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MAN, THE BIOSPHERE, AND SPACE

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16. Abstract

Several medical and biological problems in the flights of the manned space stations are discussed, including the different atmospheres used in U.S. and USSR spacecraft, the problems of transferring crew members between the Soyuz and Apollo spacecraft with the different atmospheres, the microbe exchange and fungi experiments on the Soyuz-Apollo mission, and physiological problems on long space flights, including details for the Russian cosmonauts who were on the Soyuz-Apollo and the Soyuz-Salyut flights. Possible applications of the results of space medical research to terrestrial health problems and the future possible colonization of interplanetary space are also discussed.

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MAN, THE BIOSPHERE, AND SPACE

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[Article by N. A. Agadzhanyan; dedicated to the 15th anniversary of Yu. A. Gargarin's space flight]

[Text] Nikolay Aleksandrovich Agadzhanyan is a Doctor of Medical Sciences and Chief of the Laboratory of the Institute of Medical and Biological Problems of the Ministry of Health USSR. His basic scientific studies are devoted to the physiological aspects of changes in the surrounding gaseous medium on an organism, the adaptation of man to high mountainous conditions, and also problems of biological rhythms.

The calendar for the second half of the 20th century already holds much significant data of the cosmic era. Just 18 years ago, on October 4, 1957, the first successful launching of an artificial earth satellite was conducted in the USSR. The first satellite was followed by others, which fulfilled the ancient dream of mankind--to penetrate the depths of the universe. On April 12, 1961, Yu. A. Gagarin was the first man to see the magnificent map of the universe and our beautiful planet through the viewport of the spaceship "Vostok-1." Other major achievements in studying and mastering space were completed following man's first flight into space: man's first emergence into open space, the investigation of the moon with automatic spacecraft, the flight of unmanned space stations to planets of the solar system and landings on their surface, the first flights of men to the moon, and creation of the first manned orbital stations.

The study and mastery of space will be continued in the new Tenth Five-Year Plan. Special attention will be paid to using cosmic means in studying the earth's natural resources, in meteorology, in navigation, and for other needs of the national economy. These trends in the development of cosmic investigations are approved by the 25th Congress of the CPSU.

The development of space navigation has had a significant effect not only on overall scientific and technical progress, but also on all aspects of the life of contemporary man.

The successes that were attained in solving the medical and biological problems of space flights promote the introduction of these attainments into the practice of the national health service. Thus, various medical instruments and catheters for the main vessels and the heart have been designed on the basis of materials that were developed especially for space techniques. Many methods that have been developed to record physiological information and process it automatically for space studies are receiving an ever wider application in medical practice. This is especially true for apparatus for studying the mineral saturation of bone tissue.

Experiments on the effective cultivation of the higher plants in closed vessels, and also experiments in cultivating lower algae and water-type bacteria by controlled photosynthesis methods and extracting complete protein from them are attracting ever greater attention.

Orbital stations and possibly even our heavenly neighbor the moon can become clinics of a special kind for treating some illnesses (varicose veins, for example) that require a set of specific conditions. Weightless therapy, total isolation of the patient from earthly microorganisms, cultivation of algae and bacteria.... Now only the first steps are being made to master space, and although the outlines of future achievements are not yet defined, there can be no doubt that ever greater achievements will be marked in the coming decades.

The universal global character of cosmic investigations naturally motivated and promoted the development of international scientific and technical cooperation in every way possible. The successful solution of many medical and biological spaceflight problems required the application of the qualified scientific forces not only from within the country but also the cooperation with scientists of other countries.

The combined experimental flight of the "Soyuz" and "Apollo" spaceships took place in June 1975 in accordance with the agreement signed in May 1972 between the governments of the USSR and the United States on cooperation in the area of study and use of space for peaceful purposes.

Many things aroused anxiety and doubt in the first period after the agreement was signed. Too many problems had to be solved in a relatively short time. Indeed, the topic of discussion was the docking in space of different designs of spacecraft. But that was not the only problem. One of the basic medical-biological problems of a combined flight of the Soyuz-Apollo spaceships was providing a safe transfer of the cosmonauts from one spaceship to another and then a safe return to their own ship.

There was discussion on the transfer from the Soyuz, which has an atmosphere close to that on earth in the living cabin, to the Apollo, which has a monogas oxygen atmosphere at a lower pressure. A direct transfer from one spacecraft to another was excluded under these conditions because of the pressure difference in the cabin. A transfer from the Soyuz cabin with a pressure of 760 mm Hg to the Apollo with a pressure of 260 mm Hg, that is from a higher to a lower pressure, could lead to the occurrence of specific functional disorders called decompression disorders.

Thus, there were not only different spaceship designs in the experimental Soyuz-Apollo flight, but also a different composition in their atmospheres. Moreover there were different languages for interaction between members of the crews under the complex conditions of space flight and constant communication with earth. How could all these barriers be overcome? The scientists and designers had to work strenuously to overcome them. Finally, as we marveled at the combined Soviet-American triumph on the day the Soyuz and Apollo docked, we realized that there was not only heroism and courage in this triumph, but also a large amount of effort, labor, experience, mutual understanding, and trust among the five brave cosmonauts: Aleksey Leonov, Thomas Stafford, Valeriy Kubasov, Vance Brand, and Donald Slayton.

We will examine briefly the current status of the problem of creating an artificial atmosphere in the living cabins in order to more accurately show how the "atmospheric" barrier was overcome in transferring cosmonauts from the Soyuz spaceship to the Apollo spaceship.

The general requirements for the atmosphere of the pressurized living cabins can be formulated in the following manner: the atmosphere should not only provide for life activity with respect to pressure, the content of oxygen and other gasses, temperature, moisture, ion concentration, and harmful impurities, but also should make it possible for a man to work during the flight, should satisfy the necessary comfort requirements, should be safe for the organism, and should be not only controllable but also suitable for regeneration by simple and reliable technical means.

As the duration of space flights increases, the requirements on the gaseous medium for habitation will become ever more strict, and to an ever larger degree will require consideration not only of the direct effects of the medium on the organism, but also the reverse reaction of the organism on its surrounding gaseous environment. Compromise at man's expense is impossible. In the Soviet Union, experience already has been accumulated on man's habitation in sealed living cabins with an atmosphere whose parameters are close to those of the earth's. In the United States, a gaseous medium consisting of pure oxygen with a reduced total pressure is maintained in the spacecraft living quarters.

A series of important practical questions arises in relation to lowering the pressure in the spacecraft living quarters, especially when a man goes out into open space. How probable is it that decompression sickness will arise during the space flight? What are the ways to prevent decompression disorders? Is the length of the stay under conditions of a changed gaseous medium a factor that in itself has independent biological significance? Is nitrogen necessary in the composition of the atmosphere? Is it advisable to replace the nitrogen in the air by another inert gas?

Our experimental data showed that animals survive for a period of several months in a monogas atmosphere of pure oxygen at a pressure of 198 mm Hg. However, judging from the results of our investigations and from S. E. Allen's experiments, a categorical denial of a biological role for nitrogen on the activity of an animal organism is premature. Allen showed that a delay in the development of the vascular systems of chicken embryos was observed under conditions of a pure oxygen atmosphere at 190 mm Hg pressure and assumed that the cause of this was the absence of nitrogen in the gaseous medium. Our studies revealed that when animals were kept for a long time (100 days) in an analogous pure oxygen atmosphere, rats were observed to have a lengthened pregnancy, still-born births occurred in their progeny, and there was a lag in weight from control animals that were born under normal conditions.

It is also rational to use an inert gas in the spacecraft cabin atmosphere in relation to the danger of fire and of a collision with a meteorite.

It was shown that if the cabin atmosphere contains pure oxygen at a 196 mm Hg pressure, the combustion rate is doubled because of the absence of nitrogen.

In turn, the presence of nitrogen in the artificial atmosphere of the living cabin can cause a man to have decompression disorders under certain conditions.

Therefore, along with the development of measures to increase the stability of the organism toward oxygen deficiency and other extremal factors of space flight, it is necessary to find means to prevent decompression phenomena. At the time of the combined experimental flight, space medicine was presented with the problem of choosing and proving safe conditions for transfer from the Soyuz spaceship to the Apollo space ship, that is those conditions which would guarantee that the members of the crews would not have decompression disorders. It was necessary to reduce the pressure difference between the spaceship cabins to prevent these disorders, namely to use an artificial atmosphere with a reduced total pressure in the Soyuz spacecraft. In this case the partial pressure of nitrogen was reduced significantly.

As a result of studies conducted in the USSR, it was established that the transfer from a gaseous medium with a 520±20 mm Hg pressure into a mono-gas medium with a 260 mm Hg pressure would not cause the development of decompression disorders. Namely such conditions were created in the Soyuz spacecraft for a safe transfer into the Apollo spacecraft. The partial pressure of nitrogen was reduced by almost a factor of two over the ordinary atmosphere (from 600 to 340 mm Hg).

A so-called transfer module was designed to carry out the transfer after the spaceships had docked. The transfer module fulfilled the role of an air lock between the living cabins, which had different atmospheres, both in total pressure and in the composition of the gaseous medium.

The transfer of a cosmonaut from one spaceship to the other was carried out each time only when the pressure in the air lock was equilibrated with the pressure in the one spaceship or the other.

Thus, in performing the combined "Soyuz-Apollo" program, the elements of the combined approach system were tested in orbit, the docking of the ships was accomplished successfully with the aid of new mating units that were designed in the USSR and the United States, and the technique was verified for a mutual transfer from spaceship to spaceship. Thus the possibility of conducting rescue operations in space was verified in practice.

The medical and biological studies at the time of the combined experimental Soyuz-Apollo space flight were conducted with a consideration of the characteristics of this flight.

Since the flight was rather short, practically all the activity of the crew members was carried out against a background of the initial adaptation period of the organism to weightlessness. It is known that namely in the first days of weightless conditions, the cosmonauts experience a series of unpleasant effects which as a rule disappear at the end of the first week of weightlessness.

However, the effects that are characteristic for the initial period of weightlessness were also observed in this flight: the feeling of blood rushing to the head in connection with the redistribution of the blood under weightless conditions; sensation of the body being upside down (for Leonov); the sensation of the instrument panel closing in (for Kubasov); puffiness in the face and stuffiness in the nose; and appearances of the so-called vestibular discomfort which increase when motor activity is increased. These symptoms practically disappeared at the end of the second day.

The flight provided for carrying out crucial service operations, including even unplanned tasks (repair of a television camera). The experience that has been accumulated in space flights shows that practically any operation that can be done on earth can be done with the same efficiency in space, especially after the initial period of adjustment to weightlessness has been completed. Because the flight program was so full, the duration of sleep was shortened on specific days. however the cosmonauts always slept well. The physiological reaction indices corresponded to the influencing factors and the flight conditions.

The pulse rate increased before the start of the flight and during the time of bringing the spaceship into orbit. Leonov's pulse rate varied within the limits of 74-90 beats/min and Kubasov's was 94-96 beats/min. During orbital flight the pulse rate did not differ significantly from the preflight values and was in the limits of 48-74 and 60-87 beats/min respectively. After the flight the cosmonauts experienced some tiredness, but their humor was good and they felt well. The cosmonauts lost weight: Leonov lost 2.4 kg and Kubasov lost 1.2 kg. The activity of the cardiovascular system was within the preflight limits for each individual after several hours after the flight for both cosmonauts. There was only a small decrease of the orthostatic stability (i.e. the stability while standing at rest).* In a test with a measured physical load, the pulse rate increased significantly more after the flight than before the flight. An insignificant increase in the amount of hemoglobin, a decrease in the number of erythrocytes, and also a slight leukocytosis were observed in the blood.

The observed changes had a reversible character and had no significant effect on the working capacity and the quality of fulfilling the flight program. As we have noted, the members of the crew of the Soyuz-Apollo ships completed two combined medical-biological experiments at the time of the flight-- the study of microbe exchange and a study of the nature of the daily change in the zone formation of fungi under weightless conditions.

It is known that under space flight conditions, the process of interchange of microorganisms between crew members has its peculiarities that tend to intensify the process. This experiment, which was conventionally called the "microbe exchange", also included investigations of the immune reactions of the crews and a study of the pathogenesis of various microorganisms.

For this purpose, the Soviet and American cosmonauts took samples of the microflora from various parts of the body and also from various surfaces of the spaceship living quarters with special equipment during the flight. Blood was taken from the cosmonauts before and after the flight to study the features of the immune reactivity of the lymphocytes.

* [Medical definition of "orthostatic stability"; the source translates as "the stability in a state of rest."]

The other experiment was directed toward the study of the effect of complex space flight factors on the characteristics of the behavior of the zone formation rhythms in the Pushchin strain of fungus from the class Actinomycetes. The point is that until recently practicaly nothing was known on the reaction of the periodicity of many basic biological rhythms to a long space flight, on the effect of the absence of the force of gravity on the almost 24-hour (circadian) rhythms, or on the effect of the change of the cycles of light and darkness under weightless conditions on the circadian rhythms, as compared with an earthbound control.

Today it is well known that one of the conditions for the existance of living systems is rhythm of the biological functions that is peculiar to living matter. Now it has been firmly established that any biological phenomenon or any physiological reaction has a periodic nature, and that all functional systems, as well as the organism as a whole, are rhythmic systems. Along with the characteristics of the physiological reactions, all biological objects also have daily or circadian oscillations in these functions with a period about 24 hours long.

The circadian rhythms are the basic biological rhythm, an inherent property of all earthbound living systems, and these rhythms constitute the basis of their organization.

It has been shown that the circadian rhythms depend not only on internal (endogenic) factors, but also on the cyclical changes of factors of the external (exogenic) medium, on the so-called timers.

The effect of the natural timers, such as the changes in light, temperature, humidity, etc., depend on the period of the earth's rotation about its axis in the electromagnetic field. The circadian rhythms essentially are a reflection of the adaptation of living organisms to the earth's rotation about its axis. No natural timers, which are related to the earth's rotation about its axis, exist under spaceflight conditions. Moreover, the earth's gravitational force is absent, and the state of weightlessness itself can also affect the character and duration of the biological rhythms. The local radiation factor (heavy and multicharged cosmic radiation particles) can also affect the biological rhythms. There is no distinct alternation of light and darkness within a 24-hour framework in space. As the spaceship moves in orbit around the earth, day and night change very frequently--on every orbit.

More complex rhythms will be combined to form new biological rhythms for the inhabitants of an interplanetary spaceship, since the spaceship will find itself in zones of constantly changing cosmic phenomena during flight. The effect of stress factors on the time structure is important for space biology and medicine. The complexity comes from the fact that time conditions will be different from those in the geosphere. Along with the timers that are known on earth, new ones can appear in space: gravitation, ionization, and the action of magnetic fields.

When unfavorable factors act on the organism or when pathological processes occur, one of the early manifestations of disorders as a rule is the phase shift of one of the daily rhythms.

We have established in particular that the greatest resistance of animals against acute oxygen starvation is observed in the morning hours, and the least is at night time. The evaluation of the complex time regulation of various rhythmic biological processes must consider the fact that the social-biological essence of man has fundamentally new time regulation qualities.

The choice of the Pushchin fungus as the subject of the biological experiment was conditioned by the fact that this fungus is especially sensitive to daily changes in the surroundings. It changes its zone formation rhythm, for example, as a function of changes in the light, the tmperature, the culture medium, etc.

To conduct the experiment, cultures of the fungus were synchronized with the circadian rhythms that exist at various points of the Soviet Union and the United States with a half-phase shift in the culture cycle. At the time of the experimental Soyuz-Apollo flight, two devices with fungus cultures were installed in the living cabin of each spaceship. During the flight, one of the fungus culture devices was taken from the Appolo to the Soyuz and replaced by another fungus device from the Soyuz. The spaceship crews photographed the fungus culture growth periodically at various times in a 24 hour period. The growth was manifested by the change in the process of zone formation (a ring-shaped type of zone, similar to the rings on a tree cut). The heavy nuclear particles were counted by special indicators that were placed in the devices with the fungus cultures.

There is reason to assume that this experiment will allow a better understanding of the nature of the changes that arise in biological subjects under the effect of space flight conditions, mainly weightlessness.

This experiment will allow a more in-depth evaluation of the physiological mechanisms of the effect of space flight conditions on the behavior of the basic vital functions and in particular on the biological rhythms that control the growth of cells and the periodicity of their functioning and multiplication. All this will make it possible to obtain additional data on the role of various factors in the formation and behavior of biological rhythms.

The results of investigations, conducted in the USSR and the United States on the orbital stations "Salyut" and "Skylab" made a great contribution to the development of the medical-biological space flight problems. It is known that providing man safety, health, and working capacity is an important condition in acclimating him to new surroundings.

Three stations were sent into near-earth orbit by the Soviet Union from 1971 to 1975. Nine men worked aboard these stations. The manned flight of the spaceship "Soyuz-11" and the orbital station "Salyut-1" (G. T. Dobrovol'skiy crew commander, V. N. Volkov flight engineer, and V. I. Patsayev research engineer) lasted about 24 days. The length of the manned flight of the spaceship "Soyuz-14" and the orbital station "Salyut-3" (P. R. Popovich crew commander and Yu. P. Artyukhin flight engineer) was about 16 days. The length of the flight of the spaceship "Soyuz-17" and the orbital station "Salyut-4" (A. A. Gubarev crew commander and G. M. Grechko flight engineer) extended almost 30 days.

And, finally, the longest flight in the history of domestic astronautics, the 63-day manned flight of the second expedition in the orbital station "Salyut-4" -- P. I. Klimuk commander and V. I. Sevast'yanov flight engineer -- was completed on June 26, 1975.

Along with the traditional problems of controlling the state of the cosmonauts' health, the problem of controlling the state of their physiological systems and working capacity arose during the flight of the second expedition in the "Salyut-4" orbital station.

The radiation conditions were favorable at the time of the flight. The gaseous medium of the living quarters in the "Salyut-4" station was equivalent to earth's. The total pressure was 735-811 mm Hg, pO_2 was 175-235 mm Hg, pCO_2 was up to 10 mm Hg, and the air temperature was 18-25°. The food value of the daily rations was almost 3,000 cal. The average daily water requirement for each cosmonaut increased gradually during the flight.

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The work and rest schedule provided for 8 hours of professional activity and 8 hours of sleep. Roughly 2.5 hours was provided for physical conditioning and another 2.5 hours for eating. The rest was personal time. The onboard daily cycle was roughly 23-24 minutes shorter than the earth's because of the orbital precession. Thus the schedule of work and rest, of sleep and being awake migrated every day. So at the end of the 63-day flight of the second expedition on the "Salyut-4" station the shift was almost 24 hours. Both the Soviet cosmonauts and the American astronauts were observed under the action of weightlessness to have a similar perception of the new living surroundings and the same signs and symptoms that arise under these conditions. As a rule, the differences reduced to the time for the onset, the degree of the manifestation, and the means of description of the same phenomena.

The cosmonauts' transition to weightlessness was accompanied by the appearance of short-term sensations of being upside down and the feeling of being torn from the seat, the feeling of heaviness in the head and a feebly marked vestibular discomfort, the sensation of blood rushing to the head, edema in the face, and stuffiness in the nose. A strange feeling of coldness and talking through the nose occurred in the initial flight period. One of the specific impressions from being in "the wonderful land of weightlessness" is the strange pose that the cosmonaut's body takes in weightlessness. The first American astronaut-physician Joe Kerwin, who was part of the first crew on the Skylab orbiting station, noted that every time the muscles are relaxed in weightlessness, the astronaut's body takes on a pose "with raised shoulders, while he feels that he is taller than he really is, his arms are pulled forward, and the knees are bent.... Fluid runs from your legs. You look at your colleagues and see that their legs have become smaller and thinner like wartcress, and you clearly recognize that you are undergoing physiological changes."[1]

In the cosmonauts' opinion, the initial adaptation period is over by the end of the first week. As Klimuk showed, the organism remembers the weightlessness and knows the way it is necessary to go in order to adapt. It was impossible to determine which way to turn with the eyes closed under weightless conditions. Orientation relative to the ship's coordinates was based only on visual reference points. In the cosmonauts' opinion, the vestibular organs do not play a significant role in orientation in weightlessness. Everything is done by the visual analyzer. During the second expedition of the "Salyut-4" orbital station, the length of sleep was 5-6 hours per daily cycle in the initial period of the flight, but working capacity was not reduced (the average sleeping time was 7-8 hours per daily cycle for the whole flight. Drowsiness was observed in the morning hours. Possibly this was one of the manifestations of the desynchronization that is related to the migration of the daily cycle for the cosmonauts aboard the orbital station.

The periodicity of the body temperature and pulse rate of the cosmonauts was studied on the 37th day of the flight. Analysis of the results showed that in this period the cosmonauts developed a rather clearly expressed daily periodicity in the heart beat frequency and the body temperature, that was characterized by a high correlation with earth-bound data. All this is evidence of the fact that the physical systems of the organism had adjusted themselves to the new assigned schedule of work and rest, i.e. they had adapted themselves to the migration of the daily cycle. There is reason to assume that the rigid temporary program of work and rest, the strict maintenance of the time for communication sessions and for eating, etc. all had an important significance in the readjustment of the rhythm. The crew's working capacity was rather high for the whole duration of the flight.

A functional test with a physical load on a bicycle dynamometer during the flight cased the cosmonauts to have an adequate reaction with respect to the cardiovascular system.

One of the basic reasons for the observed slight reduction the orthostatic stability during the flight probably was the lowering of the venous tonus as a result of the deconditioning of its regulation mechanism in the absence of the hydrostatic pressure of the blood.

Lowering the physical load on the muscles decreases the role of the "muscular pump" in the blood circulation. Studies of the muscular system by measuring the perimeters of various regions of the extremities showed that Klimuk had lost 5 cm in the perimeter of the thigh and 3-4 cm in the perimeter of the shin by the end of the flight, while Sevast'yanov had no significant observable changes.

After the end of the flight and the landing, the cosmonauts were observed to be fatigued. The cosmonauts' basic sensation in this period was the apparent weight increase in the body itself and of surrounding objects. A feeble ache in the muscles of the lower extremities and the spine was also noticed. These sensations gradually weakened and disappeared completely after 3-4 days. A change in the coordination of movements and some vegetovascular instability were noticed immediately after the landing. Klimuk had a weight loss of 3.8 kg and Sevast'yanov lost 1.9 kg. The weight was restored quickly. A lowering of the quantity of erythrocytes, hemoglobin, and eosinophiles was noticed in the blood. Monocytosis, neutrophilic leukocytosis, and an increase in the albumin content with a simultaneous decrease in the globulins were observed. The concentrations of pyroracemic and lactic acids, of 11-oxycorticosterioids, and of noradrenaline were observed to have increased in the blood. The urea concentration was lowered and the inorganic phosphorus concentration was increased. The data on the hormonal change point to an increase in the gluco-corticoid function of the adrenal glands and a decrease in its androgenic function. However, an analysis of these results shows that the 63-day flight had no significant effect on the metabolism indices that were investigated.

It should be noted that significant biochemical changes were observed in the Skylab program space flights, namely: an increase in the loss of sodium, nitrogen, potassium, calcium, and phosphorus; an increase in the secretion of aldosterone in the urine; diuresis and loss of liquid; and also an increased secretion of angiotonin. Losses of muscle mass and a decrease in the bone tissue density were observed. A small but certain negative balance (loss) of calcium was observed during the course of all the missions of the Skylab program, especially in the 34-day flight. The increased content of oxyproline in the urine, of the parathyroid hormone in the serum, and of calcium and phosphorus in the blood points to a decreased density of the bone matrix. There is interest in further investigations of the effects of the long-term action of weightlessness on the calcium balance and in studying the calcium metabolism in the state of weightlessness.

The action of the complex factors of space flight on the organism makes it extremely difficult to determine the specific significance and role of separate flight factors on the total reaction of the organism.

Besides weightlessness and a changed daily rhythm,* the cosmonauts were also subjected to the effect of nervous and emotional stress, which forced the organism to react to various levels of nervous and humoral regulation, with its multicomponent manifestations on the part of the somatic and autonomic sphere and of the endocrine system. A more significant effect on the organism is the nervous and emotional stress that occurred in the period of getting the spaceship into orbit, the docking of the ship with the orbital station, in fulfilling some of the demanding dynamic operations, and the preparations for the descent and return to earth. The absence of strain and mechanical stress on the body structure, which takes place on earth, leads to a functional unloading of separate physiological systems of the organism under weightless conditions and is manifested in the form of a changed afferentation from the mechanoreceptors, a changed distribution of fluids in connection with the absence of hydrostatic pressure, and a lowering of the load on the support and motor organs and on the tonic musculature.

The indirect effects of weightlessness are related to the unusual conditions of the working activity, rest and living, and also to the lowered muscular activity.

Developing working habits and the required movement coordination under weightless conditions is related to a significant rearrangement of a combined and consolidated dynamic stereotype and requires a definite time for a stable adaptation. A relative stabilization of the organism's physiological reactions sets in after 4-6 weeks in flight under weightless conditions.

* [i.e. about 23 minutes less than 24 hours per "day."]

The character of the organism's readaptation after a long flight depends to a large degree on the effectiveness of the application of onboard prophylactic measures

Medical studies, that were carried out at the time of the flight of the second "Salyut-4" expedition, showed that the in-flight schedule of work, rest, and a developed complex of prophylactic measures provided for the maintenance of a good state of health and a high working capacity during the flight and in the readaptiation process. The successful completion of a program of medical-biological studies in the Salyut and Skylab orbital stations is evidence of the fact that a new era has arrived in the mastery of space. The successes that were attained offer a firm scientific foundation and open a wide vista for realizing the most daring plans.

Even at the dawn of the 20th century, when only a few believed that man would ever fly in space at all, the thoughts of K. E. Tsiolovskiy were rushing far ahead, to the time when the cosmos would cease to be a hostile element for man, when he would learn to create "oases of life," cosmic cities, in space. "Little by little, man will make his abode in the ether. He will surround the sun, and the wealth of the people will increase a billion times."[2]

There it is, mankind's cosmic future, in its concise businesslike outlines.

The manned earth satellite is the first-born of the "ethereal settlements." Journeys through the solar system and reaching the asteroids--"the foundation and building material"--[will occur]. [There will be] use of solar energy on the widest scale and the development of "industry in the ether."

How can the words "industry in the ether" be understood? How can we relate to them in the epoch of prolonged space journeys? Here is what Tsiolkovskiy wrote about this: "Industry in the ether will come to flourish with inconceivable magnificence, and the construction of the largest structures will be completed easily and rapidly."

Whole settlements will arise in space; "homes" of steel and glass will appear. Each dwelling will be separated into compartments. The sun's rays will penetrate through glass walls into the living quarters and into green houses. The recycling of matter will be similar to that on earth: plants will clean the air and will give fruit and pure oxygen in return. The sun will heat the dwellings and will drive the power plants. And, finally, the sun will set the living quarters in motion by its radiation pressure and transform them into a controlled spaceship. They will be able to transfer from one orbit to another to travel in the solar system.

One can argue about the order--first the planets, then interplanetary space, or visa versa. Tsiolkovskiy expressed a preference for the second and thought that first people would create artificial cosmic settlements, would come to master the sun's energies, and would utilize the asteroids.

We will examine some current projections that have arisen in the epoch of the scientific and technical revolution in our cosmic era. Only a few years after the launch of the first artificial earth satellite, the famous aircraft designer D. Romik presented a plan for a prefabricated construction for a cosmic city of 20,000 inhabitants.

But perhaps the plan for colonizing interplanetary space, presented by J. O'Neil, professor of physics at Princeton University, is even more fascinating and alluring. In order to escape from the crises of overpopulation and scarce resources, he proposed to resettle part of the earth's population in space near the moon, on the extensive inner surfaces of gigantic aluminum cylinders, where there would be no shortage of free land and pure air and water. These cosmic dwellings would be placed at the Lagrange points, where there are stable conditions of "gravitational cancellation." By the end of the current century in his opinion, a million people would be able to live under natural sunlight, a normal atmosphere, and excellent controlled climatic conditions, in valleys among meadows, groves, fields, rivers, lakes, birds, and animals under conditions of complete freedom from environmental pollution. This idea was formulated in its most complete form from a practical scientific and technical viewpoint and was presented at the conference conducted at Princeton University on the subject "Space Settlements." It was determined that even at the current state of technical development it is possible to design a habitable space station in the form of a cylinder 1 km long and 100 meters in diameter, that would be ready by 1988 to support the existance of about 10,000 people. O'Neil felt that the cost of building the manned station would not exceed $20 billion, i.e. it would be similar to the cost of the Apollo program. The cost of subsequent structures would start to decrease rapidly.

In O'Neil's opinion, space settlements would grow fast enough, such that the earth's population, which will reach 8 billion people by 2020, will start to decrease and will level off at the "ideal" level (about 1.2 billion people). In roughly 100 years, more than 90% of the earth's population could live in comfortable cosmic settlements among an abundance and variety of food products and consumer goods.

Meanwhile, our still unique and very beautiful planet earth, the planet which has given the universe the first space explorer, will grow younger again and will become a beautiful place, where people will visit at vacation time. But what will happen next?

Tsiolkovskiy advanced a well-ordered, essentially materialistic, system of views on the cosmic future of mankind. "I believe in the brilliant future of mankind," he wrote, "I believe that mankind will not only inherit the earth, but will also transform the realm of the planets. Then, from the sun's sphere, man will start to settle the universe. Of this I am deeply convinced. This is the destiny of terrestrial man."

The progress of man's thought will make possible tomorrow what was impossible yesterday. Man has started his assault on the universe, and there will be no end to it, just as there is no end to the great universe in which man lives.

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