in the origin of terrestrial life can help us form a picture of the possible traits that a system of extraterrestrial life might possess. With this background of knowledge we have a better idea of where to look for extraterrestrial life.

CHAPTER III

SUITABLE SITES FOR EXTRATERRESTRIAL LIFE

The flames of the younger stars are rich in atoms of hydrogen, carbon, nitrogen, oxygen, and calcium which are the principal constituents of living matter. On the surface of the cool stars can be found a few familiar molecules but nothing as complicated as the proteins. The heat and radiation near a star's surface would cause the molecules of protoplasm to be dissociated. Therefore, we can eliminate the trillions of radiant stars as possible sites of extraterrestrial life. This probably represents more than half of the material in the universe.

No life, it is generally agreed, exists on meteors and meteorites because they lack an atmosphere. These bodies are too cold for liquid water when they are at great distances from the stars and are too unprotected from the lethal radiations of hot stars to sustain life. The same argument holds for comets since they are simply assemblages of dust and fragmented meteoric material infused with escaping gases. Meteors, meteorites and comets can then be eliminated as possible sites.

The most likely sites for extraterrestrial life appears to be the other planets. The question arises as to how many planets exist. We are aware of the eleven planets of our solar system. Are there others? At present we do not have the instruments of inquiry necessary to detect bodies of planetary dimension and mass, even at distances of the nearest stars, although some advances to correct this have recently been made.

It is generally believed that many of the stars have planetary systems associated with them. A number of hypotheses have been given concerning the origin of planets.[7] We will not discuss these, but let us assume that other planetary systems do exist.

Astronomical studies indicate that there are at least 10^{23} stars in the observable universe.[8] Each star is capable of providing the energy necessary for life. If each star had a planetary system where at least one of its planets was situated so that it could produce life, there would be 10^{23} possible sites for extraterrestrial life. For various reasons, it is unlikely that this is the case. Let us, therefore, place some restrictions on the number of possible sites.

Let us suppose that because of doubling, clustering, secondary collisions and the like, that only one star out of a thousand has a planetary system. Suppose further that only one star out of a thousand with planetary systems has one or more planets at the proper distance from the star to provide the water and warmth that protoplasm requires. Suppose that only one out of a thousand of these planets is large enough to hold an atmosphere and, further, that suitable composition for life to arise occurs only once in a thousand times. Then only one star in 10^{12} stars meet these rather rigid requirements. Performing a simple calculation, we get $(10^{23} \div 10^{12} = 10^{11})$ 10^{11} planetary systems suitable for life.

Harlow Shapley estimates that there is a minimum of 10^{8} suitable sites for extraterrestrial life.[7] He further states that he would recommend this number be multiplied by at least a thousand and possibly a million.

The astronomer, Su-Shu Huang, is less rigorous in his requirements for the existence of extraterrestrial life. He has come to the conclusion, by studying the time scales of stellar and biological evolution, the habital zones of a star, etc., that at least 3-5 per cent of the stars in the universe must support life.[9] If this be true, then there are 3-5 X 10^{21} sites for the existence of extraterrestrial life.

Calculations by Harrison Brown, using the illuminacy function, indicate virtually every star should have a planetary system associated with it. If this is the case then there are far more possible sites for extraterrestrial life than has generally been thought possible.

One must therefore recognize that there are many suitable sites for the development of extraterrestrial life existing in the universe. It is reasonable to assume that a minimum of at least 10^8 and probably many more sites capable of producing life exist in the universe.

CHAPTER IV

CONDITIONS NECESSARY FOR LIFE

The basic necessities for life as we know it is the presence of hydrogen, carbon, nitrogen, oxygen and phosphorus. These elements are abundant cosmically and can reasonably be expected to be on any and every planetary body.[10] Every planet, therefore, possesses the elements which are necessary for life, but these elements may be present only in a chemically bound form and may not be readily accessible for vital purposes. Water may occur only as hydrates in rock minerals for example. Water is the solvent in which life carries on its chemical reactions, and it must be in liquid form.

Active life on the Earth is limited to the range of temperature from -20°C to 100°C. There is no lower thermal limit to latent life, but the upper limit has a sharp cut-off point. Most organic compounds decompose at high temperatures. The rings and chains of carbon atoms cannot stand too much heat. Life as we know it is possible only within the range of temperature in which the chemical composition of organic compounds occur.

Is it necessary that all life be primarily composed of hydrogen, carbon, nitrogen and oxygen and that it emerges, grows, reproduces, mutates, survives, evolves and diversifies in the same general way as it does on Earth?

There are organisms on the Earth which can grow only in a medium void of oxygen. Others are capable of using solid sulfur as their diet. Some organisms combine together with others to make use of the unique characteristics of each for the growth and survival of both. Organisms are found on the highest mountains and in the deepest ocean trenches. These differ somewhat from our general concept of terrestrial life. Life may exist under conditions that are very different from those of the Earth.

There is a system of inorganic and organic chemistry in which liquid ammonia replaces water as the solvent.[11] In chemical reactions ammonia and water are similar in many respects. Upon self-dissociation ammonia yields the cation NH_4^+ which corresponds to the hydronium ion H_3O^+ of water. Both give a proton (H^+) in reaction producing the respective anions of NH_2^- and OH^-. In an ammono life scheme the part of oxygen may be completely taken over by nitrogen. There may be a system of life somewhere in which ammonia replaces water and nitrogen replaces oxygen.

Various alternates for carbon have been suggested.[10] Silicon seems to be the most likely alternate. Hydrosilicons are sufficiently stable thermally for any likely scheme of life. That such a system could exist is doubted by many, but it is a possibility that we may wish to investigate later.

The search for extraterrestrial life, it is hoped, will determine the conditions under which life exists. Is Earth biology universal, or are there other systems of biology capable of producing life? The answer to this question will tell us whether or not biology is guided by universal laws as chemistry and physics appear to be or if there are multiple biological systems. The answer to this question may make it possible for us to assert that when conditions are right, life is inevitable.

CHAPTER V

THE SEARCH

The first objective would be to search for a form of life that is almost identical to life here on the Earth, ie. life composed of the same chemical elements and performing the same or very similar functions. A second possibility would be to search for organisms which are generally similar in composition and function to organisms on the Earth but which differ in several important details.

Living matter radically different from that of the Earth would be a third possible outcome of the search for extraterrestrial life. The discovery of this type of life would be the most significant result. If organisms were found whose structure and metabolic machinery are based on silicon or whose metabolism is ammonia-based rather than water-based, we would be confronted with a completely new system of biology to investigate. These are not absurd possibilities, although they cannot be discussed intelligently at the present since no such systems are presently known. The discovery of this sort of life would generate many new concepts in the study of living matter.

The discovery of extinct life on some planet, though it be significant, would not provide any great biological insight into extraterrestrial life since there would be no functional material to study.

The most obvious assumption to make in beginning the search is that extraterrestrial life must be similar to terrestrial life, for if it were so radically different from terrestrial life that it exhibited none of the properties with which we are familiar, we would not be able to detect it.

The current life detecting instruments being designed and constructed are based on this assumption. Visual examination through the landing of a spacecraft on a planet and using vidicon photography to examine the nearby landscape is one means of detection being considered. The design of chemical experiments which are capable of distinguishing between the indigenous biogenic and abiogenic organic matter are necessary, however, before this means can be employed. If the metabolic systems of life on other planets are similar to those of terrestrial organisms, then metabolic tests which demonstrate that growth and reproduction occur may be used to detect life. The simplest test to demonstrate this would employ bacteriological culture techniques.

The instruments for detecting life are being designed with minimum weight, size and power requirements. However, recent advances in rocketry indicate we will soon be able to send larger and heavier payloads so that the instruments may not need to be so small and light. The instruments should be designed to give us the maximum amoung of information with restricted demands on the telementary system. The instruments must be designed to withstand the launch, the space environment during transit, the "re-entry" maneuvers, and the landing on the planet without losing their reliability. In fact, the instruments must be highly reliable.

The multivator is a life-detecting device being prepared under the directions of Joshua Lederberg.[12] It is designed to demonstrate the presence or absence of microscopic forms of life in the planet's soil. Initial experiments are designed to test for enzymes of types found in bacteria on the Earth. Soil samples blown into the multivator will be scanned for the presence of these enzymes. Information of the results will be transmitted back to Earth at about the same speed the multivator generates it.

"Gulliver" is a life-detecting instrument using a radioisotope biochemical probe to detect the metabolism and growth of extraterrestrial microorganisms.[13] The instrument detects the carbon dioxide which is formed from the metabolism of a tagged carbon substrate. The number of metabolizing organisms and their metabolic rate will determine the amount of carbon dioxide released per unit of time. Measuring the amount of C^{14} detectable in the gas phase will give a measure of the rate of growth and metabolism of the microorganisms. Plotting the $C^{14}O_2$ in the gas phase against time would tell us whether the organisms were growing or non-growing. An exponential curve would indicate growth while a linear curve would indicate no growth. If no $C^{14}O_2$ were detected, this would indicate there were no living microorganisms present in the tagged substrate.

The Wolf trap is an instrument designed to suck dust into a tube where it will be exposed to culture media suitable for bacterial growth.[3,12] Resulting growth will change the H^+ concentration and the turbidity of the medium. The occurrence of either of these will result in the detecting devices transmitting the information back to Earth.

Numerous other instruments are being considered or are being prepared which will be used to search for extraterrestrial life. Among these are the gas chromatograph, the Mars Miscrope, the ultraviolet spectrophotometer, and the J-band detector.

A problem facing man in his efforts to detect life elsewhere is to avoid the accidental introduction of terrestrial microorganisms on other planets. If terrestrial organisms should survive and multiply on a planet, the recognition of any native extraterrestrial life would be very difficult if not impossible since these newly immigrant organisms might become the predominate species. This would mar the investigations and the possible discovery of an independent origin of life. It is necessary, therefore, that the instruments and the spacecraft be sterilized prerequisite to exobiological exploration.

Sterilization is in itself a major problem. Sterilization of the spacecraft lowers the reliability of its systems and reduces the chances of a launch within the periods which are fixed by astronomical restraints. The gain is significant biological and biochemical information which would be gained by spacecraft sterilization must be balanced against these losses. We must make every effort to develop instruments and spacecraft components that can withstand the necessary sterilization processes without the loss of their reliability. If life has arisen independently on any other planet we wish to explore, then we are obligated not to destroy forever the chances of discovering the fact and subsequently adding to man's knowledge of life in the universe.

We have one means at our disposal of searching for extraterrestrial life without the risk of contaminating the planet on which it is located, if we assume the existence of intelligent beings in space with a technology as advanced or even greater than our own. We must further assume that the logic we use is that most often used in other civilizations and that other civilizations attempt to contact other communicative civilizations. This is by means of the radio telescope.

We have the technology necessary to detect radio signals over the distances that are thought to separate communicative civilizations.[3]

We must assume that another communicative civilization would use the same frequencies we use in interstellar communications, or we must provide a highly sensitive radiometer capable of operating on any radio frequency. The latter would be expensive, require complex equipment and require long periods of time for dissemination of the signals received.

To study enough stars to give a high probability of success would require approximately thirty years. Project Ozma showed that continuous negative results are discouraging. A scientist's interest wanes if he does not have some positive results. Any project aimed at the detection of intelligent extraterrestrial life by radio telescope should simultaneously involve some more conventional research so those conducting the research could divide their time between conventional research and the search for an intelligent signal. This arrangement would most likely produce the fastest success.

CHAPTER VI

LIFE ON MARS

The possibility of life on Mars has led to much speculation. The seasonal wave of darkening across the planet has led many to believe that some form of life must exist there. Some have suggested the existence of highly intelligent beings who by incredible feats of engineering have saved for themselves the depleting water supply on the planet by building mammoth canals crisscrossing the planet.

Most of the life-detecting instruments previously mentioned were designed with the exploration of Mars in mind. Efforts to land instruments on a neighboring planet are presently directed toward Mars. Eventually a group of scientists will probably be sent there since the information sent back to Earth by instruments will never satisfy man's curiosity about his neighbor.

The actual Martian conditions today make the existence of advanced forms of life very unlikely. Microorganisms, however, could survive under the existing physical conditions there. The atmosphere of Mars is composed of carbon dioxide, a trace of water, and possibly nitrogen. No oxygen has been detected. If it exists, it must be in very low concentration. The surface of Mars must receive a high flux of ultraviolet light since its atmosphere does not appear to have any built-in system of protection against ultraviolet light such as the ozone layer which surrounds the Earth. Martian organisms would have to protect themselves by burrowing into the surface or have evolved a mechanism compatible with the existence of a high flux of ultraviolet light.

The polar caps of Mars have been shown to be ice or frost. They come and go with the seasons. The caps are probably not more than a few centimeters thick since they recede at about thirty-five miles per day during the summer. As the cap at one pole recedes, the cap at the other pole seems to form under a cloud. Water appears to be transported from pole to pole. A dark band has been observed to follow the receding polar cap. This phenomenon has led many to speculate on this as being a growth of vegetation across the planet.

The Martian temperature ranges from about 30 degrees centigrade near the equator during the day to a low of -70 degrees centigrade. The atmospheric pressure is between 10 and 25 millibars. This may not affect the survival of microorganisms, but it does affect the availability of water. Mars has about 1/1000 as much water as is found in the Earth's atmosphere. Above average accumulations of water may occur in micro environments, however.

The physical conditions on Mars are well within the range in which microorganisms can survive. It has been shown that some Earth microorganisms can survive and multiply under such conditions if water is available.[14] F. B. Salisbury is about the only present-day biologist who maintains that advanced life possibly exists on Mars.[15]

The experimental approach to the detection of Martian life has already begun with the fly-by of Mariner IV which gave us the range of the atmospheric pressure and the information that no detectable magnetic field existed on Mars. The photographs relayed back to Earth revealed that the surface of Mars is crater-ridden. The next step is to land some instrument there which would possibly detect the presence of microorganisms. Success at this point would be followed by man landing there to observe this life firsthand.

SUMMARY AND CONCLUSION

The formation of our Sun was not a unique occurrence. It is reasonable, therefore, to assume that as other stars formed, many of them had an associated system of planets. Some of these planets must have occupied a position in relation to their star similar to the position of the Earth in relation to the Sun. The physical conditions on a part of these planets were probably close enough to those on Earth that life could have arisen. Therefore, many possible sites for extraterrestrial life surely exist.

The same laws of chemistry and physics, so far as is known, hold throughout the universe. Since the conditions necessary for life must have occurred many times, it seems reasonable to assume that life evolved in a larger number of sites and that some of these sites have produced intelligent beings as advanced or more advanced than our own civilization.

Our search for extraterrestrial life will be directed first toward Mars. It is doubtful that we will find intelligent life, but we may find some forms of microscopic life and perhaps some marcoscopic organisms. No decision has been reached as to where the next search would be made, but one will surely be made.

Manned exploration of the solar system and/or radio telescopes scanning distant galaxies for intelligible messages may tell us whether we are alone in the universe or that other planets are inhabited by living organisms before the dawn of the twenty-first century. Laboratory experiments will endeavor to retrace the path of chemical evolution and may provide evidence for the existence of extraterrestrial life.

The universe is so large that it is a statistical certainty that life, even intelligent life, exists somewhere beyond planet number three.

It may be that the couplet given by Robert Frost in commenting on research tells the tale of extraterrestrial life. Said he:

> "We sit around the circle and suppose:
> The secret sits in the middle and knows."

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