Editors
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LIFE sciences and SPACE research

A SESSION OF THE THIRD
INTERNATIONAL SPACE SCIENCE SYMPOSIUM

WASHINGTON, D.C., 1962

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Edited by

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FOREWORD

Men are beginning to sail around the earth in space ships. The first orbiting ventures have been confined underneath the protective umbrella of radiation belts. They have been carried out in vehicles that are likely soon to be considered primitive, and the ventures themselves, soon outstripped. Men have just begun taking their first steps toward the moon, but already they have their eyes fixed on farther planets.

The purpose of this Third COSPAR Symposium is to describe some of the research findings pertinent to manned space flight and to indicate some of the present limitations and opportunities encountered in manned orbital flight to date: Gagarin was the first to orbit the earth, in a single circumnavigation that took place just at the time of the Second COSPAR Symposium in 1961. Since then, Titov, Glenn, Carpenter and Schirra have completed successful single craft orbiting missions. In August 1962, two months after this Third Symposium was held, Nikolayev and Popovich were sent up in two beautifully coordinated flights launched 24 hours apart. During their flights, Nikolayev and Popovich maintained direct radio communications with each other and were intermittently in close visual contact with one another's ships. Their flights were brought back at about the same time, Nikolayev after being in orbit four days and Popovich three.

As is usual in voyages of exploration, empirical experience is running considerably ahead of basic studies. Partly this is because it is difficult adequately to imitate the space environment on earth, but it is mainly true because scientists, and particularly biologists and medical scientists, have not been sufficiently challenged and attracted to the problems. There is not enough known to give assurance beyond peradventure of doubt as to the kinds of conditions to be met and as to the reactions likely to be encountered among the men who are entering this new environment. For example, Titov, who made the second orbiting flight, lasting about 24 hours, complained of peculiar symptoms implicating a possible new range of problems that might be associated with vehicular motion or weightlessness. If these phenomena were to dominate future space ventures, considerably more basic research into the nature and cause of the phenomenon and its prevention would need to be undertaken. But apprehensions of this sort were quickly dispelled by the empirical evidence of symptom free flights of much longer duration of Nikolayev and Popovich. Then it turned out to be nothing more than what seafarers experience on the surface of the rolling oceans.

In the two previous COSPAR Symposia there were only four papers relating to the life sciences, out of a total contribution of more than two hundred communications. This is not because biologists are shy. Rather, it is because, in relation to the projectable limitations and opportunities of manned space exploration, we are still almost totally ignorant. At the present time it is both simpler and more effective to send up instruments. Man is already actively and successfully exploring space without having to take his own feet off the ground.

There is still much uncertainty as to just where is the cross-over point when man and his accoutrements will become indispensable for the successful accomplishment of some future space missions. Ultimately, man and machines can do more things more successfully and more economically in space than machines can accomplish alone. With the dimension of machine and scientific instrument complexity that may be launched fairly soon, man will be indispensable as a technician for the successful operation of the physical complex itself. Too little attention has as yet been devoted to the theoretical and practical problems and requirements for more successful articulation between men and machines.

The papers in this volume represent modest contributions to the vast problem areas in the life sciences which are defined by man's total interests in space exploration. The questions before us concern what kinds of experiments of biological interest have been conducted in the space environment. What kinds of radiation hazards and protection requirements are in store for men who will venture out from underneath the protective umbrella of the radiation belts? And, what have been some of the personal experiences of the men who have already sailed on the new sea?

Generous financial assistance by UNESCO made it possible for a number of scientists from distant countries to attend.

We hope this Symposium will provide a lure to other scientists in these and other disciplines who will take this as a point of departure for accelerated advancement of this general field.

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INTRODUCTION

It is my pleasure to welcome you to the Life Sciences Session of the Third International Space Science Symposium. I wish to greet especially two of the delegates, Major Titov and Colonel Glenn, whom we all welcome not only to this meeting but also back to earth.

The International Geophysical Year of 1957–58 saw the launching of the first artificial earth satellite. In 1958, the body which had sponsored this world scientific enterprise, the International Council of Scientific Unions, decided to create a Committee on Space Research (COSPAR) to foster international cooperation in space science. Thus COSPAR is organized as an international learned society which can draw upon the knowledge and advice of the world's best experts in all fields relating to the scientific use of rockets and satellites. Gathered at this symposium, from thirty countries, are experts on geophysics, meteorology, cosmic rays, astronomy, radio science, upper-air chemistry, and many other fields of science. This session is devoted to the life sciences.

Life in cosmic space is twofold: host life and guest life. Russian and American astronauts have been *guests* in space during their flights. But even without such flights there would be life. Perhaps a meeting like this one was held millions of years ago on an unknown planet belonging to an unknown star in a remote galaxy. Who can tell? But we have fair indications suggesting that there may be some form of life on Mars, and perhaps on Venus. This is *host* life in space. To find out about its existence, its character and development ranks easily, in my opinion, as the most important objective of space science. The brief term for this new field of endeavor is *exobiology*. But exobiology has not come very far yet, because it is extremely difficult to surmount the stage of speculation. And what is more: unless we take extreme precautions, there is a chance that the opportunity for finding out about host life in space may be spoiled before we even get started, because life on Mars might be poisoned by terrestrial germs or chemicals deposited there. Professor Imshenetsky reviews these problems in Part I of this volume.

Part II is devoted to basic studies relating to manned space flight. We cannot possibly review this subject and do justice to the work of thousands of scientific workers in just a few hours. Other occasions will arise; we have been informed that a symposium on basic environmental conditions of man in space is in active preparation by the International Academy of Astronautics with the cooperation of UNESCO.

Part III concerns manned space flight itself. Last year by a fortunate coincidence, Gagarin's flight took place on 12 April while COSPAR was assembled at its meeting in Florence, Italy. I was the first foreign colleague to congratulate Prof. Blagonravov on this tremendous achievement. But I did not foresee that at the next meeting we would have two men present to testify themselves about the scientific results of their flights. I may briefly underline the importance of these flights to the scientists represented in COSPAR. Such a statement is necessarily qualified like almost any statement in science. Three particular points are worth noting:

1. Manned orbital flight was a tremendous achievement and a flight to the moon will be even more so. Yet cosmic space goes infinitely beyond that. A trip to the moon brings man closer to the center of the galaxy in the same proportion as stepping up a doorstep brings him closer to the moon.

2. Man keeps his natural limitations in space. His eyesight is still limited to the spectral range of visual light, he can see no radio sources nor ultraviolet radiation; instruments are needed for this purpose. Nevertheless, by his alertness, intellect and personal interest man is unparalleled for exploring. No computing device or automatic station will accept the instruction: "report on anything interesting you see". Yet this is the simplest and most sensible instruction to give to man in space.

3. Man keeps his needs: air, water, food. When Columbus discovered America air, water and food were here and so was man, for innumerable centuries. Man's trip to the Moon will be incomparably more severe and direct benefits will not be forthcoming. Nevertheless space exploration carries hopes for the peoples of the world and spokesmen of several nations in the United Nations Organization

have testified to that. They all share in the pride of achievement, but also hope for indirect benefits accruing from a better understanding of the hazards of our planet and a better use of its natural resources following this increased understanding.

H. C. van de Hulst

CONTENTS

PART I

EXOBIOLOGY

PERSPECTIVES FOR THE DEVELOPMENT OF EXOBIOLOGY

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Abstract: In the majority of the papers dealing with the status and prospects of the development of exobiology a theoretical analysis predominates. More attention should be given to the discussion of methods and experiments carried out at the present time or planned for the near future.

In investigating life in the cosmos, we attach considerable interest to detection of compounds specific to living beings, in particular, organic compounds of phosphorus, porphyrins, amino nitrogen and others. In searching for microorganisms on other planets and in interplanetary space the greatest danger is that, as a result of errors in technique, the investigator will detect earthly microorganisms which have invaded and reproduced in the nutrient mediums used. Information on the vitality of microbes detected in the ground taken in the zone of eternal frigidity, in big pieces of rock salt, in meteorites, etc. confirms these apprehensions. Initially, search for heterotrophic bacteria should be carried out, then for phototrophic, denitrifying, sulfate-reducing, nitrogen-fixing microorganisms, as well as bacteria oxydizing sulfur, iron, methane and hydrogen.

Instruments for detection of cosmobionts can be based on nephelometry, potentiometry, manometry and on the use of carbon labelled compounds and added to the nutrient medium. Investigations elucidating the influence of low and high temperatures, vacuum, and radiation on living cells are possible to carry out on earth and therefore are most accessible to exobiology. They give interesting results and in some degree make it possible to approach the study of the conditions to which life would be exposed in space.

The sterilization of space ships is of paramount importance for further exobiological investigations. Under space conditions microbes will not completely perish on the space ship surface and, therefore, careful

sterilization is necessary. The assertion that earth microbes, having reached the lunar surface, will not be able to develop is not free of objections. To carry out sterilization so that space ships will not contain dead bodies of microbes is impossible. Therefore, the wish expressed sometimes that "carcasses" of microbes should not be conveyed onto other planets is practically unrealizable.

Краткое содержание: Большинство статей, рассматривающих состояние и перспективы развития космической биологии дают, главным образом, только теоретический анализ проблем, относящихся к этой науке. Следует уделить больше внимания обсуждению методики настоящих и будущих экспериментов. Изучая жизнь в космосе, мы особенное внимание должны обратить на обнаружение химических соединений, присущих живым организмам, в первую очередь, органических соединений фосфора, порфирина, аминного азота и некоторых других. При попытках обнаружить микроорганизмы на других планетах и в межпланетном пространстве, всегда существует риск, что из-за неправильных методов, исследователь обнаружит земные организмы, которые были занесены туда, а затем попали в питательную среду и размножились. Данные о микробах, которые были обнаружены в зоне вечной мерзлоты, в больших кусках каменной соли, в метеоритах и т.д., подтверждают эти опасения. Сначала нужно стараться обнаружить гетеротрофные бактерии, затем фотосинтезирующие, денитрифицирующие, десульфурирующие и азотфиксирующие микроорганизмы, а также бактерии, окисляющие серу, железо, метан и водород. Конструкция приборов для обнаруживания космических бактерий может быть основана на нефелометрии, потенциометрии, манометрии или основана на применении химических соединений, содержащих меченный углерод и добавляющихся к питательной среде. Исследования, выясняющие влияние высоких и низких температур, вакуума и радиации на живые организмы, могут быть проведены в наземных условиях и поэтому сравнительно легко осуществимы. Эти исследования дают ценные результаты и до некоторой степени позволяют приблизиться к тем условиям, в которых протекает жизнь в космическом пространстве. Для дальнейших космобиологических экспериментов чрезвычайно важна стерилизация космических кораблей. Не все микробы на поверхности корабля погибают в космическом пространстве и поэтому необходимо тщательно стерилизовать корабль. Утверждение, что земные микробы достигнув поверхности луны, не будут в состоянии размножаться, не совсем правильно. Стерилизовать корабль так, чтобы на нем не оставалось мертвых микробов, невозможно. Поэтому высказываемые иногда пожелания о том, чтобы "трупы" бактерий не заносились на другие планеты, практически не осуществимо.

1. Introduction

Advances in physics, mathematics and engineering have made exploration of space a reality. This has resulted in the emergence of several new scientific branches, among which an important place belongs to exobiology—a science studying the existence, extent and characteristics of life beyond the earth, as well as the effects of space factors on living creatures.

Exobiology has attracted attention of biologists working in various fields: genetics, general biology, microbiology, biochemistry and virology. Articles dealing with various problems of exobiology have appeared in various scientific journals, but most of them are entirely theoretical and contemplative in character. An imbalance is evident between biological generalizations and the consideration of possible technical methods and experiments in this field. The present report is therefore directed entirely to a discussion of experimentation in exobiology already accomplished or to be accomplished in the nearest future. The contemporary state of the problem has already been given in theoretical terms in several publications [1, 2, 3, 4, 5, 6, 7].

2. Detection of extraterrestrial life

2.1. Initial statements

Until the first experimental evidence on the existence of extraterrestrial life and metabolism of cosmobionts is obtained, we have to proceed from theoretic premises, analogies and present knowledge about temperature and other conditions on planets or in space. We believe however that, whatever the direction of studies, the experimenter must use at first the conceptions of life and criteria of living and non-living which we use when studying living objects on earth. It is sometimes pointed out in articles that cosmobionts are feasible which contain no carbon, that biological systems may exist based on silicium or germanium compounds, that water may be replaced by other solvents such as glycols, etc. It would be utterly unwise not to make attempts at detecting living forms analogous to terrestrial creatures in structure and way of life. And this is the more true, since it is possible that life phenomena are not so multiple as sometimes suggested. In any case, it is only when our experiments fail to find living forms similar to terrestrial ones that we should radically change programs and methods of study and search for living forms different in principle from those existing on earth. Undoubtedly, chemical analytical data on the atmosphere and ground composition of planets, as well as other accurate data on planetary environments which will be obtained by that time, will greatly aid us in planning new directions of study.

2.2. Biochemical analysis

Of no less interest than the detection of living creatures is the possibility of discovering in space chemical substances characteristic of living organisms. It may be supposed that such substances originate from simpler chemical compounds under the influence of physical factors, and that their appearance corresponds to the "organic substance evolution" which was discussed in detail at the Symposium on the Origin of Life held in Moscow in 1959 [7a]. Detection of such substances on a planet bearing no life could throw light on the particular aspect of the origin of "living matter" which is at present most difficult to explain.

It may be very much debated what compounds are most characteristic of life and what should be looked for in the first place. It seems to us that attempts to detect organic phosphorus compounds, porphyrins and amino-nitrogen would be most logical. It is quite likely however that some explorers will consider it more demonstrative to detect other compounds. In any case, prime attention should be paid to the construction of instruments, small in size and capable of analysing the surface of a planet for the possible presence of various organic substances and of transmitting analytical data to earth. Naturally, this will require a preliminary comparative examination of a number of analytical methods suitable for a given environment.

2.3. Technical difficulties

A most obvious hazard in the search for living creatures in space and on planets is the possibility that as a result of technical failure the explorer will isolate terrestrial microorganisms which have penetrated and multiplied in the nutrient media used. There are existing microbiological studies very similar in character to those connected with the detection of life in space. I refer to microbiological analyses of rocks, meteorites, soil samples from areas of permanent freezing, large pieces of salt rock, etc. In the literature there is no lack of reports claiming isolation of organisms from such samples which have supposedly been in an anabiotic state for hundreds, thousands or millions of years. Unfortunately, all such reports do not withstand criticism from a technical point of view.

When reports were published that living bacteria, algae and other forms were revealed upon thawing of soil samples taken in Siberia in areas of eternal congelation, the Institute of Microbiology of the Academy of Sciences, USSR organized a special expedition. The expedition took monoliths from eternal frost levels using an electric saw in such a way that contamination with organisms penetrating from the upper layers with filtering water was excluded, and transported the samples by airplane. Inoculation of samples into numerous different nutrient media failed to reveal any living organisms.

All this goes to show that microbiological analyses of cosmic samples should be made with irreproachable technique so as to avoid completely contamination with terrestrial forms during the taking of the sample and during its analysis.

2.4. Microbiological studies of meteorites

The importance of technique may be further illustrated by results of microbiological analyses of meteorites. The possibility of transport of living germs to the earth with meteorites was admitted by such prominent scientists as Helmholtz, Van Tieghem, Lord Kelvin and Richter [8, 9, 10, 11]. But it should not be overlooked that with few exceptions meteorites remain lying in the ground for more or less long periods before they are safeguarded for examination. During that time various organisms may penetrate inside the meteorites together with soil water. Subsequent thorough washing of samples with antiseptics or flaming them kill only cells remaining on the surface. Inoculations with powdered meteorites give rise to growth of various coccal, spore-forming and non-spore-forming bacteria, which had been considered by Lipman [12], without any foundation, as "inhabitants of meteorites". This applies equally to positive results obtained in other similar studies. It should be remembered here that

Pasteur [13] used a specially constructed probe for obtaining samples from a carbon meteorite which fell in 1864 in d'Orgueil. He failed to isolate living organisms upon inoculation.

The question of the possible presence of viable cells in meteorites thus remains open. Isolations free of technical fault would therefore be of great scientific interest.

2.5. Physiology of possible cosmobionts

Despite the microbiological studies with stratostats carried out to date, the upper limit of earth's biosphere has not yet been established. It may be assumed theoretically that terrestrial microorganisms may be carried up to altitudes of dozens of kilometers. Investigations in that direction are immediately related to the problem of life export and import, that is, the problem of interplanetary transport of living materials. In such studies, however, the experiment probably deals only with terrestrial forms. Of much greater interest for general biology is the problem of the physiology of microorganisms inhabiting other planets.

At present the overwhelming majority of biologists are inclined to support the idea that chemo- and photoautotrophs evolved as a result of specialization of function and have more recent origin than heterotrophs. Formation by purely chemical means of various organic substances made the existence of heterotrophs possible. Search for the latter organisms will therefore comprise the first task, and physiological distinctions of heterotrophs will determine the methods for their detection. It is quite possible that simultaneously with heterotrophs can exist forms utilizing oxygen of nitrates or sulphates, such as denitrifying and sulfate-reducing bacteria. Their detection should also be planned following experiments on the detection of heterotrophs. The absence of oxygen in the atmosphere of Mars suggests that there may exist photosynthetic bacteria, which, in distinction to higher plants, evolve no oxygen.

Conditions for life on the planets may be quite different and sharply distinct from those existing on earth. In considering the possible bearing of such environments, one should set higher probabilities on the creative role of selection, rather than to assume something analogous to particular examples of resistance among terrestrial microorganisms.