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BEFORE THE LONG JOURNEY: DEVELOPMENT OF
SOVIET SPACE BIOLOGY AND MEDICINE

O. G. Gazenko

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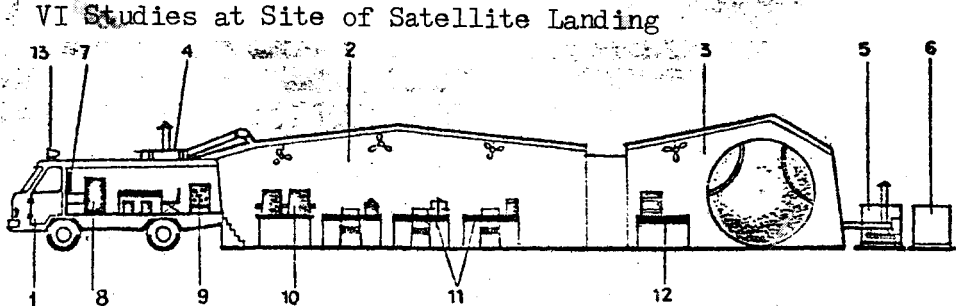
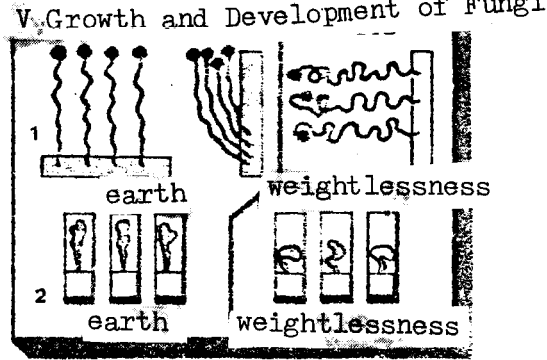
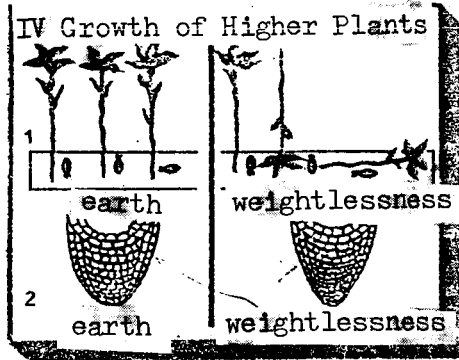
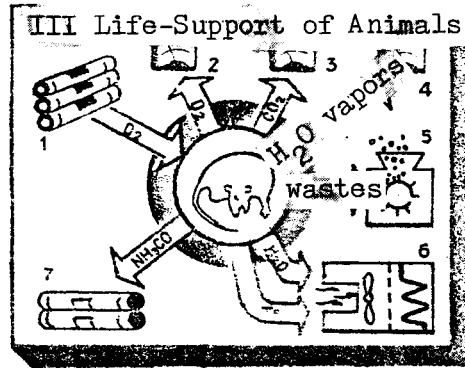
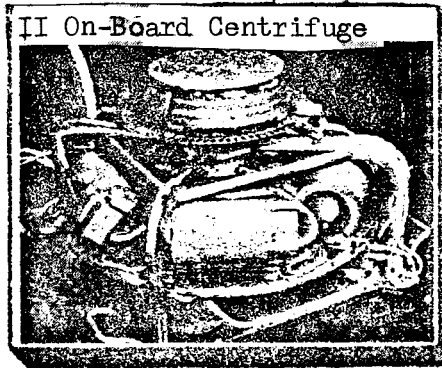
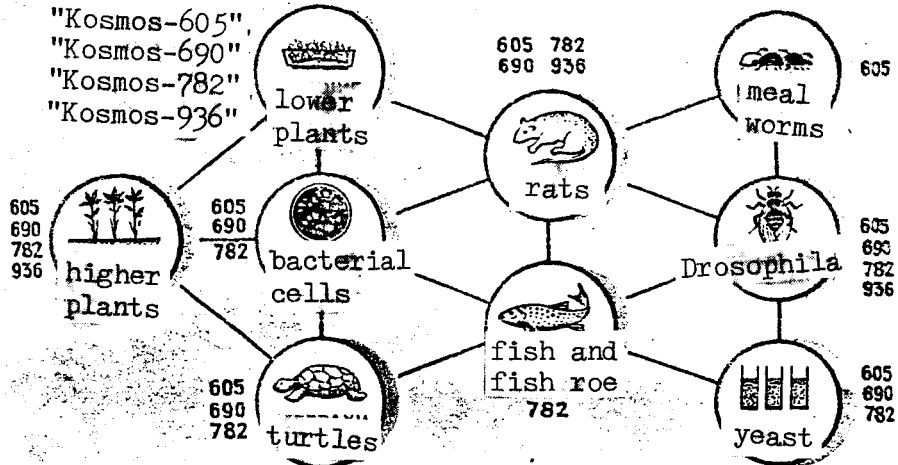


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16. Abstract Academician O. Gazenko, Chief of the Institute of Biomedical Problems, USSR Ministry of Public Health, reviews the short but intense history of Soviet research in space biology and medicine. He stresses the solid academic approach of the Soviet Academy of Sciences in giving a good start at the very beginning of the space age, and he names key people and institutions who initiated these studies. He sees as the basic feature of the first period of space biology the search for answers to a few fundamental questions of survival in space. They have been replaced now by refined, in-depth studies of the biological, biophysical, and biochemical processes in human organism in the space environment and the search for methods which should enable cosmonaut crews to live in space for several years during interplanetary journeys. Thousands of specialists in hundreds of institutions are now busy with these studies. Discussing the typical problems of this effort, Gazenko each time shows how they benefit medical science and practice in general.			
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I Targets of Biological Studies on Biosatellites



Captions for Illustration on Previous Page

I. Starting from 1973 the scientists of our country have been conducting biological experiments on domestic satellites of the type "Kosmos" (605, 690, 782 and 936). These studies have been made jointly with scientists of Czechoslovakia, the United States and France. Scientists of Hungary, Poland and Rumania also participate in them.

II. For the first time on the biosatellite "Kosmos-936" a centrifuge was installed which created an artificial gravitational force.

III. The life-support system for animals that operates on biosatellites: 1--automatic system for atmospheric regeneration; 2--magnetomechanical on-board analyzer for oxygen content; 3--on-board analyzer for carbon dioxide; 4--miniature high-accuracy moisture meter; 5--automatic system for removal and collection of animal wastes; 6--air conditioning system; 7--absorber of harmful gaseous contaminants.

IV. Plants have cellular receptors for gravitational force. Therefore, on the earth, regardless of the position of the seed in the soil, the plants grow roots into the ground and stems vertically into the atmosphere. The role of "sensors" for the gravitational force in the cells is played by starch grains--amyloplasts. Figure 2 illustrates the coverings of the primary rootlets. On earth the amyloplasts are located, influenced by gravitational force, in the lower part of the cells, while in weightlessness--they are distributed uniformly over the cell, and cannot determine the direction of growth.

V. Experiments with lower (1) and higher (2) fungi. If on the earth they grow upwards, then in zero gravity the lower are perpendicular to the substrate, which plays the role of soil, regardless of its position, while the higher adopt an irregular shape.

VI. In such a mobile laboratory studies are made of animals and plants that had been in space immediately after landing of the biosatellite: 1--truck; 2--research ward; 3--ward for disassembly work; 4--heater; 5--heating and ventilation unit; 6--gas unit; 7--control panel; 8--container for experimental objects;

9--power supply panel; 10--biological box; 11--operating table; 12--table for studies; 13--loudspeaker.

Experimental data were also available. As early as 1934, first we and slightly later the United States undertook attempts to study the effect of the upper layers of the atmosphere on living organisms, in particular, on the mechanism of Drosophila heredity. In 1949 there were the first flights of animals--mice, rabbits and dogs--on geophysical rockets. These tests studied the effect on the living organism not only of the conditions of the upper atmosphere, but also the actual flight in the rocket.

It is always difficult to determine the birthdate of any science: yesterday, 134 they say, it was not, and today it is. But at the same time in the history of any branch of knowledge there is an event that signifies its formation. Thus, the works of Galileo say, can be considered the start of experimental physics, like the orbital flights of animals marked the birth of space biology--everyone probably remembers Layka, the dog sent into space on the second Soviet artificial earth satellite in 1957.

Then another series of biological tests was organized on the satellite-ships which made it possible to study the reaction of animals to the conditions of the space flight, to observe them after the flight, and to study the remote genetic consequences.

And so by the spring of 1961 we knew that man could make a space flight--preliminary analysis had shown that everything must be successful. Nevertheless, since the matter concerned a human everyone wanted to have known guarantees in case of unforeseen circumstances. Therefore the first flights were prepared with insurance, and if you please, overinsurance. Here one cannot help but recall Sergey Pavlovich Korolev. You can imagine how many concerns and worries the Chief Designer had who had prepared the first human flight into space. Nevertheless, he scrutinized all the details of the medical and biological service for the flight, worrying about its maximum reliability. Thus, Yuriy Alekseyevich Gagarin, whose flight was to last $1\frac{1}{2}$ hours and who could have generally done without food and water was given food and other necessary supplies for several days. And this was correctly done.

The reason is that then we simply did not have enough information. We knew,



Dogs Began to Develop the Road into Space. Belka and Strelka in the Space Cabin.

for example, that in weightlessness disorders could occur in the vestibular apparatus, but whether they would be as we imagined them was not clear.

Another example is space radiation. We knew that it existed, but it was difficult to determine at first how dangerous it was. In that initial period the study of the actual outer space and its mastery by man were parallel: not all the properties of space had been investigated and the flights were already starting. Therefore the protection against radiation on the crafts was stronger than the real conditions required.

Here I would like to stress that the scientific work in space biology from the very beginning was set on a solid, academic basis, and the approach to the formulation of these, seemingly applied problems was very fundamental. Academician V. A. Engel'gardt, being the academician secretary of the department of general biology of the USSR Academy of Sciences at that time, focused much energy and attention in order to give space biology and medicine a good start. The laboratory of Academician N. M. Sisakyan gave great assistance to the expansion of research and the creation of new teams: on his initiative as early as the beginning of the 1960's 14 laboratories of different academic institutes were working in the area of space biology and medicine, and strong scientific personnel were concentrated in them. Academician V. N. Chernigovskiy made a great contribution to the evolution of space biology and medicine. As vice-president of the USSR Academy of Medical Sciences he involved many scientists from his academy in

the working out of these problems. The direct leaders of the first experiments in space biology were Academician V. V. Parin who made a special study of the problems of space physiology, and Professor V. I. Yazdovskiy. It is also necessary to recall the first director of the Institute of Medical and Biological Problems, Professor A. V. Lebedinskiy.

From the very beginning the study was headed by major scientists, and this also guaranteed the good organization of the research and, as a consequence, the depth and accuracy of the theoretical foresight which was excellently confirmed by the actual space flights. Three of them should be noted especially. This is the biological experiment on the second artificial satellite that showed that a living creature in a spacecraft could be in outer space without harm to itself. This is the flight of Yuriy Gagarin that showed that space does not have an adverse effect on the emotional and mental sphere of man (and there were such fears), and that man, as on earth, could think and work in a space flight. Finally, this is the walk in open space of Aleksey Leonov: man in a special space suit was outside the craft and worked there, and most important to the scientists, he confidently oriented himself in space.

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In this series one should also place the landing of the American astronauts on the surface of the moon. The "Apollo" program also confirmed certain conclusions that had been theoretically drawn on earth. It confirmed, for example, the nature of human movements on the moon where gravity is considerably weaker than on earth. Practice also confirmed the theoretical conclusion that rapid flight through the radiation belts surrounding the earth is not dangerous to man.

By the word "practice" I have in mind not only the flights of people. They were preceded by flights of our automatic stations of the type "Luna" and "Zond," and the American "Surveyors," which thoroughly explored the situation both on the route and on the actual moon. On the "Zonds," by the way, living creatures circled the moon and successfully returned to earth. Thus the flight of people to our nocturnal light was prepared for very solidly.

As is evident from the cited examples, the most characteristic feature of the first period of space biology was the search for answers to basic questions.



Oleg Georgiyevich Gazenko Demonstrates to the Journalists Assembled at the Press Conference the First Dogs that Returned to Earth from Space--Belka and Strelka.

Today, when these answers, at the same time fairly detailed, mainly have been obtained, the search has gone deeper. The modern stage is characterized by more thorough and finer study of the deep and fundamental biological, biophysical, and biochemical processes occurring in the living organism under conditions of a space flight. And these processes are controlled not simply by study, but also by tests.

What explains this? Man's flight into space on a rocket does make a difference to the state of the organism. Of course its adaptive capabilities are remarkably great and flexible, but not limitless. Moreover for every adaptation something always has to be paid. Say, the state of health in the flight is stabilized, but the efficiency of work is lowered. Man adapts in weightlessness to "unusual lightness," but loses strength in his muscles and the toughness of his bones... These examples lie on the surface. But it is evident that the deep life processes are subject to this law (and there is confirmation of this). Their adaptation is not so noticeable, in the short flights they can not appear at all, but the flights are becoming longer and longer. What is the payment for this adaptation? Can one agree with it or is it undesirable? It is known, for example, that in

the astronauts' blood during a flight the number of erythrocytes is reduced--the red blood corpuscles that carry oxygen. The decrease is insignificant, not dangerous, but this is in a short flight. How will this process occur in a long flight?

All of this has to be known in order to construct a preventive protection system and thus expand the human possibilities for living and working in space. And not only for cosmonauts--specially selected and trained people--but also for scientists, engineers, workers, perhaps artists.

There is a deepening of the actual concept of "space biology and medicine." 136
According to plan, this is an applied science which on the basis of data of general biology formulates its recommendations, its methods and procedures for man's behavior in space. It was so from the beginning. But now it has become clear that space biology and medicine is not a derivative of general biology, but all biology as a whole, only studying the organisms under the special conditions of existence. For everything that man does on earth he is beginning to do in space as well: eating, sleeping, working, resting, and in very distant flights people will be born and die--in a word, man is beginning to live in the full biological sense in space. Therefore, we now will not find, most likely, a single section of biological and medical knowledge to which we would be indifferent. 137

As a consequence of this the scale of studies has risen: if in the first steps of space biology and medicine literally tens of scientists participated, then now already hundreds of institutions and thousands of specialists of the most diverse, and sometimes unexpected at the first glance, profile have become involved.

Here is an example: the Institute of Organ and Tissue Transplants which is headed by the famous surgeon Professor V. I. Shumakov. What could be in common between a study of the healthy organism under the special conditions of a space flight and such an extreme measure for saving the hopelessly ill as organ transplants? But there is something in common. The area of mutual interest refers to the problems of immunity--the natural protection of the organism to the action of bacteria, microbes, and other foreign bodies. It has been established that under



Man's First Flight into Space. The Last Parting Words Before the Start Are Given to Yuriy Gagarin by the Chief Designer Sergey Pavlovich Korolev.

the conditions of space flight the immunological protection of the organism is weakened. There are a number of reasons for this, one of which is the following. In normal life we meet microbes everywhere and always. In the closed space of the spacecraft the atmosphere is almost sterile and the microflora is considerably poorer. Immunity becomes practically "unemployed" and "loses shape" as athletes do if they do not train for a long time.

But during organ transplants so that the organism does not reject them, it is necessary to artificially lower the level of action of the immunity. Here our common questions arise: how does the organism behave under these conditions, how to save it from infectious diseases?...

There is another region of mutual interests. We assume that with time people will fly for a very long time and will live in space. This means that they can also become sick. Therefore the need arises, first, to imagine what kind of sicknesses these could be, and second, to provide people in flight with diagnostic



Flight Successfully Completed--Spacecraft, Having Passed Through the Dense Layers of the Atmosphere Enveloped with Heat, Lands

apparatus, and of course, means of treatment. This could be medicine, but it could also be an artificial kidney--one cannot exclude the probability that in the long-range expeditions such resources will be needed. Thus, together with the specialists from the Institute of Organ and Tissue Transplants we ponder how to equip the participants of future space expeditions with "spare parts," and what must be the "repair technology."

However, an operation in space is of course an extreme case. The main role will be played by prophylactics, the prevention of diseases. And here not the last role can be played by nutrition as a means for controlling metabolism and its changes if they occur, as well as a means for reducing nervous and emotional stress. In a definite manner the compiled diet with the inclusion into the food of the appropriate preparations will have done its part unnoticeably for man; the procedure will not have the nature of taking medicine. We have conducted corresponding studies over a number of years with the Institute of Nutrition of the USSR Academy of Medical Sciences under the leadership of Academician A. A. Pokrovskiy of the Academy.



This Is How Cosmonaut Aleksey Leonov
Depicted His Walk in Open Space.

Another example: the N. N. Priorov Central Scientific Research Institute of Traumatology and Orthopedics (TsITO); headed by Academician of the USSR Academy of Medical Sciences M. V. Volkov. The sphere of interests of the institute is the bone-support apparatus of man. At the same time not only methods of treating fractures and contusions, and means of prosthesis are studied, but also every type of change in the bony tissue. The latter also interest us, for in space definite changes also occur in the bony tissue. The methods for affecting these processes which are used both in space and in the clinic, are very close in their basis.

Hypokinesia--low mobility-- which is prevalent in our time, is even more manifest in space. The condition of a man who rises from his bed after a two-month illness is comparable to the condition of the cosmonaut who has returned from flight: both must be taught again how to walk on land.

The fact is that in weightlessness a part of the blood is shifted from the lower section of the body to the upper, and rushes to the head. In addition, the muscles, not receiving the usual load, become weak. Roughly the same occurs during

a long bed confinement. When man returns to earth (or gets up after a long illness) the reverse process occurs--the blood rapidly flows back from top to bottom, which is accompanied by vertigo, and can even lead to fainting.

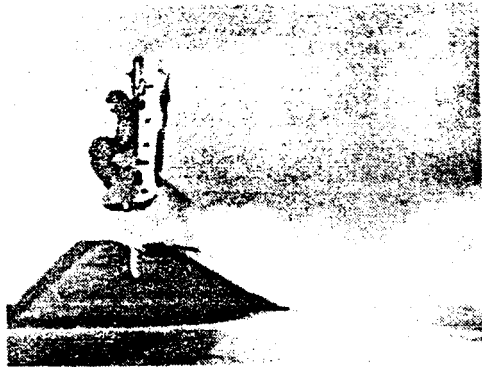
In order to avoid similar phenomena the cosmonauts in flight load their muscles on special training equipment, and use the so-called vacuum system which promotes the movement of part of the blood to the lower half of the body. After returning from the flight they wear for a certain time postflight prophylactic suits which, on the contrary, prevent the rapid flow of blood from the upper half of the body.

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Now similar resources are employed also in the treatment institutions. In the TsITO training equipment of the space type makes it possible for patients to "walk" without rising from their beds. The postflight suits have successfully passed testing in the A. V. Vishnevskiy Institute of Surgery--with their help the patients stand on their feet more rapidly in the literal sense.

Redistribution of blood in the organism is not simply a mechanical process; it also affects the physiological functions, and therefore is of great importance both for space biology and medicine, and for clinical cardiology. This is especially true since the questions of regulation of circulation with a change in the spatial position of the body have not yet been sufficiently studied on healthy people. Here in the joint studies with the A. L. Myasnikov Institute of Cardiology and the Institute of Organ and Tissue Transplants we obtained the first (this work has only begun) important data on, for example, how pressure is altered in different vessels and cavities of the heart with a change in body position in space, and how and at what rate the biochemical composition of the blood is altered during a physical load, blood which flows from the brain, or from the liver, or from the muscles, that is, separately from each organ. This makes it possible to make a deeper judgment on its work and condition.

The research about which we are speaking is exceptionally enriching our knowledge of the human physiology and biochemistry; this is an example of the fundamental study of the biological essence of man. And the example is not the only one.



Before Going on a Space Flight the Cosmonauts Pass a Diverse Course of Training Which Includes Both Developing Landing and Splashdown of the Cosmonauts.

I have already recalled that in space in man the number of erythrocytes in the blood is reduced, and that it is important to analyze the reasons for this phenomenon. Special studies, in particular on the biosatellite "Kosmos-782" indicated that in space the stability (resistance) of these cells is reduced, and therefore they are destroyed more often than in the normal earth conditions; their average life span is decreased. Now, naturally, one has to explain how the stability of the erythrocytes could be maintained. This is important for space, but could also prove useful in the control of anemia and other blood diseases.

The fact that space biology participates in the fundamental studies of the human organism, in a completely specific way, characterizes the modern stage of its development.

Basic research lays the foundation for the further development of practical activity. In our case the foundations are being laid for the further penetration of man into space.

Even now the demands of study of outer space are forcing scientists to think about expanding the composition of specialists flying into space. In the next years one can expect the appearance in orbit of scientists--researchers of space, engineers, organizers of the extraterrestrial production of various materials which cannot be obtained on earth, workers for the collection of space objects and service of production, etc. For these specialists, apparently, it is necessary to expand the currently rather narrow "gate" of the medical selection, that is to

reduce the formal requirements for the state of health, to diminish the volume of preparatory training. At the same time, of course, complete safety must be guaranteed, and I would say, harmlessness of the flight for these people.

In an orbital flight this is done fairly simply: one can not only impose constant control on the condition of the crew, but also in an extreme case there is always the possibility of returning man to the earth in several hours. Another matter is interplanetary flights; they will be considerably more automatic. The expeditions, say to Mars, will last 2.5-3 years. This means that the approach to the organization of such expeditions must be different than for flights in orbit. Here, evidently, the requirements for health in the selection of candidates cannot be lowered. Moreover, the candidates, as it seems to me, must have not only excellent health, but also certain specific qualities--say, the ability to easily adapt to the changing environmental conditions, or a definite nature of reaction to extreme factors. /39

It is very important for the organism to be able to adapt to a change in the biological rhythms. The fact is that our inherent rhythms have a particularly terrestrial origin. For example, the most important of them--diurnal--is directly related to the change of day and night. But earth's days exist only on earth, on other planets the days naturally are different, and they have to be adapted to. Our institute is formulating a method for biorhythmological selection of cosmonauts: it detects people capable of easily adapting to such reconstructions in the time pattern.

Questions related to the moral climate that will be established on board are acquiring very great significance. The concern here is not only with the personal qualities of people, but also the organization of their work and daily life--life in general, with regard for the needs, including aesthetic, of each crew member. This set of questions perhaps is the most complicated. For example, the problem of free time is one.

It is believed that during the flight to Mars the working load for each member of the crew will not be more than four hours per day. Subtract eight hours for sleep, and 12 remain. What are they to do? In the limited space of the spacecraft, with the unchangeable composition of the crew this is not easy. Books?

Music? Movies? Yes, but not just any ones. Music, even favorite, can evoke superfluous emotional agitation and intensify the feeling of separation from home. Books and films of a dramatic and tragic theme are also capable of evoking negative reactions, while the genre of adventures, fantasy, books about travelers, polar research workers, and spelæologists in which there is material for comparison and competition will indisputably be well received. Crossword puzzles and rebuses can be worked, but chess or checkers can hardly be recommended for in such games there is the element of rivalry that is undesirable in such a situation.

All of these considerations emerged as a result of the research already underway. They, in my opinion, are very stimulating for an intent study of human psychology, and I think that with time, when the indicated problems will have been sufficiently worked out they will be of great benefit also on earth-- in the organization of the labor and rest of people.

Survival of the expeditions occupies a special place in the setting up of interplanetary flights. Now the cosmonauts simply take everything that they need in the flight from earth (only partially the atmosphere is regenerated; in certain flights experimental regeneration of water was conducted). But they will not take supplies for three years with them. It is necessary on the interplanetary craft to create a close ecological system resembling earth's, but in miniature, which will equip the crew with food, water, fresh air and will recover wastes. This task is incredibly complicated! Essentially we are speaking of competing with nature: that which it has been creating for many millions of years on the entire planet people are attempting to reproduce in the laboratory in order to then carry it in a spacecraft.

Such work has been underway already for many years in our institute and in the L. V. Kirenskiy Krasnoyarsk Institute of Physics. Something has already been done, but nevertheless it is still impossible to speak of great advances here. Many specialists generally assume that real practical success can only be attained in about 15-20 years. Of course it is possible earlier, but not by much.

Finally, there are the problems of genetics and reproduction. In our institute jointly with the Moscow State University and the Institute of Developmental

Biology of the USSR Academy of Sciences studies are being conducted for the purpose of determining the effect of weightlessness on embryogenesis and morphogenesis. The experiments, in particular on the biosatellite "Kosmos-782," have shown that weightlessness does not prevent insects (Drosophila) from having normal progeny, while in more complex organisms--fish, frogs--in a number of cases disorders, deviations from the norm were detected. This indicates that they need the force of earth's gravity at the very first stages of embryonic life for normal development, and therefore, this force should be created artificially.

And so the problems of long space flights are the most important in our current work. Here the question is lawful: how long can man stay in space? It is currently impossible to answer exactly. In the organism during flight a number of processes occur which have not yet been successfully controlled. They have not been studied to the end, man has not yet flown more than three months, and we do not know how these processes will occur during longer periods of flight. An objective experimental verification is necessary, and the question of the possibility, say of a three-year flight of man in space must be answered on an orbit around the earth. Only then will we have a guarantee that such an expedition will be successful.

But I believe that man will not meet invincible obstacles on this path. Such a conclusion can be made on the basis already of today's knowledge. For the space era of mankind has only begun, it is only 20-years-old, and descriptively speaking, we now are only making ready for that distant journey which faces mankind in space.