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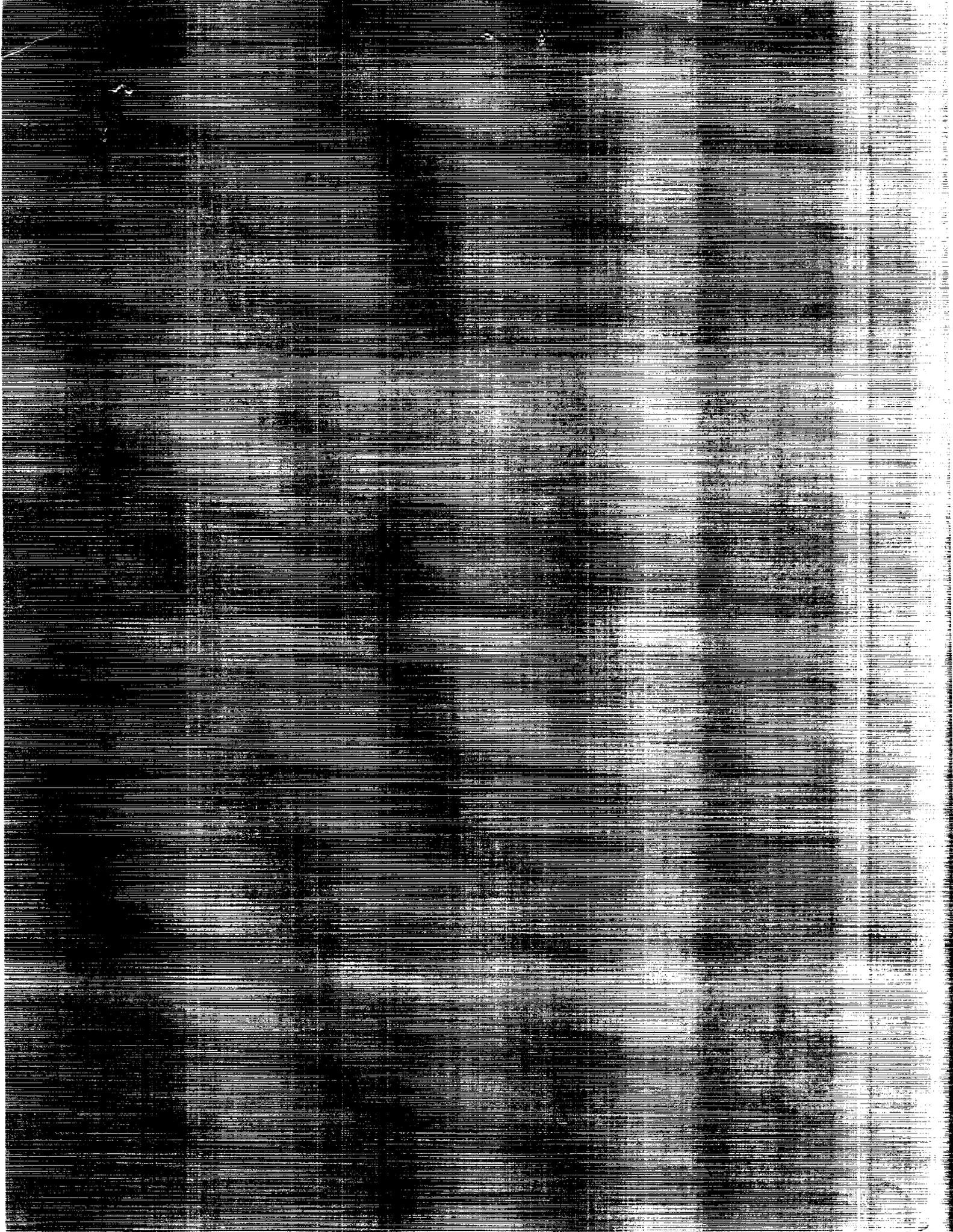
# USSR Space Life Sciences Digest

*Issue 29*

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# USSR Space Life Sciences Digest

*Issue 29*

*Edited by*

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*Washington, D.C.*

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Scientific and Technical  
Information Division

**1991**



## TABLE OF CONTENTS

<i>Reader Feedback Form</i>	<i>vi</i>
<i>Reader Survey</i>	<i>vii</i>
<i>From the Editors</i>	<i>ix</i>
ADAPTATION	1
Biochemical aspects of human adaptation to the combined effects of head-down tilt, decreased barometric pressure and increased level of O <sub>2</sub> .	1
Hygienic Evaluation of Microclimate. (Book Review)	2
AVIATION MEDICINE	4
The category of health as a theoretical problem in aerospace medicine.	4
BIOLOGICAL RHYTHMS	6
Association of annual biological rhythms in red blood counts in healthy individuals and annual rhythms of changes in solar activity.	6
BODY FLUIDS	7
A technique for individual assessment of the level of redistribution of blood in humans during the acute period of adaptation to weightlessness.	8
BOTANY	9
The significance of the force of gravity in formation and growth of callus tissue in <i>Arabidopsis</i> .	9
CARDIOVASCULAR AND RESPIRATORY SYSTEM	12
The phenomenon of adaptive stabilization of the structures and protection of the heart.	12
Stress and circulation in humans.	14
Characteristics of the effects of caffeine on circulation and oxygen tension in the brain of alert rabbits undergoing head-down tilt.	16
Types of hemodynamics in flight crews and their significance for clinical and flight certification practice.	17
Changes in hemodynamic parameters on long-term space flights.	19
Endurance of +G <sub>x</sub> acceleration in humans after a 370-day period of hypokinesia.	20
DEVELOPMENTAL BIOLOGY	22
Characteristics of limb and lens regeneration in tritons exposed to space flight.	22
The growth of oocytes of the Spanish triton in weightlessness.	24
DIGESTIVE SYSTEM	26
Digestion and Hypokinesia	26
ENDOCRINOLOGY	27
Hormonal regulators of calcium metabolism after space flights varying in duration.	27
Morphology of the thyroid gland and concentration of thyroid hormones in blood of rats in experiments on COSMOS-1667 and -1887 biosatellites.	28
Functional activity of the pituitary-thyroid system in response to a 370-day period of hypokinesia with head-down tilt.	31
Morphological changes in the ultimobranchial glands of caudate amphibians under conditions of space flight.	33
EQUIPMENT AND INSTRUMENTATION	34
State-of-the-art automated evaluation of functional state in cosmonautics and preventive medicine today.	34
GENETICS	36
Cytogenetic consequences of treatment with hyperbaric oxygen.	36

**USSR SPACE LIFE SCIENCES DIGEST  
TABLE OF CONTENTS**

**ISSUE 29**

HABITABILITY AND ENVIRONMENT EFFECTS	37
Habitability and man-rated bioregenerative life support systems	37
Handbook on Space Flight Safety	44
HEMATOLOGY	47
Changes in rheological parameters and hemodynamics in response to a 14-day period of hypokinesia with head-down tilt.	47
Rosette formation in peripheral blood of rats exposed to hypokinesia.	48
Results of hematological studies in long-term hypokinesia with head-down tilt.	50
HUMAN PERFORMANCE	51
The effect of various pharmacological agents on general state, heart rhythm , and performance efficiency of operators.	51
Predicting mental performance of cosmonauts on long-term flights.	52
A technique of semi-full-scale simulation and its use inflight to increase psychological readiness of cosmonauts.	54
IMMUNOLOGY	56
Proliferative, suppressor, and cytotoxic activity of splenocytes of rats in the experiment on COSMOS-2044.	56
LIFE SUPPORT SYSTEMS	58
A hygienic evaluation of certain moisture and carbon dioxide absorbers recommended for cleaning the air of pressurized environments	58
A methodology for evaluating and selecting a life support system during the initial stages of design	60
The higher plant component in man-rated biological (bioregenerative) life support system.	62
The effect of space flight on the sowing and productive properties of seeds.	65
MATHEMATICAL MODELING	67
A model of the caloric response of the semicircular canal.	67
METABOLISM	68
Hormonal and metabolic reactions of the human body to long-term fasting.	68
Parameters of thiamine metabolism in tissues of rats exposed to hypokinesia.	70
MUSCULOSKELETAL SYSTEM	71
The bone system of experimental animals under conditions of weightlessness: The effect of space flight on the skeleton of tortoises.	71
A computer tomographic investigation of the musculoskeletal system of the spine in humans after long-term space flight.	76
Morphohistochemical investigation of the skeletal muscles of rats in an experiment on biosatellite COSMOS-1887.	79
NEUROPHYSIOLOGY	83
Delta-sleep peptide as a modulator of cardiac activity: Theoretical recommendations for practice.	83
Nystagmus in individuals with asymmetrical afferentiation of the otoliths.	85
The role of glucocorticoids in postvibrational shifts of inhibitory mediation in brain structures.	86
Epidural and subdural recording of intracranial pressure in response to postural tests.	88
Assessment of autonomic homeostasis in the operational medical system for monitoring the health of cosmonauts.	89
The effect of weightlessness on eye movement responses.	91
Psychophysiological characteristics of people susceptible and resistant to motion sickness.	93

**USSR SPACE LIFE SCIENCES DIGEST**  
**TABLE OF CONTENTS**

**ISSUE 29**

<b>NUTRITION</b>		94
Hygienic aspects of the use of calorie-deficient diets enriched with wild plants.		94
<b>OPERATIONAL MEDICINE</b>		95
Prospects for improving pharmacological support of space flights.		95
Do we need a physician on the crew for the Mars mission?		96
<b>PERSONNEL SELECTION</b>		98
Some new approaches to the problem of medical occupational selection.		98
On psychological selection of cosmonauts for repeated flights.		100
<b>PSYCHOLOGY</b>		102
Risk factors for the occurrence of neuroses and psychosomatic illnesses in flight crews.		102
Psychological determinants of time to complete flight training.		104
Dynamics of parameters of communicative activity in the system for psychological analysis of cosmonaut functional status.		105
A multimethod evaluation of the psychophysiological state and behavior of humans undergoing a 370-day period of hypokinesia with head-down tilt.		106
The study of cosmonauts' sleep in flight on space station Mir.		108
<b>RADIOBIOLOGY</b>		110
The effects of low-frequency electromagnetic fields on physiological systems.		110
Study of changes in the electrical parameters of the skin of irradiated rats.		111
Research on audiogenic reactions of rats after ultraviolet-irradiation of their eyes.		112
Physiological properties of posture (balance) maintenance in dogs during immediate response to radiation.		113
The protective action of mexamine in microwave irradiation of rats.		114
<b>REPRODUCTIVE SYSTEM</b>		115
The effect of hypergravity on mammals during the period of delivery and birth of offspring.		115
<b>SPACE BIOLOGY AND MEDICINE</b>		116
Review of the major results of medical research during the flight of the second prime crew of the Mir Space Station.		116
Problems of Space Medicine and Biology. Biomedical Problems in the Support of Space Flight in Light of the Ideas of K.E. Tsiolkovskiy.		127
Ninth All-Union Conference on Space Biology and Medicine,		129
<b>ECONOMICS OF SPACE FLIGHT</b>		
Economics of Space Measured by Terrestrial Standards		138
<b>KEY WORD INDEX</b>		141

**USSR Space Life Sciences Digest: Issue 29 Reader Feedback Form**

To our readers: We are working in a large number of highly technical, specialized areas for which adequate Russian-English glossaries have yet to be compiled. We ask your help in improving the accuracy and specificity of our English terminology. Please fill out the form below whenever you encounter an incomprehensible, incongruous, awkward or otherwise inappropriate term. While we solicit all suggestions for improved renderings, the statement that a term is inappropriate provides us with useful information, even when no better alternative can be suggested. A copy of this form will appear in all future issues of the Digest. Thank you for your help.

Abstract Number rendering	Incorrect or inappropriate term	Suggested

**PLEASE RETURN TO: Dr. Lydia Stone  
Lockheed Engineering  
and Sciences Company  
600 Maryland Ave. SW  
Suite 600, East Wing  
Washington, DC 20024**

**USSR Space Life Sciences Digest**

**Reader Survey IVa**

We periodically send out a survey to assess how well the Digest meets reader needs and in what ways it might change to improve its performance. Please take the time to fill out this survey and return it to: Dr. Lydia Razran Stone/Lockheed Engineering and Sciences Corporation/ 600 Maryland Avenue SW, Suite 600/Washington, DC 20024. Of course you need not answer all questions and you are encouraged to add comments of your own.

Name: \_\_\_\_\_

Position/Organization: \_\_\_\_\_

Address: \_\_\_\_\_

Phone Number: \_\_\_\_\_

Major Research Interests: \_\_\_\_\_

Approximately how long have you been receiving the Digest? \_\_\_\_\_

Is the Digest your primary source of information about Soviet work related to your research interest(s)? \_\_\_\_\_

About Soviet work in other areas of space life sciences? \_\_\_\_\_

Please rate the following characteristics of the Digest according to the rating scale below:

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = very poor

Selection of material for relevance to space life sciences issues ( )

Presentation of relevant information from papers and other materials ( )

Technical terminology ( )

Overall readability ( )

I believe the Digest should give more coverage to (research area or type of material)

: \_\_\_\_\_

I believe the Digest should give less coverage to (research area or type of material):

\_\_\_\_\_

\_\_\_\_\_

Please check one:

In the last year or two, the overall quality and utility of the Digest have:

- generally improved (    )
- generally decreased (    )
- remained about the same (    )
- fluctuated erratically (    )
- other (    )
- unable to judge (    )

Please provide additional comments in the space below. We welcome your feedback!

## FROM THE EDITORS

This is a double issue of the Digest, covering material in issues 3 and 4 of the Soviet "Space Biology and Aerospace Medicine" [Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina] Journal for 1990. Of particular interest in this issue are a theoretical article on habitability and life support systems (page 37), an overview of medical results of the flight of the second Mir prime crew (page 116), and an inflight interview with Mir cosmonauts on the economics of the Soviet space program (138).

Scientists acting as technical reviewers for this issue are:

Dr. Gary Coulter	Dr. Ronald Dutcher	Dr. Mary Anne Frey
Dr. Victoria Garshnek	Dr. Lauren Leveton	Dr. Russell Rayman
Dr. Walter Schimmerling	Dr. John Uri	

Because the number of responses to the survey included in Digest Issue 28 was so small, we are reprinting it and again asking readers to take the time to complete and return it. Survey responses are our primary source of information on how to improve the Digest. We welcome negative as well as positive feedback.

**Issues 27 and 28 ERRATA:** Issue 27, abstract P1222, page 52, paragraph 2, should read "heel bone," not "head bone."

Issue 28, abstract P1280, page 55, paragraph 2, desquamation rate was found to increase, not decrease.

We would like to thank Drs. Laurence Young and Arnold Toback for pointing these errors out to us.

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### PAPER:

P1328(29/90)\*\* Balandina TN, Nikitin YeI, Kovalenko YeA, Savina VP.

***Biochemical aspects of human adaptation to the combined effects of head-down tilt, decreased barometric pressure and increased level of O<sub>2</sub>.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 56-57; 1990.

[5 references; 1 in English]

Biochemistry, Metabolism, Lipid Peroxidation; Hematology, Erythrocytes  
Humans, Males

Adaptation, Head-Down Tilt, Low Barometric Pressure, Hyperoxia, Exercise

**Abstract:** Seven male subjects were placed in a barochamber and exposed to 100% oxygen for 25 minutes. Then in a position of -8° head-down tilt at 100% oxygenation, they were "raised" to an altitude of 7100 m. These conditions were maintained for 5 hours. Temperature was maintained at 37°C. In some conditions subjects engaged in physical exercise either during hours 1, 3, and 5 in the barochamber for 5 minute sessions or during hour 5 of confinement for 25 minutes. Venous blood was taken before ascent, after 25 minutes of desaturation with 100% oxygen before ascent and during the first 15 minutes after subjects left the barochamber. Blood parameters measured included: malonic dialdehyde, a secondary product of self-induced lipid peroxidation; activity of the erythrocyte catalase neutralizing the negative effects of endogenous peroxides; resistance of the erythrocyte membrane to exogenous peroxides (an indirect indicator of the level of self-induced lipid peroxidation in the cell); and total number of erythrocytes (as an indicator of the hemolytic effects of the hydroperoxides formed).

In the first condition, without exercise, increased activity of catalase indicated activation of the protective antioxidant system. This in turn led to decreased formation of products of self-induced lipid peroxidation including, malonic dialdehyde. In the second condition, in which subjects engaged in three short periods of physical exercise, changes were in the opposite direction and did not differ significantly from preflight values. Erythrocyte hemolysis (which increased in the first condition) normalized when exercise was added. Exercise also stabilized the structure of the erythrocyte membrane. When more prolonged exercise was added to this paradigm there were only minimal changes in all parameters, and hemolysis did not increase.

The authors conclude that, in the absence of exercise, the combined conditions studied strained erythrocyte metabolism and lead to compensatory reactions. Exercise on two different schedules prevented disruption of metabolic equilibrium in the cell.

Table 1: Dynamics of biochemical parameters during exercise (600 kg/m for 5 minutes in hours 1, 3, and 5) and exposure to barochamber in a head-down tilt position with partial oxygen pressure of 300 mm Hg, temperature of 37°C and altitude equivalent of 7100 m

Table 2: Dynamics of biochemical parameters during exercise (600 kg/m for 25 minutes in hour 5) and exposure to barochamber in a head-down tilt position with partial oxygen pressure of 300 mm Hg, temperature of 37°C, and altitude equivalent of 7100 m

**BOOK REVIEW:**

BR18(29/90) A.A. Azhayev.

Review of G.N. Novozhilov, O.P. Lomov. *Hygienic Evaluation of Microclimate.*

Leningrad: Meditsina: 1987; 112 pages.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 63; 1990.

**KEY WORDS:** Adaptation, Microclimate, Heat, Human Performance, Industrial Hygiene, Countermeasures, Endocrinology, Metabolism, Mineral Metabolism

Review: This book by Novozhilov and Lomov is devoted to the physiological/hygienic issues of human acclimatization to hot climatic conditions, techniques for integral evaluation of the microclimate in industrial settings, and incidence of disease and level of performance in hot environments. The authors present experimental material on the principal mechanisms of human adaptation to adverse microclimates and use these data to derive a rationale for measures to prevent disease and improve performance.

The first chapter demonstrates convincingly that basing evaluation of microclimate in industrial settings on separate meteorological parameters does not always provide a complete picture of the thermal effects of the environment on humans. In this connection, the authors propose to use composite indicators such as are extensively used in the West. The authors validated integral microclimate parameters in their research, performed in areas with hot climates, and established a range for their potential use.

In chapter 2, the methodology of contemporary adaptation theory is considered. The concepts of adaptation held by leading physiologists, practitioners of hygiene, and pathophysiologists are presented. On the basis of their experimental research, the authors propose to distinguish several stages of adaptation on the basis of status of homeostatic reactions. They believe that the decisive factor in human thermal adaptation is the development of the capacity to maintain thermal equilibrium. The role of thermal regulation and perspiration as the principal mechanisms of physiological adaptation to high temperature are considered in this light.

Detailed material is presented on the effects of overheating on the endocrine system and mineral metabolism. The data obtained by the authors clearly attests to the role of the endocrine system and mineral metabolism in human adaptation to hot climates.

The issues treated in most detail in this book are those of performance and incidence of disease under high temperature conditions. By systematizing their own data and those in the literature, the authors have developed a conceptual model that predicts the probability of occurrence of adverse effects of heat as a function of meteorological conditions and duration of exposure to heat.

The material in chapter 5, devoted to the issue of preadaptation to heat, is original and innovative. The authors offer a new technique to accelerate adaptation to hot climatic conditions, including the use of high temperatures and physical exercise. Their method of accelerated adaptation was tested in the preparation of sailors for cruises in the South Pacific. It was convincingly demonstrated that pre-adaptation to heat increases human performance during initial exposure to a tropical climate.

Novozhilov and Lomov's book is well written and illustrated. However, there are isolated problems with its structure. The title "Hygienic Evaluation of Microclimate" does not really reflect the contents: human adaptation to high temperatures, incidence of disease and

## ADAPTATION

performance under these conditions. The stages in the process of adaptation to high temperature are considered in chapter 2, but the stages of the adaptive reaction proposed by the authors are given at the end of the book.

In evaluating this book as a whole, one can say that it is scientifically innovative, timely, and of practical significance. The authors have demonstrated convincingly that methods using composite indicators to evaluate the microclimate of work settings should be used more extensively for physiological and hygienic research performed under various climatogeographic conditions.

This work will be of great interest to physiologists and practitioners of hygiene, and the methodological recommendations will be of practical use.

PAPERS:

P1294(29/90)\* Ponomarenko VA.

***The category of health as a theoretical problem in aerospace medicine.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3):17-23; 1990.

[15 references; none in English]

Aviation Medicine, Human Performance, Health, Prophylaxis

Humans, Flight Personnel; Research Program, Equipment and Instrumentation,  
Computer Systems

Extreme Factors, Countermeasures, Neurophysiology, Neurotransmitters, Nutrition,  
Drugs, Non-Traditional Medicine, Immunology, Psychology, Stress, Stress Protectors,  
Metabolism, Endocrinology

Abstract: The author suggests that the time is ripe for the creation of an integrated scientific approach to the problem of ensuring the health of flight personnel. This approach is to be based on recently developed methodologies of aviation medicine, characterized by the following:

— increased interdisciplinary linkages (psychophysiology—hygiene — psychology— information science— ergonomics), which would foster a view of health as an integral property of "health - performance-reliability" and "health-performance— efficiency" systems. This makes it possible to define the category of health not only from the medical point of view, but in light of processes such as instruction, training, and creation and utilization of man-machine systems;

— introduction of such innovations as information processing technology into research and the practice of medical and specialized support of health. The essence of this technology involves the incorporation of computer technology. not just to process and display data, but to create data bases, expert systems based on artificial intelligence, instructional and game programs, and finally, predictive models to be used in maintaining professional health at medical and technical levels;

— creation of automated adaptive systems for monitoring psychophysiological status of individuals during flights, the appropriateness of the state of the environment to the complexity of flight tasks, and changes in the information environment as a function of the dynamics of psychophysiological state, etc.

— the incorporation of the issue of health maintenance and the new field of rehabilitation medicine into aerospace medicine. The novelty of this approach involves the development not only of means of treatment, but of mechanisms for controlling the compensatory properties of the body by developing specific protective measures ranging from biological blockers to monitoring and correction of psychological processes and states;

— development of a new type of technique for creating systems to protect against occupational stress, including teaching methods to counteract interference of physiological and psychological factors with problem solving on the job.

The following research program is recommended to support the new approach:

1. Research on the role of hormones, neurotransmitters, oligopeptides, and other regulators and their mediators in the development of adaptive processes.
2. Study of endogenous stress protectors and stress-limiting mechanisms.

## AVIATION MEDICINE

3. Optimization of nutritional balance of the diet, using nutrients and drugs to increase tolerance.
4. Study of changes in regulation of metabolism during the development of extreme states and creation of techniques for correcting such changes.
5. Study of the role of humoral and local immunity in the development of occupational diseases and functional disorders.
6. Research on the potential use of means of treating and preventing illness in flight crews without loss of work time.
7. Development of methods of reflexotherapy (acupuncture and related methods), self-regulation (biofeedback), and other nontraditional methods of preventing and treating disease.
8. Development of means and methods for diagnosis, information retrieval, and expert systems for diagnosing and predicting level of occupational health.
9. Development of techniques for optimizing processes of instructional and job performance from a biological standpoint

Table 1: Effect of various flight factors on performance

Table 2: Occupational diseases in flight personnel and functional investigation of their properties, treatment, and prevention.

**PAPER:**

P1330(29/90)\*\* Komarov FI, Chirkova EN, Suslov LS, Klionskaya AG, Bobina LV, Makarova TB.

***Association of annual biological rhythms in red blood counts in healthy individuals and annual rhythms of changes in solar activity.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 60-62; 1990.

[11 references; none in English]

Biological Rhythms, Hematology, Red Blood Counts  
Humans, Males and Females  
Biospherics, Solar Activity

**Abstract:** Studies were performed from December 14, 1984 to December 27, 1985 during a phase of minimum solar activity. Participants were 15 healthy men, aged 19-25, in similar working and living conditions, and 12 healthy women, aged 24-50, living in a variety of conditions. Blood was taken from the finger of fasting subjects every Friday for the period of the study. Time course of red blood count was represented by 55 measurement points. Red blood count was made immediately after sampling and was expressed in absolute number of cells per liter of blood. Wolf number was also recorded for the same period. A special algorithm was developed to look for latent rhythms (biological and heliogeophysical) with the period unknown. Only rhythms differing from "noise" with confidence level of 95% were considered.

On the basis of mathematical analysis the authors conclude that a set of 11 biorhythms are responsible for the annual dynamics of red blood count in healthy individuals. Men's and women's biological rhythms in red blood count appeared to differ in a number of parameters, but also showed much commonality. It was concluded that the duration of the major periods in annual biorhythms of erythrocytes, leukocytes, and solar activity are the same. These periods also coincide with the "wave periods" of the solar system.

**Table:** Annual set of biorhythms in concentration of erythrocytes in the peripheral blood of healthy individuals, rhythms of change in solar activity and wave periods of the solar system

**Figure 1:** Annual dynamics and major biorhythms in concentrations of erythrocytes in peripheral blood of subjects S (male) and B (female)

**Figure 2:** Percent of identification of annual biorhythms in a group of men and women

PAPERS:

P1338(29/90) Zavadovskiy AF, Korotayev MM, Vavakin YuN.

***Increasing human resistance to headward fluid redistribution.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 63.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Body Fluids, Headward Fluid Shifts, Cardiovascular and Respiratory Systems, Cerebral Hemodynamics

Humans, Age Differences, Patients, Atherosclerosis

Countermeasures, Head-Down Tilt, Repeated Exposure

Abstract: The goal of this work was to study the potential for increasing human resistance to hydrodynamic redistribution of blood in the cranial direction. As a model for inducing fluid redistribution to the upper body, we used a head-down tilt position on a tilt table at an angle of  $-30^\circ$  for 20 minutes. A total of 50 subjects aged 30-46, and 10 aged 50-56 with symptoms of arteriosclerosis of the brain participated. During the test we studied parameters of cerebral hemodynamics using the method of impedance plethysmography and also parameters of intracranial cerebrospinal fluid pressure using echoencephalography.

When subjects in both age groups were retested after a cycle of repeated head-down tilt on the tilt table, they showed significantly less rush of blood to the head and outflow from the vessels of the legs, and a decrease in parameters of pulsed blood filling of the vessels of the basin of the internal carotid artery and vertebrobasilar system. Decreased severity of changes in pressure of cerebrospinal fluid within the skull were also observed. Intracranial circulation of blood and cerebrospinal fluid changed as both arterial and venous tonus in the brain increased, leading to stabilization of blood flow in the brain at a minimal level of intracranial hyperemia.

Thus, repeated exposure to head-down tilt induces development of adaptive responses preventing excessive fluid redistribution in the cranial direction, normalizes hemogravitational shifts, and may be used to increase tolerance of this position in individuals of middle age and older (up to 56).

## BODY FLUIDS

P1331(29/90) Abashev VYu, Andriyako LYa, Bubeyev YuA, Degtyarev VA, Remisov YuV.  
***A technique for individual assessment of the level of redistribution of blood in humans during the acute period of adaptation to weightlessness.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 5-6.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Body Fluids, Fluid Redistribution, Cardiovascular and Respiratory Systems  
Humans, Males  
Assessment Technique, Tilt Test, Composite Index

Abstract: Despite the success of space medicine in the area of developing prophylactic countermeasures for preparing cosmonauts for flight, the inability of many cosmonauts to work during the first hours and days of flight could threaten completion of the flight mission. One of the major reasons for their state is the redistribution of blood and body fluids in the cranial direction. There has not been enough study of this phenomenon under actual flight conditions to enable adequate curtailment of the shifts or prediction of the efficacy of prophylactic countermeasures as a function of severity of the fluid shifts in a given individual.

The goal of our research involved development of a technique for evaluating the distribution of blood in the body of a given individual, on the basis of use of ordinary medical monitoring parameters. The research was performed on 32 men. As a standard method, we used the method of radiotracer  $\gamma$ -radiometry. Because of the absence of quantitative data on fluid redistribution under conditions of weightlessness, hemodynamic parameters were measured at body angles ranging from +70 to -50°, making it possible to reproduce virtually the entire physiologically possible range of blood redistribution.

It was shown that, of the parameters considered (EKG; venous-arterial pulsogram; and impedance plethysmogram of the head, chest, and legs), those with the greatest taxonomic values for evaluating level of blood filling were the venous-arterial pulsogram of the vasculature of the neck and an impedance rheoencephalogram.

However, since none of the parameters was universal enough, we recommended the use of an composite index called "equivalent angle." This term refers to the level of distribution of blood in the human body corresponding to an angle of inclination during performance of postural (tilt) tests at normal g. The error of estimate of the level of distribution of blood using this parameter did not exceed 5% compared to the standard method. The criterion proposed was tested under actual flight conditions.

## PAPERS:

P1292(29/90) Laurinavichyus RS, Kenstavichene PF.

***The significance of the force of gravity in formation and growth of callus tissue in Arabidopsis.***

In: M164(29/90) Flom TV (editor)

Trudy XXIII Chteniy Posvyashchennykh Razrabotke Nauchnogo Naslediya i Razvitiyu Idey K.E.

Tsiolkovskogo: Sektsiya "Problemy Kosmicheskoy Meditsiny i Biologii" Mediko-Biologicheskiye Problemy Obespecheniya Kosmicheskikh Poletov v Svete Idey K.E.

Tsiolkosvskogo

Труды XXIII Чтений Посвященных Разработке Научного Наследия и Развитию Идей К.Э.

Циолковского: Секция «Проблемы Космической Медицины и Биологии» Медико-Биологические Проблемы Обеспечения Космических Полетов в Свете Идеи К.Э. Циолковского

Proceedings of the XXIII Lecture Series Devoted to Developing the Scientific Ideas of

K.E.Tsiolkovskiy: Section on "Problems of Space Medicine and Biology. Biomedical Problems in the Support of Space Flight in Light of the Ideas of K.E. Tsiolkovskiy.

Kaluga 13-16, September 1988.

USSR Academy of Sciences: 1989: 98 pages.

Affiliation: Commission on Development of the Scientific Heritage of K.E. Tsiolkovskiy, USSR Academy of Sciences; K.E. Tsiolkovskiy State Museum on the History of Cosmonautics

Pages 65-70.

[6 references; 3 in English]

Morphology, Cytology, Plant Tissue Culture, Callus Tissue, Dedifferentiation, Developmental Biology

Botany, *Arabidopsis*

Space Flight, Salyut-7, Weightlessness Simulation, Horizontal Clinostatting

Abstract: It has been suggested that cultures of plant tissues are promising for use to study the effects of gravity on individual fundamental processes such as morphogenesis, cell division, and differentiation. In such cultures, the balance of phytohormones may be manipulated to induce processes of dedifferentiation, and differentiation, embryogenesis, and organogenesis. To test the potential of such models, experiments were performed using cultures of callus tissue of *Arabidopsis thaliana* under conditions of simulated weightlessness using horizontal clinostatting and in space on board Salyut-7. The role played by gravity in the process of formation and growth of nondifferentiated callus tissue from differentiated seedling tissues was investigated through analysis of cytomorphological parameters.

To obtain callus, sterilized *arabidopsis* seeds were sown on a 1% agar nutritive medium. The process of germination and callus generation began in weightlessness when the cosmonauts sowed the seeds, thus excluding the possibility of gravitational induction. The two clinostatted (horizontal and vertical) groups of seeds and the flight seeds were grown in darkness at a temperature of 26°C. The clinostatting treatment lasted 6 weeks, and the space flight conditions 9 weeks. The callus was then treated with Carnoy's fixative. Microscopic sections of the callus were stained and an image analysis system was used to determine the area of the cells and nuclei, the nucleus:cytoplasm ratio, the frequency of occurrence of meristematic centers, starch-containing cells, and components of the vascular system. Mitotic index was also determined. The data were processed statistically.

Callus formation, which began when the seeds were introduced into the medium, was 100% for both the control and flight conditions. There was no statistically significant difference between the control and experimental conditions with respect to wet biomass. However, there were clear differences in the morphology of the calluses developing in space and on the ground. The former were spherical while the latter were oblate in shape. The callus tissue differed in

weight and consistency. In the control they were loose and soft, while in the space condition they were denser and harder.

The early stages of callus growth are accompanied by many cell divisions followed by lengthening. Since these processes are asynchronous, the cell population soon becomes heterogeneous in shape, size, and histological characteristics. The primary mass of callus tissue of *arabidopsis* contains small- and medium-sized cells. However, other cellular and histological formations of various origins also occur.

Frequently xylem occurs in the callus mass, with its relative concentration decreasing as the callus cells increase in mass. Many forms of plant callus contain cells filled with starch, which may be characteristic of small actively dividing cells — the basis for young, actively growing callus. Both clinostatting and microgravity led to a decrease in the number cells containing starch grains.

The number of meristematic centers (small actively dividing cells surrounded by a ring of larger vacuolized cells) decreased significantly in space compared to control conditions. This is related to the decrease in the proliferative activity of callus cells in space.

The use of high technology equipment to make morphometric measurements of large amounts of data made it possible to quantitatively assess callus growth. Exposure to space was associated with a significant decrease in cell area, while horizontal clinostatting on the ground led to decrease in area of both cells and nuclei and a decrease in the nucleus:cytoplasm ratio. In the clinostatting conditions, small cells were more common and large cells less common. In space the frequency of two classes of small cells was 2-3 times as great as in the control, and all classes of large cells were less frequent.

The authors conclude that weightlessness or its simulation (horizontal clinostatting) did not exclude the possibility of dedifferentiation of cells but did have a significant effect on cytomorphological characteristics of the cell populations forming the callus tissue. The most probable mechanism through which the force of gravity interacts with physiological processes responsible for proliferation and growth is transport of substances in the nutritive medium-callus tissue system. However, gravity might also directly affect callus cell growth.

Table 1: Quantity of cyto- and histological formation in callus tissue as a function of altered gravity quantity per 100 microscopic fields

Parameters	Control	Horizontal clinostatting	Vertical clinostatting	Control	Space Flight
Xylem elements	10	16	10	5	7
Starch-containing cells	92	63	58	57	29
Meristematic centers	38	52	23	13	1

Table 2: Mitotic activity of cells of callus tissues of *Arabidopsis* as a function of gravity

Condition	Number of cells observed	Mitotic Index, %
Control	1457	7.98±0.31
Horizontal clinostatting	2023	5.70±0.49*
Vertical clinostatting	1755	7.27±0.29
Control	6585	8.12±0.20
Space flight	7441	3.48±0.16*

\*Difference statistically significant, with  $p < 0.05$

Table 3: Mean area of cells and nuclei of callus as a function of growth under conditions of altered gravity

Condition	n	Area (standard units)		Nucleus-plasma ratio
		cell	nucleus	
Control	1793	2068.2±23.1	346.8±4.6	0.155±0.002
Horizontal clin.	1584	1814.7±21.7*	177.1±2.9*	0.102±0.001*
Vertical clin.	2134	2017.2±21.6	314.5±4.1	0.175±0.003*
Control	21959	2327.3±11.2	253.5±6.2	0.126±0.002
Space flight	20075	1671.9±7.9*	223.7±6.2	0.128±0.001

\*Difference significant at  $p < 0.05$ .

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

### PAPERS:

P1296(29/90)\*Meyerson FZ.

***The phenomenon of adaptive stabilization of the structures and protection of the heart.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 28-35; 1990.

[57 references; 31 in English]

Cardiovascular and Respiratory Systems, Cardiac Structures, Protection

Rats, Isolated Hearts

Adaptation, Preadaptation, Stress, Immobilization, Ischemia, Reperfusion, Endocrinology,

Adrenergic System, Calcium

Abstract: The work described here addresses the extent to which adaptive protection of the heart from ischemic, reperfusion, and adrenergic damage depends on central mechanisms and the extent to which it is determined by mechanisms occurring in the heart itself. The research reviewed investigated isolated hearts of animals preadapted to stress to see if the cardioprotective effects of such adaptation would be realized when the effects of neural and humoral factors were eliminated or limited. Preadaptation was achieved by subjecting rats to immobilization on their backs for increasing periods of time each day (first exposure was 15 minutes, last exposure 60). Experiments performed on isolated hearts contracting in an isotonic regime showed that reperfusion occurring after a 20-minute period of ligation of the left coronary artery induced significant arrhythmia in hearts of untreated animals. In animals preadapted to stress, duration of arrhythmia was half that of controls. Another experiment showed that adaptation sharply limited depression of amplitude of contractions and decreased extent of contracture in reperfusion after 15 minutes of complete ischemia. Resistance to excess catecholamines was also enhanced in isolated hearts by preadaptation.

Cardiac damage resulting from adrenergic and reperfusion exposure is due substantially to excess  $Ca^{++}$  in cardiomyocytes. Thus it was logical to test resistance of isolated hearts of preadapted animals to the arrhythmogenic effects of high concentrations of  $Ca^{++}$ . To do this, the concentration of  $Ca^{++}$  in the perfusion solution was increased by a factor of 7.3. After 15-20 seconds, this treatment evoked ventricular extrasystoles in hearts of control animals. No such extrasystoles occurred in hearts of preadapted animals. Contracture effects of excess  $Ca^{++}$  in the perfusion solutions of isolated hearts were also attenuated for preadapted animals. These results were confirmed in studies of the bioelectric activity of cardiomyocytes. It was further discovered that a single 6-hour period of immobilization and preadaptation by repeated exposure to shorter (15 minutes - 1 hour) but increasing periods of immobilization had opposite effects on absorption of Ca by components of the sarcoplasmic reticulum (SPR). A single 6-hour period of immobilization depressed this process, while preadaptation activated it. As a result, if there are high concentrations of  $Ca^{++}$ , the rate with which the SPR of subjects previously undergoing a single long period of stress absorb  $Ca^{++}$  is depressed compared to control. In adapted animals, in contrast, absorption rate continues to increase at concentrations where the control group has levelled off. Thus, preliminary adaptation not only increases the capacity of the SPR cardiomyocytes to accumulate  $Ca^{++}$ , but protects the SPR membrane from the harmful effects of long-term immobilization stress. These results show that preadaptation to short term periods of stress increases the efficiency of the SPR  $Ca^{++}$ -pump and its resistance to stress damage.

To study the effect of adaptation on the SPR and  $Ca^{++}$ -pump, the authors studied dynamics of inactivation of this pump when it was exposed to temperature of 4°C. The parameter tracked

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

was accumulation of free  $\text{Ca}^{++}$  in homogenates of SPR and mitochondria. In the control condition concentration of free  $\text{Ca}^{++}$  increased by 62% above baseline after 3 days of cold exposure, and after immobilization stress the same parameter doubled. In preadapted animals under the same conditions level of  $\text{Ca}^{++}$  decreased by a factor of 2.5 and when preadapted animals were stressed after 4 days, calcium levels did not differ from baseline, suggesting radical improvements of the stability of the membrane structure.

An additional study examined the effect of preadaptation to stress and exposure to long-term stress on rate of oxygen utilization by suspensions of mitochondria processed with dinitrophenol and on rate of phosphorylation using succinate as a substrate. Protective effects of preadaptation were also found in these experiments, suggesting that this treatment induces stabilization of the structures of the sarcolemma, SPR, and mitochondria, all the basic components of a cardiomyocyte. Compensatory cardiac hyperfunction has been shown to prevent stress activation of reparative DNA synthesis.

Using special methods, the authors showed that given surgically induced myocardial infarction, preadaptation to stress had no effect on how much tissue was ischematized, but decreased amount of necrotic tissue by more than 40%, so that the necrotic portion of ischematized tissue was smaller than in the control. The effect of preadaptation was stronger than the effect of the  $\beta$ -blocker Inderal. The authors conclude that adaptation to stress does not have an anti-ischemic effect, but does have a strong cytoprotector effect, evidently due to adaptive stabilization of structure. They suggest genetic mechanisms of the phenomenon of adaptive stabilization should be studied.

Table 1: Compensatory hyperfunction of the heart prevents stress activation of reparative synthesis of DNA in cardiomyocyte nuclei

Table 2: The effect of preliminary adaptation to short-term stress and of the  $\beta$ -blocker Inderal on sizes of ischemic, recovery and necrotic areas in experimental myocardial infarction

Figure 1: The effects of adaptation to stress on amplitude of contraction, contracture, and output of creatine phosphokinase in isolated rat hearts during ischemia and reperfusion

Figure 2: The effects of adaptation to short term exposure to stress on action potential and contraction of the papillary muscles under combined exposure to high concentrations of  $\text{Ca}^{++}$  and altered stimulation frequency

Figure 3: The effects of long-term storage of homogenate of rate of  $\text{Ca}^{++}$  transport in the SPR

Figure 4: The effects of adaptation to stress and of long-term stress on rate of oxygen utilization by a suspension of the mitochondrion processed with dinitrophenol and on rate of phosphorylation with succinate as substrate

Figure 5: Hypothesized mechanism for stabilization of cellular structures in repeated exposure to stress

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1297(29/90)\* Fedorov BM, Sebekina TV, Sinitsyna TM, Streltsova YeN, Vakulenko VM, Nikolayeva TG.

### ***Stress and circulation in humans.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 35-40; 1990.

[36 references; 16 in English]

Cardiovascular and Respiratory Systems, Hemodynamics, General, Cerebral  
Humans, Males  
Human Performance, Mental Work, Stress, Hypokinesia

**Abstract:** This paper discusses a research program to study the effects of mental work and associated stress on the cardiovascular system. Studies utilized: healthy individuals under normal conditions of motor activity (group 1) and healthy individuals undergoing hypokinesia (group 2). Variables measured included major indicators of cardiac activity, the circulatory system, and regional circulation in the brain through simultaneous use of electrocardiography, tetrapolar impedance plethysmography of the torso, measurement of blood pressure, linear blood flow in the carotid and ophthalmic arteries, study of blood flow in the anastomoses of the branches of the exterior and interior carotid arteries in compression tests, impedance rheoencephalography, and measurement of blood flow in 30 zones of the grey matter of the cerebral cortex using  $^{133}\text{Xe}$ .

More than 100 healthy males, aged 25-45 years were studied. Stress was created using two types of mental tasks: 1) mental solution of two arithmetic and one linguistic problem with intervals between them and 2) continuous solution of arithmetic problems. All tasks were performed with subjects lying down. After a 30-second exposure of the problem, subjects closed their eyes and performed the solution silently.

Under conditions of mental stress occasioned by task performance, blood pressure increased, while heart rate, stroke volume, total peripheral resistance of vasculature of systemic circulation, and minute volume changed in different directions in different individuals. Changes were frequently in different directions in the same individual at different points in time. Three types of changes occurring during mental work were identified. In the first, heart rate increased, total peripheral resistance decreased, stroke volume and cardiac output increased, and blood pressure increased due to increased cardiac output. In the second type, heart rate increased, total peripheral resistance increased, stroke volume decreased, cardiac volume either decreased or remained the same, and increase in blood pressure was attributable to increased total peripheral resistance. In the third type, as duration of stress induced by the task increased, type 1 changes were replaced by type 2 changes. Initial decrease in peripheral resistance and increase in cardiac output were replaced by increased resistance and decreased (below baseline) output. In healthy subjects increase in heart rate and blood pressure were self-limited. When hypertension occurred, heart rate increases were replaced by relative slowing of heart rate to or even below baseline. This is attributed to triggering of depressor reflexes from baroreceptor zones.

When regulation of the circulatory system and associated depressor reflexes was disrupted through a 3-week exposure to hypokinesia, mental stress was associated with much greater increases in heart rate and blood pressure and greater persistence of changes. In subjects having normal motor activity circulatory parameters rapidly normalized after mental task performance was discontinued.

With respect to regional blood flow in the brain, performance of the tasks was accompanied by changes in blood flow in the internal carotid and ophthalmic arteries, changes in tonus of large

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

and medium sized arteries, increased total blood flow in the grey matter, and redistribution of blood flow in various zones of the cortex of both hemispheres.

The most characteristic changes during mental task performance involved increased regional blood flow in the supramarginal gyrus, and, to a lesser extent, in the angular gyrus and the parietooccipital areas of the left hemisphere, and in the upper frontal gyrus. In the majority of subjects, blood flow also increased in Broca's center and the upper temporal gyrus.

Task performance caused a sharp decrease in circulation in the anastomoses between branches of the external and internal carotid arteries. At the same time response to a compression test (occlusion of the facial artery) decreased sharply or disappeared. Impedance rheoencephalography showed that task performance was accompanied by increased tonus of large and mid-sized cerebral arteries, most likely resulting from increased rate of blood flow and increased number of perfused capillaries.

The authors interpret their results as showing a combination of emotional stress and mental concentration.

Figure 1: Diagram of location of electrodes on the surface of the head

Figure 2: Representative example of redistribution of regional blood flow in the grey matter of the left hemisphere of the brain during stressful mental work

Figure 3: The effects of stressful mental work on parameters of impedance plethysmography

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1307(29/90)\* Beketov AI, Konyayeva Yel.

***Characteristics of the effects of caffeine on circulation and oxygen tension in the brain of alert rabbits undergoing head-down tilt.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 64; 1990.

Cardiovascular and Respiratory Systems, Neurophysiology, Brain Circulation, Oxygen  
Circulation

Rabbits

Head-Down Tilt, Caffeine

Translation of abstract: The effects of caffeine in a dose of 20 mg/kg on measures of blood flow and  $pO_2$  in various regions of the cortex and the confluence of the sinuses of the brain were studied in experiments on alert rabbits with implanted electrodes, taking into account changes in blood pressure and heart rate. Changes in blood flow were studied using the hydrogen clearance method, and changes in  $pO_2$  were investigated using polarography. Three experiments were performed in which the effects of caffeine on rabbits were studied when injection of the drug occurred 10 minutes before and after shift into head-down position (angle of tilt =  $-45^\circ$ ). After injection of caffeine, head-down tilt was initially accompanied by changes of blood flow in different directions in different areas of the cortex, followed by increase in cerebral and decrease in total blood flow. Changes in blood flow and  $pO_2$  when rabbits were shifted into horizontal and head-down position were also a function of the time when caffeine was injected (before or after head-down tilt). The data obtained suggest that under conditions of head-down tilt, there is a substantial change in the response of the brain's blood supply system to caffeine.

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1323(29/90)\*\* Suvorov PM, Doroshev VG, Ivanchikov AP, Sidorova KA.

### ***Types of hemodynamics in flight crews and their significance for clinical and flight certification practice.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 44-48; 1990.

[18 references; 1 in English]

Cardiovascular and Respiratory Systems, Hemodynamics, Typology

Humans, Flight Crews, Patients, Neurocirculatory Asthenia, Myocardial Dystrophy, Myocardial Sclerosis, Essential Hypertension, Age Effects

Aviation Medicine

**Abstract:** A total of 293 flight personnel served as the experimental group for this study. An additional 49 healthy subjects in other professions served as controls. Parameters of central hemodynamics were recorded on an oscillograph. A tachyoscillogram of the brachial artery was also recorded, as were a sphygmogram of the radial artery and an EKG using three standard leads. Parameters were measured during the first part of the day at 1 and 10 minutes in a horizontal position and at 1, 10, and 20 minutes in upright (80°) tilt, and at minute 1 after the tilt test. The experimental group consisted of 40 pilots suffering from hypertonic neurocirculatory asthenia, 36 with myocardial dystrophy of metabolic or infectious origin with good functional capacity of the cardiovascular system, 26 with myocardial sclerosis without circulatory insufficiency, and 42 suffering from stage 1 essential hypertension.

In an additional study, hemodynamics were investigated at rest in 100 flight personnel aged 20 to 60 years, with normal blood pressure and a variety of health problems. The age group 20-35 contained, aside from healthy subjects, individuals with kidney stones, neurocirculatory asthenia, instability of the vascular autonomic system, and respiratory disease. The second age group (36-49 years), aside from healthy subjects, contained those with aortal atherosclerosis and other disease. In the oldest group (50 yrs and above), 2/3 of the subjects had been diagnosed with atherosclerosis. A number also had ischemic heart disease and stage 1 essential hypertension. Impedance plethysmograms were used to measure cardiac minute volume, cardiac index and stroke index. Energy consumed in moving blood; contraction strength of the left ventricle; and operational and actual specific peripheral resistance and their ratio; total peripheral resistance; heart rate; and systolic, lateral systolic, mean dynamic, diastolic and pulsed blood pressure were measured.

Hemodynamic types were identified using three criteria. In the first variant, the eukinetic type was defined as subjects with actual minute volume that was no more than  $\pm 15\%$  different from required minute volume. In the second variant this range was  $\pm 20\%$ , and in the third  $\pm 25\%$ . According to previous data, eukinetic types make up half a given age group, and hypo- and hyperkinetic types 25% each. It was found that the  $\pm 15\%$  range gave the best correspondence to this figure.

As age increased, the percentage of individuals with the hyperkinetic type of hemodynamics decreased and the number with hypo- and eukinetic increased. As age increased actual minute volume and contractile power of the left ventricle decreased, and energy required to move blood, mean dynamic blood pressure, and both types of specific peripheral resistance increased; however, required minute volume remained the same. This may be due to the weight gain and decrease in metabolism common as people age. Increase in number of subjects suffering from atherosclerosis is likely to be responsible for the increase in actual specific peripheral resistance and mean dynamic blood pressure and for the decrease in actual minute volume. Groups of flight personnel close in age but differing in the disease they suffered from did not show differences in relative numbers belonging to any of the hemodynamic types.

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

When 49 subjects representing all three hemodynamic types were subjected to a vertical tilt test, all types showed a decrease in cardiac index (most pronounced in hyperkinetic subjects), with an increase in peripheral resistance. However, cardiac index remained higher and peripheral resistance lower in hyperkinetic than hypokinetic individuals. In general each subject belonged to the same type in horizontal and in vertical positions. Data suggest that the main cause of essential hypertension is not change in hemodynamic type, but lack of correspondence between minute volume and overall peripheral resistance. No relationships were found between type of hemodynamic regulation and characteristics of EKG in an upright position in subjects who were healthy or suffered from myocardial dystrophy or myocardial sclerosis. However, EKG characteristics were related to state of health. In flight crews, type of hemodynamic regulation was not related to disqualification of flight personnel. The authors conclude that types of hemodynamics in flight personnel should all be considered normal variants, remaining stable under conditions of upright tilt and during work. Hemodynamic type can be used as an aid to differential diagnosis.

Table 1: Types of hemodynamics, determined using various methodologies

Table 2: Major parameters of hemodynamics in flight groups of various ages

Table 3: Hemodynamic types in flight personnel suffering from different diseases

Figure: Dynamics of parameters of circulation in a passive upright position in healthy individuals as a function of type of hemodynamic regulation

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1332(29/90) Alferov IV, Anashkin OD, Voronova OK, Poyedintsev GM.

***Changes in hemodynamic parameters on long-term space flights.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 8-9.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Cardiovascular and Respiratory Systems, Hemodynamic Parameters, Typology  
Humans, Males, Cosmonauts  
Space Flight, Repeated Flights

Abstract: We studied the reaction of the human cardiovascular system to space flights varying in duration. We used a mathematical method for diagnosing the state of the cardiovascular system, involving a set of new noninvasive methods for measuring hemodynamic parameters. We studied systolic activity of the left heart in cosmonauts under conditions of relative rest, pre-, in-, and postflight. We computed the values of stroke volume, cardiac output, and other hemodynamic parameters and also their deviation in- and postflight relative to mean preflight values.

Stroke volume in flight decreased by a mean of 12%, minute volume by 10%. Postflight the value of stroke volume remained below preflight but due to increased heart rate, cardiac output increased by 12%. Our analysis of individual differences revealed three types of response to space flight factors. Decrease in stroke volume occurred in 7, increase in 4, and reactions in different directions in 5 cosmonauts. When an individual flew more than once, responses on subsequent flights were more likely to involve decrease in these three parameters.

P1335(29/90) Vil'-Vil'yams IF, Kotovskaya AR, Kokova NI, Sukhanov YuV.

***Endurance of +Gx acceleration in humans after a 370-day period of hypokinesia.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 31-32.

NOTE: THIS IS THE TRANSLATION OF AN ABSTRACT. WE HAVE NO ADDITIONAL INFORMATION ABOUT THIS WORK.

Cardiovascular and Respiratory Systems, Acceleration Tolerance, +Gx  
Humans, Males

Hypokinesia With Head-Down Tilt, Long-Term, 360 Day, Countermeasures, Exercise

**Abstract:** Introduction. The development of cosmonautics poses the question of supporting long-duration space flights. To solve this problem it is important to elucidate how endurance to acceleration changes as duration of simulated weightlessness increases, and to determine the efficacy of prophylactic countermeasures under these circumstances.

**Method.** A total of 40 centrifugation trials were performed with 8 individuals. Subjects were exposed to acceleration of up to 8.3 g before and after hypokinesia with head-down tilt for 120, 240, or 360 days. The subjects were divided into two groups: A and B. Physical exercise and drugs to correct metabolism were utilized by group A subjects throughout hypokinesia. In addition, after 360 days of hypokinesia they utilized anti-g suits and fluid supplements. For the first 120 days of hypokinesia, group B used no prophylactic measures. Subsequent to this period they engaged in exercise and took metabolic drugs. On day 360, anti-g suits and fluid supplements were used.

**Results:** In the process of hypokinesia, endurance of acceleration was on the whole satisfactory for all subjects, although it decreased compared to baseline. After hypokinesia there was more likelihood of difficulty breathing, transient visual disturbances, extrasystolic arrhythmia, pallor, and hyperhydrosis of the skin, and multiple pinpoint hemorrhages. These phenomena were possibly related to deconditioning of the major physiological systems under conditions of simulated weightlessness.

The severity of physiological shifts occurring during acceleration at various times during the hypokinesia treatment differed in groups A and B. In group A, after 120 days of hypokinesia acceleration was subjectively harder to endure than during baseline and heart rate was 8% higher. Visual disturbance, pallor and hyperhydrosis of the skin, and multiple pinpoint hemorrhages occurred in 33, 100,[sic.] and 33% of the cases, respectively. After 240 and 360 days of hypokinesia with head-down tilt, frequency of these physiological changes under exposure to acceleration did not alter, while heart rate reached the level of baseline studies, which was probably associated with the positive effects of the prophylactic measures used. The results attest to the fact that in group A there were two phases of change in tolerance for acceleration in the process of hypokinesia with head-down tilt — a phase of decrease and a phase of relative stabilization at the previous level.

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

In group B, after 120 days of hypokinesia with head-down tilt, endurance of acceleration deteriorated noticeably. Visual disruptions, pallor, hyperhydrosis, and pinpoint hemorrhages occurred more frequently than in group A (in 80, 60, and 100%, of the cases, respectively). Compared to baseline, heart rate increased by 20%. The increase in stress on physiological systems under these conditions was probably due to the absence of prophylactic measures during the first 120 days of hypokinesia. After 240 days of hypokinesia with head-down tilt, these physiological disturbances, as a rule, were less common, occurring in 20, 20, and 60% of the cases, respectively, while heart rate decreased by 13%, and was 7% above baseline. Extrasystolic arrhythmia was 40% more frequent than after 120 days (in 20% of the cases). After 360 days of hypokinesia, physiological shifts in response to acceleration, as a rule, were the same as after 240 days, although multiple pinpoint hemorrhages occurred more frequently (in 80% of the cases). Improvement of endurance of acceleration after 240 and 360 days of hypokinesia might be associated with the positive effects of the prophylactic measures. The results attest to the fact that in group B, there were three stages of change in endurance of acceleration during hypokinesia: a phase of marked deterioration, a phase of relative improvement, and a phase of relative stabilization.

Conclusion: Human tolerance of +Gx acceleration depended on duration of hypokinesia with head-down tilt and on the use of prophylactic countermeasures, including anti-g suits. The use of the set of prophylactic countermeasures generally maintained a satisfactory level of acceleration endurance at all stages of hypokinesia with head-down tilt lasting up to a year, although they did not completely correct the adverse effects of simulated weightlessness.

## PAPERS:

P1349(29/90) Mitashov VI, Oygenblink EA, Tuchkova SYa, Grigoryan YeN, Mal'chevskaya IE.  
***Characteristics of limb and lens regeneration in tritons exposed to space flight.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 323-25 .

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Developmental Biology, Regeneration, Limbs, Lens  
 Amphibians, Tritons  
 Space Flight, COSMOS-1667, -1887, -2044

Abstract: The first experiments on regeneration of limbs and lenses in tritons were performed on biosatellite COSMOS-1667 and continued in experiments on COSMOS-1887 and -2044 and two Foton series satellites. The selection of this species was determined by the fact that regeneration is most developed in lower vertebrates, and has been studied most extensively in caudate amphibians. Rate of regeneration in mature tritons depends on a number of environmental factors - temperature, illumination, season of the year, and also age of the animal. We used qualitative data, such as rate of regeneration, stage of the regenerate, and their size; as well as quantitative, such as proliferative activity of the regenerate's cells, determined by computing indices of tagged  $^3\text{H}$ -thymidine nuclei, as criteria for evaluating the regeneration process.

Prior to launch, the lenses of both eyes of the tritons were extirpated and the front legs amputated at the level of the shoulder. On board, the animals were maintained in the "Triton" container with moisture containing inserts. The top of the container was covered by a membrane which allowed air flow. Animals of temperature and transport control groups were housed in analogous containers. Postflight, some of the animals were sacrificed and fixed, and the remainder kept for further observation.

In the COSMOS-1887 experiment it was established that immediately after landing, regenerates of the limbs of flight animals were more advanced in stage than those of the control groups. This pattern was maintained 14 days postflight. Autoradiographic analysis showed that the value of the index of labeled blasteme cells in the legs was significantly higher in the flight group immediately after landing than in the temperature control. These results confirmed those of previous work on COSMOS-1667, showing a tendency for limb regeneration to be accelerated, but in the former case the effect was observed only immediately after reentry, which was evidently associated with the shorter duration of the flight. Study of lens regeneration showed that, immediately postflight, regenerates were somewhat behind in stage compared to those of the control group, but after 14 days, flight animals were ahead with respect to both stage and size.

The effect of dynamic space flight factors, including vibration and impact, on morphogenesis of regenerates is of some interest. It was established that if tritons with regenerating limbs are exposed to vibration on the ground, then morphogenesis of a number of regenerates is disrupted.

## DEVELOPMENTAL BIOLOGY

This takes the form of failure of toes to complete their development, adhesion of the phalanxes, and decrease in the number of toes. In study of the effects of space flight factors on the nature of morphogenesis of limb regenerates in two experiments, the data suggested disruption of regenerate morphogenesis, but in two others the structure of the regenerates was no different from that of the controls. However, disruption of development of regenerates was also observed in animals of the control group. In total for the four flight conditions, disruption of morphogenesis was observed in 38 regenerates, while 14 regenerates showed normal structure. In the corresponding control groups there were 28 regenerates with anomalous development and 26 with normal structure. In regenerates of the flight groups, and also in conditions with vibration, the apical epithelium of the regenerate exfoliated and cavities containing blood cells and connective tissue sometimes formed. In the flight group, data from electron microscopic studies revealed degenerative changes in the structure of a number of cytoplasmic organelles in the cells of the apical epithelium. This may be the reason for the disruption of morphogenesis of the regenerates.

Thus, space flight factors do not prevent regeneration of limbs and lenses, although they may modify the recovery processes in the lower vertebrates. It is highly likely that the degree of modification depends on stage of regenerate exposed to space flight and on flight duration

P1350(29/90) Ostroumova TV, Luchinskaya NN.

***The growth of oocytes of the Spanish triton in weightlessness.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 329-31 .

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Developmental Biology, Oocyte Growth, Genetics, Delayed Effects  
Amphibians, Spanish Tritons  
Space Flight, COSMOS-1887, -939

Abstract: The possibility of conducting experiments on biosatellites gave a new impetus to research on the role of gravity in development. It has been demonstrated that the first stages of development are the most sensitive to microgravity or changes in gravitational vectors. However, disruption of spatial distribution of the components of an egg may not be the only consequence of exposure to weightlessness. It is well known that exposure to space flight conditions, especially long-term exposure, and the period of readaptation to conditions on Earth are accompanied by significant changes in fluid-electrolyte metabolism and hormonal balance. Such disruptions of homeostasis may affect the sensitive components of oogenesis. For this reason, investigation of the effects of space flight on gametogenesis and, in particular, oogenesis is important for fundamental biology, space medicine, and genetics.

Experiments on the effects of space flight factors on oogenesis of Spanish tritons were performed on biosatellite COSMOS-1887 and satellite COSMOS-1939. A total of 14 tritons aged 6 months, with mean body length of 10-11 cm, were used in the 14-day flights. The gonads of the experimental and control animals were fixed on the day of landing, 2 weeks or 2 months later. Number of oocytes was counted in a microscope field in a series of semifine sections for control and experimental animals. Mean diameters of the oocytes and their nuclei were measured and density of distribution of nucleoli were determined. Based on the data obtained we graphed the variations in measured parameters. At this age, oocytes in the ovaries of tritons are at the stage of pre-vitellogenesis, with a few at the stage of low growth (0-2 per visual field). Comparison of the state of oogenesis in experimental and control tritons immediately after landing showed that 2-week exposure to space did not lead to the death or resorption of oocytes. Neither were there reliable differences in the number of oocytes in experimental and control conditions at any of the stages studied, nor did the mean size of oocytes, their nuclei, or the distribution of nucleoli differ. In control tritons, immediately after landing oocytes were larger than in the experimental condition, which may suggest some depression of oocyte growth in flight. Two weeks after landing, the oocytes of flight animals were significantly larger than controls. A similar pattern held for sizes of nuclei. The greatest difference between experimental and control groups involved distribution of density of nucleoli: in flight animals the number of nucleoli per unit length of the surrounding nucleus was twice as great as the control value. Two months postflight (flight data were obtained from the COSMOS-1939 experiment) there was also a reliable increase in the size of nuclei and number of nucleoli in the nuclei of flight tritons, but no difference in the size of oocytes.

Thus, we observed that space flight factors have a delayed stimulating effect on the process of oogenesis in the Spanish triton. Two weeks after landing, the size of the oocytes and their nuclei

## DEVELOPMENTAL BIOLOGY

and the number of marginal nucleoli in nuclei increase. A stimulating effect is also noted 2 months postflight, but not in all parameters. Space flight factors have a stimulating effect only on oocyte growth, since there was no additional multiplication of oogonia, and the number of oocytes at the stage of low growth was unaltered in flight animals.

Intensive growth of oocytes in amphibians is supported by the rDNA amplification during metamorphosis. An increase in the number of marginal nucleoli in experimental animals 2 weeks postflight is associated with stimulation of the natural process of nucleoli multiplication, which normally occurs at this stage of growth. At this stage there is fragmentation of the nucleoli and nucleolus-like structures, and a portion of the granular component of the nucleoli separates. The processes of oogenesis in animals occurs under the control of hormones, mainly gonadotropins, with corticosteroids having a mediating effect. The dependence of vitellogenesis and maturation of oocytes on concentration of electrolytes is also well established. The reactions of the organism to the extreme factors of space flight and subsequent readaptation to Earth conditions are reflected in the sharp change in hormonal status, as well as in fluid electrolyte balance. The delayed stimulating effect on processes of oogenesis may be induced by stimulation of vital activity after exposure to stress.

## DIGESTIVE SYSTEM

### MONOGRAPH:

M165(29/90) Smirnov KV.

Pishchevareniye i Gipokinesiya. Пищеварение и Гипокинезия [*Digestion and Hypokinesia*].  
To be published in third quarter of 1990 by Meditsina.Publishing House, Moscow.

KEY WORDS: Digestive System, Hypersecretory Stomach, Dysbacteriosis, Hypokinesia

Annotation: This monograph describes the processes of digestion under conditions of hypokinesia: the hypersecretory stomach syndrome, functional inadequacy of the pancreas and intestine, the disrupted liver function, and dysbacteriosis. Changes in the digestive systems are discussed from the standpoint of the conception of premorbid states. This book is intended for gastroenterologists, pathophysiologists, and specialists in the area of space medicine.

[Note: this is a translation of a short abstract published in Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina. We will publish more information about this book as it becomes available.]

**PAPERS:**

P13012(29/90\*\* Pozharskaya LG, Noskov VB.

***Hormonal regulators of calcium metabolism after space flights varying in duration.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 18-20; 1990.

[13 references; 5 in English]

Endocrinology, Hormonal Regulators, Calcitonin, Gastrin, PTH. Metabolism, Calcium, Body Fluids, Fluid-Electrolyte Balance

Humans, Cosmonauts

Space Flights, Short and Long-Term

**Abstract:** This work investigated how activity levels of the parathyroid hormone-calcitonin-gastrin system are related to the duration of human exposure to space. Subjects were 19 cosmonauts, 12 of whom had completed orbital flights lasting 7 days, and 7 of whom participated in long-term flights of 150, 211, and 237 days. Blood was taken 30 days preflight and on days 1 and 7 postflight, and later. Concentrations of PTH, calcitonin and gastrin were measured using a standard test kit.

On day 1 after shortterm flights, calcitonin increased by an average of 45%, PTH was virtually unchanged, and gastrin had increased by 44%. After long-term flights, level of PTH increased by more than a factor of 2 on day 1 postflight and only normalized by day 45. The only exception was one cosmonaut completing the 236 day flight, who showed lower than baseline levels of PTH throughout the postflight period. Plasma calcitonin dropped on day 1 postflight in all 7 cosmonauts and after the 211- and 237-day flights it was below detectable levels. On day 45 postflight, it had not recovered in all cosmonauts. On day 1 postflight gastrin had increased significantly (factor of 3.3) above baseline. On day 7 postflight gastrin levels were no different than on day 1. By day 45 postflight gastrin had normalized.

Table 1: Concentration of hormones in blood plasma of cosmonauts preflight (I) and on day 1 postflight (II), for short-term space flight

Table 2: Concentrations of hormones in blood plasma of cosmonauts preflight (I) and on days 1 (II), 7 (III) and 45 (IV) after long-term flights

P1315(29/90)\*\* Plakhuta-Plakutina, GI, Kabitskiy YeN, Dmitriyeva NP, Amirkhanyan YeA.  
***Morphology of the thyroid gland and concentration of thyroid hormones in blood of rats in experiments on COSMOS-1667 and -1887 biosatellites.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 25-27; 1990.

[15 references; 2 in English]

Endocrinology, Thyroid, Morphology, Hormone Levels

Rats

Space Flight, Short-Term, COSMOS-1667, -1887, Adaptation, Initial, Transitional

**Abstract:** The present study compared the state of the thyroid gland and thyroid hormones in rats completing flights of 7 (initial adaptation) and 13 (transitional period of adaptation) days on board COSMOS biosatellites (1667 and 1887). The thyroids of 7 rats exposed to space for 7 days on COSMOS-1667 and sacrificed after 4-8 hours, and 10 rats flown on COSMOS-1887 for 13 days and sacrificed after 2 days, were subjected to histological, electron microscopic and morphometric analyses. A corresponding number of animals were utilized in synchronous and vivarium control groups. Tissue samples for electron microscopy were fixed and embedded in araldite and epon. Contrast-stained ultrathin sections were observed. For optical microscopy glands were fixed and embedded in paraffin. A method was used to differentiate follicles on the basis of tinctural properties of the colloids they contained. A semiautomatic image analyzer was used to measure the height of the follicular epithelium and the size of the thyrocyte nuclei, as well as to count the number of folliculi with various color colloids. Concentrations of total thyroxin (T<sub>4</sub>), free T<sub>4</sub>, (FT<sub>4</sub>), and triiodothyronine (T<sub>3</sub>) were measured using radioimmune assay with standard reagents. Analysis of variance was used to test the data.

After the 7-day flight the thyroid parenchyme did not change significantly compared to those of the control groups, although there was a tendency for thyrocyte height and nucleus size to decrease. Flight rats displayed moderate activity of the thyroid parenchyme with a contracted colloid containing sparsely distributed marginal vacuoles. Up to 47-50% of the follicles contained a colloid stained in a mixed yellow-blue yellow shade. This coloration suggests decrease in concentration of iodized thyroglobulins. In the synchronous group such changes were observed in only 2 of 7 rats. Biochemical analyses revealed reliable decrease in concentrations of T<sub>4</sub> and FT<sub>4</sub>, by 20 and 33%, respectively.

After 13 days of exposure the flight rats displayed more severe morphological signs of decreased thyroid function compared to the 7-day flight group. The parenchyme was divided into zones consisting of moderate and large follicles, which in places were in the shape of loops. The follicles were covered mainly with cuboidal epithelium and in spots by squamous epithelium. The apical membrane of the majority of thyrocytes was even or had penetrated slightly into the follicle lumen. The nuclei were rounded and dense and arranged basally. Micrometry revealed reliable decrease in the height of thyrocytes and the size of nuclei. Instead of the blue-stained colloid that predominated in the control groups, there were greater numbers of follicles containing blue-yellow and yellow colloids, suggesting decreased iodized thyroglobulins. In addition the colloid thickened and became inhomogeneous and stratified. Desquamated epithelium in the colloid and pyknosis of the epithelial cell nuclei were noted. The glandular stroma were somewhat edematous and there was marked venous and capillary hyperemia. Electron microscopy revealed: swelling of the mitochondria, lightening of their matrix and shortening of the cristae, increased polymorphism of the granular endoplasmic reticulum, increased areas of cytoplasm containing colloid, frequent invagination of the nuclear membrane, and enlargement of the perinuclear spaces in flight rats. Up to 65 thyrocytes of 100 studied contained large accumulations of colloid drops (up to 18-20 drops). These were considered to be engorged, accompanying their diminished secretion into the bloodstream.

## ENDOCRINOLOGY

Biochemical changes in this group were consistent with morphological ones. Levels of T<sub>4</sub> and T<sub>3</sub> in blood plasma were diminished. Free T<sub>4</sub> did not differ from control, most likely due to the 48-hour readaptation period the rats had undergone. These results revealed progressive changes in the thyroid in space flight compared to the 7-day flight group. These results are interpreted as indicating progressive decrease in functional activity of the thyroid with increasing exposure to space flight conditions.

Table 1: Concentration of thyroid hormones in blood in rats postflight (in nmole/liter)

Group	T <sub>4</sub>	FT <sub>4</sub>	T <sub>3</sub>
7-day flight			
Flight	68±2*	20±1*	0.6±0.1
Synchronous	98±7	26±2	0.8±0.1
Vivarium	85±2	26±1	0.6±0.1
13 day flight:			
Flight	46.4±3.6*	23.7±2.1	1.26±0.07*
Synchronous	72.5±2.8	25.8±1.0	1.29±0.07
Vivarium	81.5±1.6	25.9±0.6	1.63±0.03

Table 2: Morphometric parameters of thyroid gland of rats after a 13-day flight]

Group	Height of thyrocytes, (divisions of ocular micro-meter)	Area of nuclei, (mm <sup>2</sup> )	Quantity of follicles per unit area, %		
			blue	yellow-blue	yellow
Flight	4.4±0.04*	21.2±0.4*	45±2*	40±2*	15±3*
Synch. cont.	4.8±0.06	24.6±0.4	83±2	13±2	4±1
Vivarium cont.	4.7±0.12	23.9±0.3	86±1	11±1	3±1

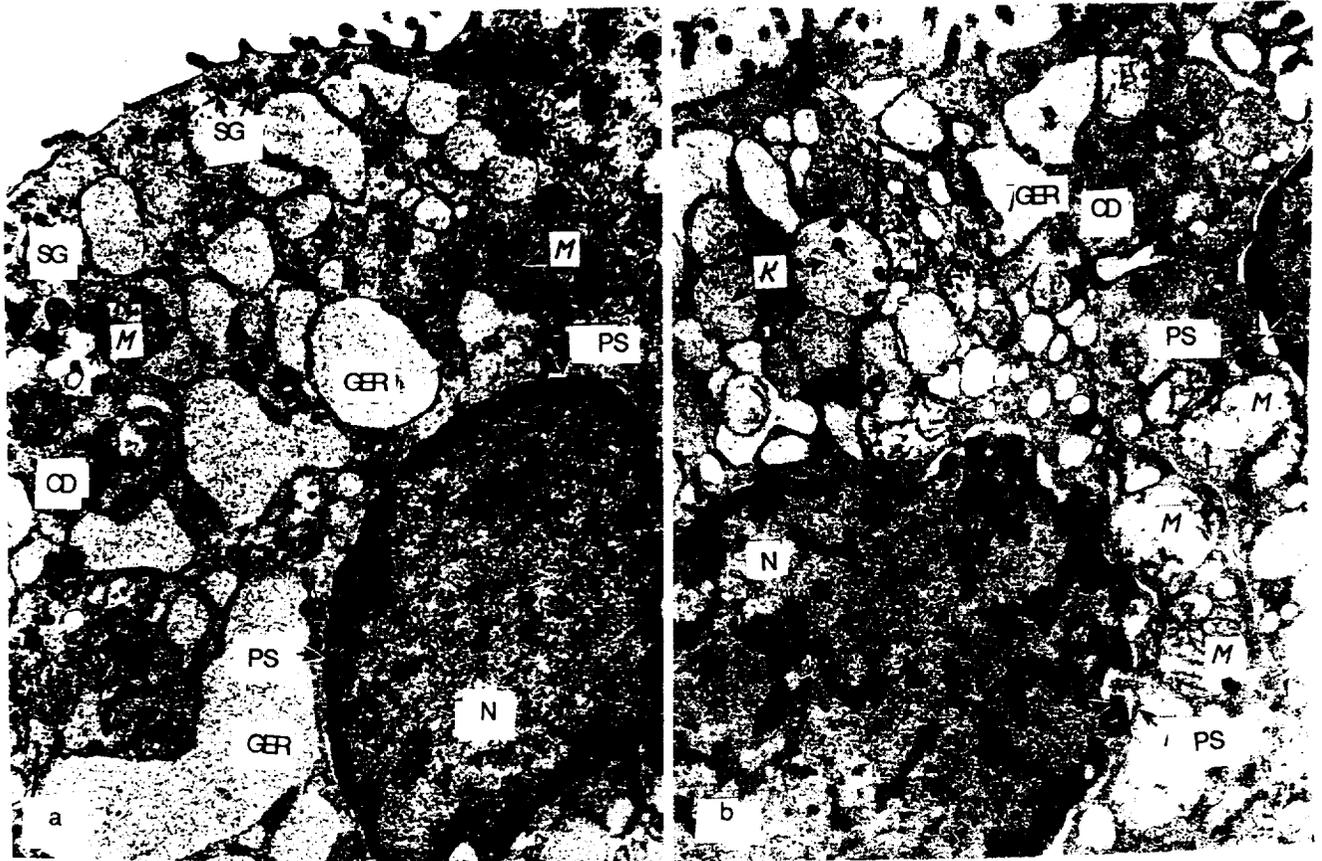


Figure: Thyrocyte ultrastructure

a - control group, apical edge of the cell with many secretory granules (SG) and isolated colloid drops (CD), expanded cavity of the granular endoplasmic reticulum (GER), small mitochondria (M), oval nucleus (N), with smooth coating and narrow perinuclear space (PS); b - flight group (13 days in space); numerous colloid drops (CD) throughout cytoplasm, swollen mitochondria (M) with disorganized cristae and lightened matrix, nuclei (N) with uneven outline with local expansion of the perinuclear space (PS)

P1316(29/90) Kabitskiy YeN.

***Functional activity of the pituitary-thyroid system in response to a 370-day period of hypokinesia with head-down tilt.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 28-30; 1990.

[15 references; 8 in English]

Endocrinology, Pituitary-Thyroid System

Humans, Males

Hypokinesia, Head-Down Tilt, Countermeasures, Exercise

Abstract: The goal of this work was biochemical investigation of the pituitary-thyroid system in response to long-term hypokinesia. Ten healthy men divided into two equal groups served as subjects. All subjects spent 370 days under conditions of hypokinesia with head-down tilt (-5°). Subjects in group A engaged in a physical exercise program in a horizontal position starting on day 20 of treatment. Group B subjects did not begin exercising until day 120. One subject in group A was removed from the experiment for medical reasons. Subjects were observed for 1 year after treatment. Blood for hormonal studies was taken before treatment, on days 50, 110, 170, 230, 290, and 350 of hypokinesia, and on days 7, 30, 60, and 250 of recovery. Thyrotropic hormone (TTH), free thyroxin (FT<sub>4</sub>), thyroxin bound with protein (T<sub>4</sub>), and triiodothyronin (T<sub>3</sub>) were measured in blood by radioimmune assay with standard reagents. Significant fluctuations of data values prevented comparative analysis of data points. Data points were instead combined into periods. For group A these were baseline, hypokinesia with exercise, and recovery; for group B they were baseline, hypokinesia without exercise, hypokinesia with exercise, recovery.

Throughout treatment TTH for group A did not differ from baseline. In group B, this parameter remained unaltered throughout the hypokinesia period without exercise, but decreased after exercise began by a mean of 21%. During recovery, level of this hormone decreased by 57% in group A and 45% in group B compared to baseline. These low levels persisted until the last measurement point, 250 days after treatment was completed. No changes in T<sub>4</sub> were noted.

Level of FT<sub>4</sub> decreased in both groups during hypokinesia by 17% and by 24% in the recovery period. Intergroup differences were not significant. T<sub>3</sub> decreased by a mean of 32% in group A during treatment. In group B it did not alter before exercise, but subsequently dropped by 29%. During recovery T<sub>3</sub> remained at the level it had reached during treatment.

The fact that T<sub>4</sub> and to a lesser extent TTH failed to decrease during treatment is attributed to emotional stress and the effects of the large numbers of tests performed on subjects. The fact that TTH decreased in group B when subjects began to exercise is explained by the fact that although the thyroid is activated through humoral factors under normal conditions, when physical loading increases under hypokinesia the role of neural activation of the thyroid also increases. The reason cited for the decreases in levels of T<sub>3</sub> and FT<sub>4</sub> in the recovery period is increased rate of their utilization by the tissues under conditions of normal activity; however, the reason for the prolonged persistence of these decreases is unclear. The authors conclude that the prophylactic measures had no significant effect on the functional activity of the pituitary-thyroid system.

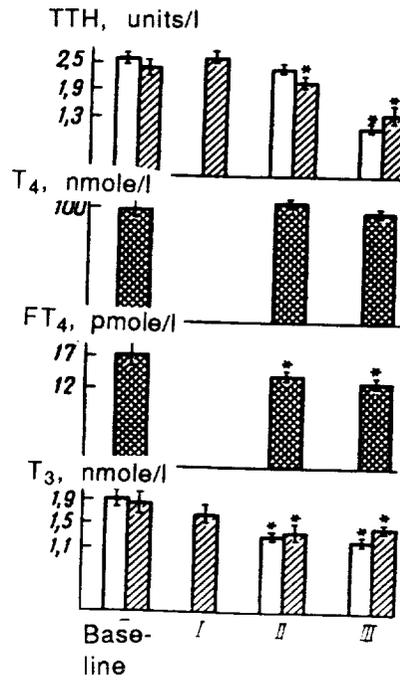


Figure: Concentrations of the hormones of the adenohipophysis (TTH) and thyroid (T<sub>4</sub>, FT<sub>4</sub>, and T<sub>3</sub>) glands  
 B - baseline. I -hypokinesia without exercise, II - hypokinesia with exercise; II -recovery  
 White bars- group A, hatched bars - group B, cross-hatched bars, A and B pooled. \* Difference from baseline significant

P1346(29/90) Besova NV, Savel'yev SV.

***Morphological changes in the ultimobranchial glands of caudate amphibians under conditions of space flight.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health  
Pages 288-289 .

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Endocrinology, Ultimobranchial Glands, Morphology  
Amphibians, Tritons  
Space Flight, COSMOS, Foton

Abstract: In adult Spanish tritons (newts) the ultimobranchial gland (UBG) is located between the peritoneal and pericardial cavities adjacent to the arterial cone. The calcitonin-secreting cells of adult amphibians, unlike those of mammals, are isolated in an independent organ and form secretory follicles. When the cells are excreting calcitonin these follicles fill with colloid. The follicles of the UBG may contain secreting as well as nonsecreting cells. Count of the number of secreting follicles in mature Spanish tritons showed that 2 to 10% of all the follicles of the UBG secrete directly. The remaining 90-95% of the cells organized into follicles do not secrete. Cells undergoing differentiation and secreting the hormone function for 2-3 weeks. Then they undergo hypertrophy, secrete the maximum amount and die. In place of the cells that have died, adjacent cells, which undergo differentiation, begin to secrete. When the cells undergo differentiation, the follicles develop a network of capillaries which permits them to redistribute the flow of calcitonin between blood plasma and coelomic fluid.

Morphological transformations of the UBG were studied onboard COSMOS and Foton series biosatellites. Histological analysis showed that in tissues of animals fixed immediately after landing, 50-90% of their UBG had been reabsorbed compared to the UBG of control animals. The cells of the gland formed 3-4 follicles, which were 5-8 times larger than normal. Undifferentiated and proliferating cells were absent in the follicles of such glands, i.e., under conditions of weightlessness the secretory cells of the UBG hyperfunction and subsequently die. Flow of calcitonin was determined by indirect immunofluorescent method using monoclonal antibodies to calcitonin.

Thus it was established that in weightlessness under conditions of hypersecretion of the UBG follicles, calcitonin is actively developed and accumulated.

### PAPER:

P1311(29/90)\*\*Adamovich BA, Bayevskiy RM, Berseneva AP, Funtova II.

***State-of-the-art automated evaluation of functional state in cosmonautics and preventive medicine today.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 11-18; 1990.

[26 references; 1 in English]

Equipment and Instrumentation, Automated Diagnosis and Prognosis, Avtosan-83, Kontrol, Vita, Ritm

Humans

Operational Medicine, Space Medicine, Preventive Medicine

**Abstract:** This paper describes the stimulating effect of space medicine on development of the concepts and automated equipment for preclinical diagnosis of healthy individuals and their use to develop systems for performing preventive medical examinations of large populations. The first piece of equipment discussed is the automated "Avtosan-82" mobile medical laboratory designed jointly by specialists in space and preventive medicine, which is housed in a bus. The configuration of the laboratory is very similar to that on board space stations and some of the equipment used is identical. The examination protocol using Avtosan-83 involves three stages. In the first stage anthropometric measurements, including height, weight, and dynamometry, as well as lung capacity measurements are performed. In stage two, cardiological studies, including EKG, ballisto- and seismocardiography, blood pressure, and mathematical analysis of cardiac rhythm are performed in resting and exercising patients. Tests of orthostatic tolerance are also conducted. Stage three involves obtaining a medical history through an interactive computer program. On the basis of all three stages the computer produces a health evaluation chart, providing results of individual tests, a rating of general health on a 4-point scale, a list of individual risk factors and recommendations for further specialized medical exams. The Avtosan-83 can handle 10-12 individuals per hour and requires 4 staff members — a physician, two nurses and a computer operator.

Further development of this area in the USSR gave rise to three types of automated prognostic systems, which are described. The Kontrol system is designed for dynamic monitoring of the functional capacities of the circulatory system utilizing a minimal set of measurements. This device can be used in various types of medical centers without expensive apparatus. An index of functional changes was developed based on pulse rate, systolic and diastolic blood pressure, body weight, height, and age. On the basis of values of this indicator patients can be divided into 4 classes predictive of adaptation. The system, which runs on a microcomputer, is most useful for when patients are observed repeatedly, for example pre- and post-exercise programs.

The Vita system is designed for use at the pre-physician state of prophylactic examinations. A total of 439 parameters are considered of which 309 are derived from the case history taken through use of an interactive computer terminal and 130 are generated by examination. Analysis produces a number of types of conclusions, including: overall evaluation of functional state (using a formula developed through stepwise regression analysis); a list of risk factors and their severity; an estimate of likely course of pathology; an assignment to an outpatient category (healthy, apparently healthy, or ill); and derivation of recommendations. The system is implemented on a minicomputer with data obtained through short-answer forms and automated collection of information through electronic medical instruments.

The Ritm system is designed for more detailed examination of the circulatory system of apparently healthy individuals and dynamic observation of health under exposure to adverse environmental factors. These factors are introduced into testing using graded levels of exercise,

## EQUIPMENT AND INSTRUMENTATION

tilt tests, and mental performance tasks, during which a number of cardiac parameters are recorded. The Ritm system consists of the following modules: 1) module for recording EKG and measuring RR-interval; 2) module for mathematical-statistical processing of dynamic values of cardiac intervals; 3) module for evaluating functional state with classification into: normal state, functional stress, excessive functional stress; exhaustion. These evaluations take into account autonomic homeostasis, stability of regulation, activity of subcortical neural centers (on the basis of ratio of strength of respiratory and slow waves of cardiac rhythm), and psychological state (evaluated on the bases of slow wave components of cardiac rhythm).

Figure 1: Exterior view of Avtosan-83 mobile automated laboratory and interior view during one of the stages of examination

Figure 2: Diagram of the medical monitoring system of Salyut-6 and of Avtosan-83

Figure 3: Dynamics of cardiological parameters in men of various ages associated with changes in functional physiological state

**PAPERS:**

P1324(29/90)\*\*Gus'kov YeP, Shkurat TP, Shimanskaya Yel, Yanusheyevich SV, Nikolayeva YeYe.

***Cytogenetic consequences of treatment with hyperbaric oxygen.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 48-52; 1990.

[29 references; 17 in English]

Genetics, Cytogenetic Mutations, Hematology, Lymphocytes  
Humans, Patients  
Hyperbaric Oxygenation

**Abstract:** Material for this study was blood from healthy donors and those suffering from a variety of diseases who had been treated with hyperbaric oxygen of 0.15-0.2 MPa, for 10 daily sessions lasting 40 minutes each. Compression and decompression times were 15 minutes each. In some instances, whole blood taken before the course of therapy was stimulated with PHA and placed in a barochamber at a pressure of 0.7 MPa for 1 hour. Whole blood was cultivated in penicillin treated tubes containing 4.5 ml Medium 199, 0.5 ml bovine serum, 100 units penicillin, 5 units heparin, and 0.1 ml PHA. The cultures were fixed either 72 or 96 hours after introduction of PHA.

Analysis of lymphocyte chromosomes of patients scheduled for hyperbaric oxygenation failed to reveal any significant deviations from levels of spontaneous mutation compared to pretreatment norms. After treatment all subjects showed a level of mutation reliably above that of controls. The most common deviations were chromatid and chromosome breaks. There was a wide range of metabolic restructurings but they did not exceed 30% of all mutations. Some patients displayed isochromatide gaps and polyploid cells. Level of individual differences was high. When blood was exposed to hyperbaric oxygenation *in vitro* similar increases in chromosome aberrations were found. Effects on blood persisted as long as 9 months in some patients. Patients showing long-term persistence of effects were those whose blood exposed *in vitro* had a high rate of mutation. The authors conclude that the possible genetic damage attributable to hyperbaric oxygenation demands further investigation.

Table 1: Restructuring of lymphocyte chromosomes in peripheral blood of patients undergoing a 10-day course of hyperbaric oxygen therapy

Table 2: Restructuring of the chromosome in lymphocytes of patients before and after a course of hyperbaric oxygen therapy *in vivo* and *in vitro*

Table 3: Restructuring of chromosomes in lymphocytes of peripheral blood of patients 9 months after completion of a course of hyperbaric oxygen therapy

Figure 1: Details of metaphasic layers with paired fragments and chromatid gaps in lymphocytes of patients undergoing hyperbaric oxygen therapy

Figure 2: Restructuring of the metabolic type in the metaphase chromosomes of patients after completion of a course of hyperbaric oxygen therapy

Figure 3: Endoreduplication with multiple chromosome restructurings after processing of donor blood at 0.7 MPa

### PAPERS:

P1293(29/90)\*Gazenko OG, Grigor'yev AI, Meleshko GI, Shepelev YeYa.  
***Habitability and man-rated bioregenerative life support systems***  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
24(3): 12-17; 1990.  
[24 references; 3 in English]

Habitability and Environment Effects, Biospherics, Ecological Specifications, Human Ecology  
Theoretical Article, Humans  
Life Support Systems, Bioregenerative, CELSS, Space Flights, Long-Term, Mars Mission

**Abstract:** The approach taken to man-rated bioregenerative life support systems (BLSS), and appreciation of their purpose and role in future space exploration, are determined by one's understanding of the problem of habitability. If the concept of habitability is defined as essentially the satisfaction of a specified list of individual physiological and hygienic specifications, then the issue of life support can be seen simply as a matter of supply and demand -- of maintaining the requisite environmental parameters and supplying the right quantities of its requisite environmental components -- oxygen, water, and food. However, if we approach the problem from an ecological view of the living environment in the broadest sense of the term, then the LSS must not merely supply certain specified substances, but must meet ecological specifications -- providing a biologically complete living environment adequate to meet the biological needs of humans and fulfilling the major functions of the natural environment on Earth.

It is precisely this difference in outlook that has generated the difference in approaches to assessment of the promise of BLSS for the future on the part of designers, on one hand, and medical people concerned with living conditions on board spacecraft, on the other.

The need to "elucidate the relationships" between the concept of habitability and the role of the systems that produce it is especially great today, when we are looking forward to space programs such as the lunar base or the Mars mission which will require humans to spend long periods of time isolated from direct contact with the Earth's biosphere. Under these circumstances the concept of habitability — and thus the role of life support systems — becomes critical to the success of the entire program. The most appropriate and adequate concept of habitability to support multi-year human activity away from the Earth involves an understanding of a BLSS as a closed ecological system, a kind of "branch office" of the Earth's biosphere.

Future prospects for increasing the duration of autonomous human existence outside the biosphere are associated with a shift from the natural environment common to all terrestrial life forms to artificial systems that are completely different in origin and nature from this environment, those created by humans through regeneration of waste products. This shift compels a review of the ideas and concepts of habitability in light of this new application

The current literature does not provide an integrated and complete explication of the concept as it is understood today, just as there is no unambiguous definition of the term "habitability" itself.

It seems possible to define habitability as the totality of environmental conditions (physical, chemical, biological, and social) that make the environment suitable for normal human vital activity, either for an unlimited or stipulated limited time (limited habitability). Obviously, in our current stage of development we are dealing with limited spacecraft habitability. Given this definition, it is evident that one future goal of human space ecology should be to decrease

## HABITABILITY AND ENVIRONMENT EFFECTS

the limitations on the duration of human habitation (although certainly not at the expense of decreasing its quality) and to transform limited habitability of spacecraft into unlimited habitability. As for ways to provide practical support of space flight in the foreseeable future, they will largely depend on what degree of inadequacy of artificial spacecraft environments (compared to the natural environment on Earth) is deemed acceptable.

Historically, doubts about habitability on long-term flights first surfaced with respect to the level and stability of standardized atmospheric parameters. Despite the absence of clearly formulated concepts of habitability, the major elements of this concept are implicit in the actual practice of space medicine. For example, the standards set for parameters of microclimate and atmospheric pressure and composition for spacecraft and space stations are clearly derived from the need for physiological/hygienic comfort.

A.M Genin was the first person in our literature, and evidently in the worldwide literature as well, to draw attention to the shortcomings of the concept of a comfortable or "neutral" environment in the context of long-duration flights. A quarter of a century ago, he suggested creating fluctuations in certain atmospheric parameters as a means of providing active stimulation for the human organism, and also discussed the more general problem of the active role of the environment in supporting significant regulatory reserves of the organism. At that time, certain other questions of human ecology were also posed, including some which applied to BLSS for humans.

Subsequently this initial attempt to take a new approach to the problem of spacecraft habitability was continued in works by Gazenko and Shepelev, which developed the idea of the utilization of a biologically complete [adequate] living environment in a BLSS, formed biogenically and analogous to the natural environment. The authors applied the idea of the active effects of the environment to specific physiological mechanisms of respiration, thermal regulation and circulation. Today, looking forward to future programs such as the Mars mission, these ideas should be reexamined, and an attempt made to analyze the possibility of utilizing them within a new concept of habitability.

But this is just one aspect of habitability, and not even the most important one, although the dynamic characteristics of the physical parameters and gaseous composition of the environment do have important physiological significance. The essence of the problem of habitability -- the quality of life -- touches on all the factors of the environment that allow it to sustain life.

Our current knowledge concerning man's environment is the traditional purview of the physiological and hygienic disciplines that study and set standards for food and the factors of the air and water environment of greatest significance to man. These disciplines implicitly assume that all factors that are not stipulated by hygienic standards are automatically provided by the natural environment -- the natural atmosphere, natural water, and natural animal and vegetable food. This implicit logic is correct today, even with respect to orbital space stations, since the cargo ships continue to deliver natural water and fresh vegetables and fruits. Without it being intended, the natural atmosphere of Baykonur is also introduced each time the space stations dock with the cargo spacecraft and transport vehicles carrying the visiting crews accompanied by their terrestrial microflora.

In the case of open systems, the *a priori* suitability and adequacy of the natural environment to the biological needs of humans is naturally accepted as an empirical fact and axiom of habitability, since these qualities are the natural by-products of the long process of adaptive evolution of human beings.

However, as soon as we begin to deal with a complete physical regeneration of the atmosphere and water from human waste products, i.e., in a completely artificial closed living environment,

## HABITABILITY AND ENVIRONMENT EFFECTS

the assumption of the *a priori* adequacy of the environment is no longer valid, since there is no rationale for assuming that such an artificial environment is suitable for long-term human habitation. As a result, questions arise that science has never faced before: What are the factors ensuring the complete biological adequacy of the natural environment? What phenomena and circumstances embody these factors? Which factors must be reproduced in an artificial environment and how should this be done to make it completely biologically adequate and suitable for long-term habitation? In answering these questions we must consider not only the direct, physiological effects of environmental factors, but also their possible informational or signal functions. Here we must acknowledge the inadequacy of our knowledge of many environmental factors, their significance for human beings, and their role as constant factors that make the environment biologically complete and biologically adequate to meet human needs.

The limits of our knowledge of human linkages with the natural environment is evident when we consider that of all the factors known to be essential to human life -- the atmosphere, water, food, and vitamins -- only the last was not recognized in prehistoric times. Furthermore, the only factors which have been clearly identified as essential are those whose absence makes itself felt in less than a year, i.e., 2% of the working lifetime of a human. However, this does not mean that there are no other natural factors critical to life the adverse effects of whose absence manifest themselves only after several years or a generation.

For the time being, factors beyond the traditional purview of habitability include: geophysical fields -- magnetic, gravitational, electrical; the constant formation and motion of atmospheric charged particles (aero-ions) varying in origin and associated with electrical fields; aerosols of various types -- mineral, organic, biological (bacteria, spores and plant pollens); unfiltered atmospheric ultraviolet radiation, which excites many photochemical reactions accompanied by the formation of free radicals and other biologically active substances. All these are real invariant factors of the natural environment and their significance for terrestrial life has scarcely begun to be elucidated. They have virtually not been studied as ecological factors of the natural environment. We still do not have accurate knowledge of the most important one from the point of view of a theory of habitability -- the biogenic factor, the natural essence of the Earth's atmosphere and water. After all, the natural atmosphere of the Earth is far from our surrogate model of the "space atmosphere" (nitrogen + oxygen + carbon dioxide), and natural water is far from being just a substance with the chemical formula  $H_2O$  (which, by the way, is very harmful in its pure form to all living things).

Science of course does have some knowledge about these neglected environmental factors, but it is considered the purview of individual disciplines -- atmospheric physics and chemistry, hydrobiology, ecological physiology, medical geography, health resort science, etc.-- and has not been integrated into a unified system of knowledge concerning man's environment. This is a significant problem for the development of our future concept of habitability, our concept of human ecology.

It is well known that the normal components of the Earth's atmosphere, aside from the norms we have set for oxygen and carbon dioxide, include many hundreds of organic substances, mainly of biogenic origin. These are products of the vital activity of all the living things on the Earth, mainly plants and soil microorganisms. In traditional toxicology they are usually called harmful contaminants. We avoid this term, since there is no substance in nature that is unconditionally harmful to man. They are only harmful in certain concentrations (examples are mercury and arsenic, which are used in medicine).

However, before now no one has ever thought about the fact that these permanent and obligatory components of the natural atmosphere may be directly beneficial or even essential to humans. N.G. Kholodnyy alone in 1948 hypothesized that there are substances emitted by plants into the

## HABITABILITY AND ENVIRONMENT EFFECTS

atmosphere (atmovitamins) that, when they enter the bodies of animals and humans through the respiratory tract, fulfill definite physiological functions, essential for normal vital activity. Further development of this idea evidently must also be included in the program for creating our future concept of the habitability of extra-biospheric manned spacecraft for multiyear periods of autonomous habitation.

The total number of recorded biogenic volatile organic components of the atmosphere already exceeds 400, and there is no reason to think that our knowledge of the organic composition of the atmosphere is complete. These recorded and as yet unrecorded substances comprise the wealth of organic components of the Earth's atmosphere that distinguish it from various surrogates in modern inhabited spacecraft. Despite the very low relative concentrations of organic components in the natural atmosphere, the overall volume of their production may approach the annual production of vegetable biomass. The atmosphere is a component of the environment to which living things are exposed every second of the day. During a single month, more than  $5 \times 10^5$  liters of air pass through the lungs of a single human being.

In contemporary science these issues have neither been studied systematically nor dealt with theoretically. Only in the science of health resort rehabilitation have significant efforts been made to reinforce the intuitive and empirical ideas (which originated with Hippocrates) concerning the therapeutic properties of natural factors by analyzing them physicochemically. In addition to the biological activity of the organic components of the atmosphere, Soviet health resort science also considers the positive role of aero-ions, aerosols, ozone, and atmospheric electricity. Aside from volatile components, the Earth's atmosphere contains a large number of multimolecular aggregates, organic as well as inorganic in origin -- the so-called aerosols, particles ranging from submicrons to microns in size. In the submicron range, these particles have been shown to be associated with changes in the physical properties and to increase chemical and catalytic activity of the aggregates that contain them. If such particles are ionized in the electrical field of the Earth, then they become aero-ions -- an additional ecological factor in the environment of life on Earth.

Finally, aerosols of inorganic origin, which are neglected in the current practice of habitability, are the source of aerogenic trace elements entering the body through the respiratory tract. Because of this mode of interaction, their intake cannot be monitored and it is not possible to determine whether there are adverse physiological effects of disruption of interactions with these components and how long such effects would take to manifest themselves

The absolute quantities of biogenic and abiogenic emissions in the atmosphere are given in Table 2.

Thus, even a superficial review of the findings concerning the physical, chemical, and biological components of the natural atmosphere does more than merely demonstrate the complexity of its composition. It is completely obvious that the pathways of many of the biosphere's biological and geochemical substance cycles cross and recross through the atmosphere. Completely apart from the need to consume or emit oxygen or carbon dioxide, a wide variety of the material interactions in which terrestrial life participates are possible only because of their contact with the atmosphere. This alone is enough to make it clear that when, on manned space flights, we replace the actual atmosphere of the Earth with a mere mixture of nitrogen, oxygen, and carbon dioxide, we are depriving cosmonauts of their most direct and most constant interaction with the natural environment, which is the universal arena for intercourse among terrestrial vital and abiogenic processes regardless of whether these interactions are acknowledged by modern science.

## HABITABILITY AND ENVIRONMENT EFFECTS

Natural water is also a complex multicomponent substance. All the forms that it takes on the Earth are, or were, the living environment for a variety of organisms which gives it many properties that are entirely characteristic of living matter. For this reason water produced through regeneration by various physicochemical methods, even if it fully meets USSR state standards, cannot support the life of aquatic organisms. For this reason scientists concerned with hydrobiological hygiene have long had recourse to the concept of biologically adequate water, which they associate with the presence of biologically active products of the metabolism of hydrobionts (lipids, fatty acids, fat soluble vitamins, free radicals, and products of lipid peroxidation, etc.).

Even this cursory overview of the individual, unintegrated findings about characteristics of the natural environment demonstrates that our actual models of the spacecraft environment are only primitive surrogates. It has shown how complex are the composition and origin (biogenic and abiogenic) of the natural atmosphere and natural water and how intimately and indeed inextricably they are related to the activity of living things.

It is obvious that on Earth there are no nonbiological mechanisms that could reproduce the natural living environment in all its biological richness. It should also be obvious that humans, like other forms of life, should be in principle unable to live in abiogenic environments for longer than the limited period provided by the inertia of biological systems. This follows theoretically from the adaptive evolution of life in the environment and does not require experimental verification. The requisite proof was furnished long ago by the history of the biosphere. The entire history of man's development as a component and a product of the biosphere, the entire period of the holistic evolution of life through interaction with its environment has served as an uninterrupted "experiment" in the actual scientific, and not merely the philosophical meaning of the word. Acknowledgement of the practical force of this principle of unity -- acknowledgement of man's place as a component and product of nature on the Earth -- must form the basis for the fundamental principle underlying modern human ecology and the concept of habitability that is derived from it.

Scientific concepts do not arise full-blown by themselves. They are formed when the need for them arises, as a result of the evolution of scientific thought and its assimilation of certain scientific facts. This is precisely how matters stand here. In the near future, when we will start to utilize nonbiospheric spacecraft requiring multiyear periods of autonomous existence, we will need a new concept of the human environment, one which encompasses the greatest number of facts concerning the characteristics of Earth's natural environment, especially those that at present remain outside the boundaries of the concept of habitability implicit in modern space hygiene.

The authors have used their ideas on the natural environment and man's place in it to derive several empirical propositions that may be used as the axiomatic basis for future conceptions of habitability. A new consideration of this concept is demanded by the new conditions for its application -- multiyear isolation of human beings from the biosphere.

1. Our knowledge of human beings' natural environment is inadequate. It does not fully reflect the environment's properties as a complex multicomponent biogenic, self-regulating, and self-renewing system.
2. The natural environment is intimately associated with living matter, which determines its biological completeness and its *a priori* adequacy to meet the needs of living things and distinguishes it in principle from any artificial, abiogenic environment.
3. Nature on the Earth is the sole variant of the environment that has been evolutionarily tested and demonstrated to be suitable for the unlimited long-term existence of humans. For this

## HABITABILITY AND ENVIRONMENT EFFECTS

reason the natural environment must be used as the absolute standard for a living environment for humans, as well as other life forms.

4. Any artificial, abiogenic environment is in principle limited with respect to duration of its habitation, to an extent directly proportional to its lack of correspondence with the natural original.

5. On isolated manned spacecraft, the environment can only be made biologically adequate if it has been formed through biological mechanisms analogous to the mechanisms that underlie the functioning of natural ecosystems.

Such an environment approximates the natural environment, more fully meets the biological needs of humans, and thus is the sole possible environment capable of supporting optimal conditions for them during long-term separation from the biosphere. For the future conquest and utilization of the resources of space, there is no alternative to such a system.

Here we have come to the relationship between the problem of habitability and the man-rated BLSS. BLSS are capable of more than merely producing the basic elements for life (oxygen, water, food) and disposing of carbon dioxide and other human waste products through biological recycling. The environments that they create are biogenic and, for this reason they may in principle maximally approximate the natural environment, despite the incompleteness of our knowledge of the latter's myriad component parts. The goal of meeting the biological needs of a space crew, in essence involves the creation of an artificial substance cycle, which nevertheless provides for the totality of human needs for matter and energy with maximal integration and efficiency.

Such a system will create a situation in which not only human performance, but the viability of the system itself will be a direct function of the vital activity of humans as one of its functional components. This relationship is so strong that the traditional idea of the man-rated LSS as something extrinsic to the humans it supports will cease to be obligatory, since the humans will become the object of support only to the extent that they themselves are an essential component of the system as a whole. The prototype for such a system is the natural environment on Earth, existing by virtue of continuous assimilation of elements from nonliving nature by living things and vice versa.

Soviet science started to work in the area of BLSS 30 years ago in connection with the goal of the exploration of space. This research clarified the general principles for the design of such systems, their functional and biocenotic (ecological) structure, properties of their major functional components, the requisite technology, and ways to increase degree of system closure.

As a result, the Soviets created ground-based models of BLSS based on the activity of one-celled algae, higher plants, and microorganisms. These models utilized certain physicochemical processes to return a number of products of organic wastes to the cycle. They demonstrated that a BLSS with a limited number of species and restricted mass of living matter was capable of relatively autonomous existence in a limited area comparable to that available on actual spacecraft. The stability of such systems was supported by mechanisms intrinsic to the system itself, with minimal intervention from outside. The stability of the systems and the number of functions they performed (some of which were not planned in advance) attest to the fact that the models possess the properties of a closed ecological system. These models confirmed the correctness of our approach and of the principles we used to create closed ecological systems, and demonstrated in principle that human life can be supported for long periods of time in isolation from the environment of the Earth.

## HABITABILITY AND ENVIRONMENT EFFECTS

For a long time in the future complete satisfaction of human needs on space stations will continue to depend on the limited capacities of space technology. For a long time we will still have to contend with the fact that technical limitations have first priority. But this state of affairs is in principle temporary. The inevitable increase in the technical capacities (including provision of power) of cosmonautics will erode the predominance that must now be given such considerations and gradually increase the priority of human needs. In this regard, the problem of habitability as an important component of the science of human ecology will encompass an increasing amount of knowledge about man himself, as well as of his living environment.

The solution of the problem of habitability obviously requires, first and foremost, integration of the findings in various areas of space (and also naval, etc.) medicine -- traditional hygiene, physiology, immunology, epidemiology, psychophysiology, and social psychology -- with the findings of the physics, chemistry and biology of the atmosphere and water, as the major components of the living environment, which will lead to the development of a holistic science - human ecology.

For today the main thing is clear: it is in principle possible for humans to live and work in space for an arbitrarily long time. In principle, the duration of human isolation from contact with conditions on the Earth may be increased in direct proportion to how representative a portion of the biosphere of the Earth has been incorporated into the actual BLSS. The author's analysis has not yet dealt with the biosocial and psychosocial aspects of the problem, the limiting significance of which will increase in proportion to duration of isolation from the Earth. However, to realize the potential of such research, it is essential that experimentation be raised to a new level and that the research strategy be proactive, since, due to the nature of their subject matter, duration of experiments cannot be curtailed. The time when an implemented BLSS project must be available can only grow nearer. Today the best strategy for generating a BLSS for the near future would be to develop mixed systems based on a combination of physicochemical and biological processes, with gradual increase of the proportion of the latter through increasing capacities of space technology.

Table 1: Characteristic time for onset of disruption of the natural links between an organism and environmental factors

Table 2: Output (in t/year) of certain mass-exchange process in the biosphere [3]

Vapors of natural or anthropogenic aerosol-forming substances	$1 \times 10^9$
Output of ions with transpirational water of plants	$1.2 - 1.4 \times 10^9$
Spores and plant pollen	$1.6 \times 10^9$
Volcanic emissions into the atmosphere	$2.3 - 3 \times 10^9$

**MONOGRAPH:**

M163(29/90) Beregovoy GT, Yarpolov VI, Baranetskiy II, Vysokanov VA, Shatrov YaT.  
Spravochnik po Bezopasnosti Kosmicheskikh Poletov  
Справочник по Безопасности Космических Полетов  
[*Handbook on Space Flight Safety*]  
Moscow: Mashinostroyeniye; 1989.  
[366 pages; 68 Figures; 30 Tables; 63 References; 2 in English]

**KEY WORDS:** Habitability and Environmental Effects, Space Flight, Safety, Radiobiology, Equipment and Instrumentation, Cosmonaut Selection, Cosmonaut Training, Human Performance, Contingency Situations, Survival

**Annotation:** This book describes hazards confronted by spacecraft crews of spacecraft and the capacity of humans to endure adverse factors. General and specific safety parameters are cited. Safety specifications for the design, systems, and materials used in spacecraft, onboard and ground-based safety devices are described. The methods for ensuring the safety of space flights utilized during the construction, testing, and use of space technology are discussed. This book is intended for specialists working in the construction, testing and utilization of manned spacecraft.

**CONTENTS**

Abbreviations (3)

Foreword (4)

**Chapter 1: General Information (5)**

- 1.1 Major aspects of space flight safety (8)
- 1.2 Reasons for danger to the crew (16)
- 1.3 Reasons for the occurrence of emergencies (35)
- 1.4 Hazards (40)
- 1.5 Human capacity to tolerate exposure to adverse factors (42)

**Chapter 2: Parameters of space flight safety (57)**

- 2.1 A methodology for quantitative estimation of level of safety of spacecraft crews in flight (57)
- 2.2 Probabilistic parameters of safety (68)
- 2.3 Statistical parameters of safety (69)
- 2.4 Specific parameters of safety (82)

**Chapter 3: Generating specifications of flight safety (94)**

- 3.1 Setting quantitative standards for level of flight safety (94)
- 3.2 Setting standards of flight safety using qualitative specifications (100)

**Chapter 4: Specifications to ensure safety of spacecraft crews (102)**

- 4.1 General remarks (102)
- 4.2 Specifications to ensure crew safety at launch and during insertion into orbit (105)
- 4.3 Specifications to ensure crew safety during orbital flight (106)
- 4.4 Specifications to ensure crew safety during descent and after touchdown (112)
- 4.5 Design specifications for manned spacecraft and its safety systems (114)
- 4.6 Specifications for material selection (116)
- 4.7 Specifications required by adverse environmental factors (117)
- 4.8 Specifications to ensure safety of crew activities on board the spacecraft (117)

4.9 Specifications for the selection and training of cosmonauts (118)

**Chapter 5: Procedures for assessing and verifying flight safety specifications for designing, testing and utilizing manned spacecraft (119)**

- 5.1 General procedures for verifying safety requirements of devices during their development (120)
- 5.2 Characteristics of the assessment and verification of safety requirements during design (121)
- 5.3 Procedures for evaluating the significance of safety parameters (122)
- 5.4 Verifying safety requirements in experimental development and ground testing (129)
- 5.5 Evaluating conditions of crew safety from the results of completed space flights (130)
- 5.6 Evaluating a rocket-space station complex on the basis of the correspondence of qualitative safety requirements (131)
- 5.7 Evaluating the program for training cosmonauts to act in contingency situations (131)
- 5.8 A methodological approach to evaluation of probability parameters of flight safety (132)

**Chapter 6. A safety program (138)**

- 6.1 General remarks (138)
- 6.2 Basic requirements for safety programs (138)
- 6.3 The major divisions of the program (141)
- 6.4 Safety measures utilized during all stages in the development and utilization of systems (141)
  - 6.4.1 Safety measures at the development stage (143)
  - 6.4.2 Safety measures at the serial production stage (152)
  - 6.4.3 Safety measures at the utilization stage (152)

**Chapter 7. Training cosmonauts to act in contingency (emergency) situations (154)**

- 7.1 Objectives, goals, stages and subject matter of training (154)
- 7.2 Generating the components of contingency (emergency) situations for training cosmonauts (165)
- 7.3 Training methods for use in cosmonaut training (167)
- 7.4 Methodological principles for planning curricula for training on multipurpose and specialized training simulators (170)
- 7.5 Methodological principles for planning training schedule (174)
- 7.6 Techniques for introducing contingency situations into the training process (179)

**Chapter 8: Methods of ensuring flight safety in the process of flight testing and utilizing space technology (182)**

- 8.1 Detection and recognition of contingency (emergency) situations (182)
- 8.2 Predicting the occurrence of contingency (emergency) situations (192)
- 8.3 Identification of unforeseen contingency (emergency) situations (195)
- 8.4 A generalized algorithm for crew and ground control personnel actions in contingency (emergency) situations (202)
- 8.5 Methods using analogues, trainers and simulators for ensuring operations safety of space flights (208)

**Chapter 9: Emergency rescue operations (214)**

- 9.1 Use of emergency rescue systems (214)
- 9.2 Crew rescue in orbit (216)
- 9.3 Specifications for an emergency rescue spacecraft (221)
- 9.4 A general schema for the rescue of the crew of a reusable spacecraft (222)

**Chapter 10: Ensuring survival of manned spacecraft crews under extreme conditions after forced landing (228)**

- 10.1 Characteristics of various climatic and geographical zones (228)
- 10.2 Survival techniques (238)
- 10.3 Survival aids (251)

**Chapter 11: Investigation of emergencies and disasters (257)**

- 11.1 Organizations of investigations into emergencies and disasters (257)
- 11.2 Methodological issues in investigation of emergencies and disasters (261)

**Appendices (268)**

- 1. Terms and definitions in spacecraft safety (268)
- 2. Crew protection devices (273)
- 3. Crew rescue devices (301)
- 4. Methods for evaluating safety of space flights

References (328)

Subject index (331)

## PAPER:

P1317(29/90)\*\*Ivanov AP, Goncharov IB, Repenkova LG.

***Changes in rheological parameters and hemodynamics in response to a 14-day period of hypokinesia with head-down tilt.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 30-32; 1990.

[19 references; 7 in English]

Hematology, Rheological Parameters, Cardiovascular and Respiratory Systems, Hemodynamics  
Humans, Males  
Hypokinesia, Head-Down Tilt

**Abstract:** A total of nine apparently healthy males, aged 25-42, were exposed to a 14-day period of hypokinesia. The following parameters were tested: dynamic viscosity of blood at three rates of shear (0.5, 1.0 and 5.0 sec<sup>-1</sup>); viscosity computed according to Casson's formula; blood yield limit; coefficient of erythrocyte aggregation; stroke volume; cardiac output; and total peripheral resistance. Rheological parameters of blood were measured using a viscosimeter at a temperature of 25±0.1°C, and hemodynamic parameters using impedance plethysmography. Blood samples were taken from the ulnar vein on days 3, 7, and 14 of treatment. Hemodynamic parameters were measured at the same time.

On day 3 of treatment, dynamic viscosity of blood increased significantly, by 50%, 52% and 66%, at the three levels of shear, respectively. The maximum change in dynamic viscosity occurred on day 14 of treatment on which it reached 68%, 77%, and 84% at the three shear levels. Viscosity measured according to Casson's equation also increased, exceeding baseline by 79% on day 3 and 124% on day 14. Changes in erythrocyte aggregation and yield limit were not significant. Stroke volume and cardiac output decreased, while peripheral resistance decreased throughout treatment, with differences reaching statistical significance on day 14.

A correlational analysis showed that on day 3, output and yield limit were highly correlated ( $r=0.69$ ), while yield limit and total peripheral resistance were negatively correlated ( $r=-0.73$ ). On day 14, stroke volume was correlated with dynamic viscosity at shear speed of 0.5 and 1.0 sec<sup>-1</sup> and with yield limit ( $r = 0.77, 0.64$  and  $0.88$ , respectively). On this day cardiac output was correlated with dynamic viscosity at shear speeds of 0.5 and 1.0 c<sup>-1</sup> ( $r=0.85, r=0.73$ ), and with yield limit ( $r=.074$ ), while resistance was highly negatively correlated with dynamic viscosity at all levels of shear.

Thus the results suggest a strong relationship between parameters of central hemodynamics and blood rheology under conditions of hypokinesia with head-down tilt. It would be reasonable to expect similar associations in weightlessness.

Table 1: Rheological parameters of blood at various points during a 14-day period of hypokinesia with head-down tilt

Table 2: Hemodynamic parameters at various stages of a 14-day period of hypokinesia with head-down tilt

P1329(29/90)\*\*Belchenko DI.

***Rosette formation in peripheral blood of rats exposed to hypokinesia.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 58-59; 1990.

[12 references; none in English]

Hematology, Rosette Formation, Macrophages, Histology

Rats, Males

Hypokinesia, Immobilization Cages

**Abstract.** Blood from 37 white male rats undergoing a 30-day period of hypokinesia in immobilization cages was studied. Blood was taken from the caudal vein in a baseline period and after 30 hours and 18 and 30 days of hypokinesia, and 1 week after treatment completion. Blood smears were stained. Histochemical studies of the activity of peroxidase, and level of lipids were performed. In 12 rats blood was taken only once on day 6, to exclude the possibility that effects were due to tissue traumatization during the blood sampling procedure.

The blood of all rats subjected to hypokinesia contained a large number of large mononuclear cells with extensive light blue cytoplasm, a large centrally located round nucleus with homogeneously stained chromatin, sometimes with nucleoli or fragments of them. The chromatin of the nucleus of these cells was coarser and more compact than in lymphoblasts. Some cells showed eccentric location of the nucleus. Some of the mononuclear cells were surrounded by erythrocytes adhering to their surface, similar to rosette formation. Some mononuclear cells had cytoplasmic outgrowths similar to pseudopods. Signs of leukocytosis and relative leukopenia were also present. The authors believe these cells are macrophages. However, there were only slight indications of destruction of erythrocytes. Blood of animals sampled only once contained large mononuclear "macrophages," and displayed leukocytosis, and increased number of medium-sized lymphocytes. Rosette formation was most pronounced during early days of hypokinesia and is evidently associated with adaptation to it.

The authors argue that the appearance of large mononuclear cells may be explained by their formation from monocytes as a result of stimulation of the latter by altered erythrocyte membranes. Change in the properties of erythrocyte membranes may be the cause of rosette formation and further interactions of erythrocytes and macrophages, which could accelerate erythrocyte destruction in hypokinesia.

Table: Concentration of leukocytes and change in the leukocyte count in peripheral blood of rats exposed to hypokinesia

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BLACK AND WHITE PHOTOGRAPH

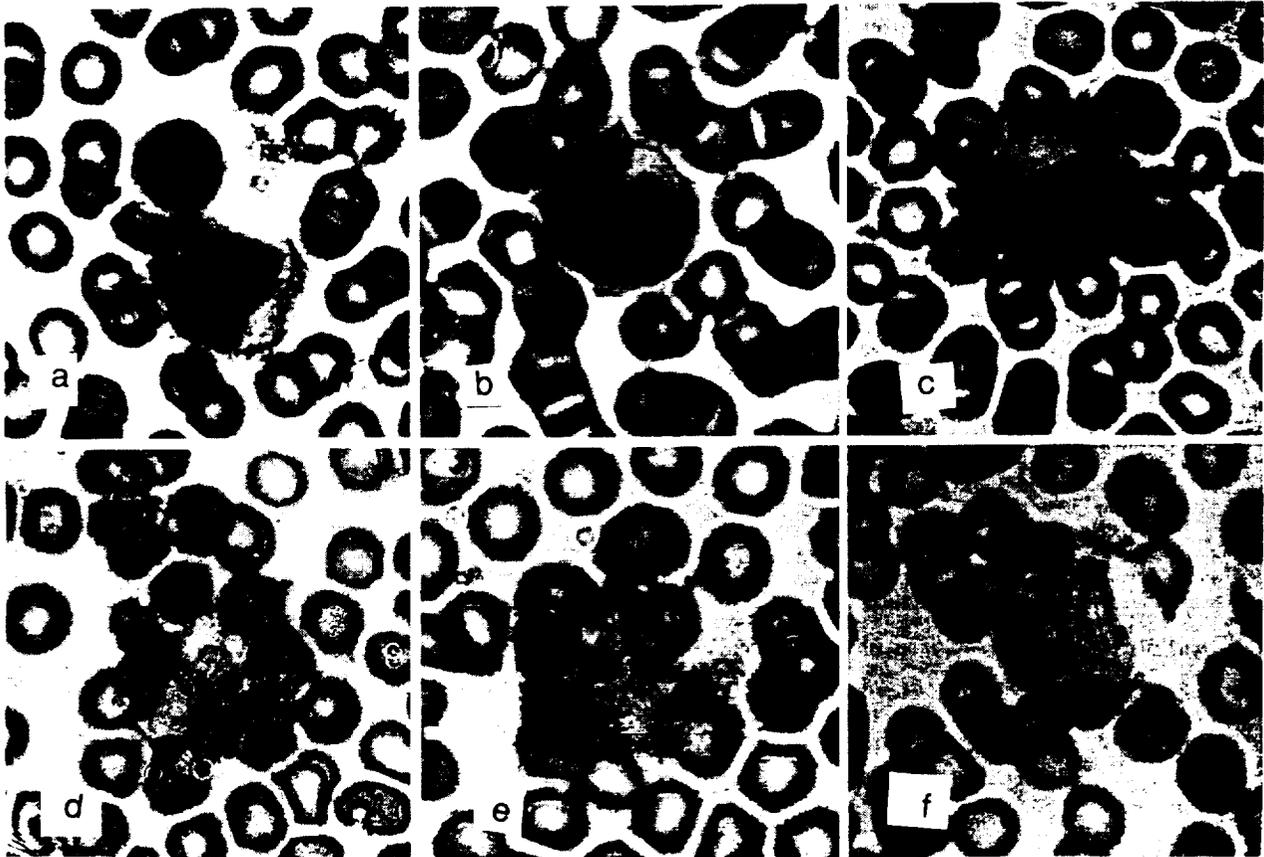


Figure: Peripheral blood of rats in hypokinesia  
 a - mononuclear cell - macrophage, forming outgrowths; b - intercellular contacts between mononuclear macrophages and erythrocytes; c, d - rosette formation; e, f, macrophage engulfing erythrocytes

P1339(29/90) Kalandarova MP.

***Results of hematological studies in long-term hypokinesia with head-down tilt.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 76-77.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Hematology, Blood Parameters, Immunology

Humans, Males

Hypokinesia, Head-Down Tilt, Long-Term, 370 Days

**Abstract:** The blood system is an important indicator of environmental effects and is of great significance in the mechanisms underlying human adaptation to the set of space flight factors.

This work presents results of research on dynamic changes in hematological parameters (count of erythrocytes, hemoglobin, reticulocytes, thrombocytes, leukocytes and their different forms, and also hematocrit, mean erythrocyte volume, mean concentrations and absolute levels of hemoglobin in a single erythrocyte, rate of erythrocyte sedimentation) in subjects undergoing a 370-day period of hypokinesia with head-down tilt. It was shown that the mean fluctuations in the morphological composition of blood in a group of 9 subjects (with the exception of certain parameters) did not exceed the boundaries of the norm throughout the entire observation period, including baseline, hypokinesia, and rehabilitation. During the baseline period, erythrocyte volume was elevated once and concentration of hemoglobin in the erythrocyte was depressed. Throughout hypokinesia with head-down tilt, monocytosis, lymphocytosis, and a tendency to neutropenia (attributable to decrease in quantity of neutrophils in some subjects), thrombocytopenia, basophilia, and decreased concentration of hemoglobin in a single erythrocyte were all noted periodically. In the majority of cases erythrocyte volume was somewhat elevated at various stages in the research. Hematocrit fluctuated, above and below the norm. During the rehabilitation period, the following deviations were observed a single time: decrease in red blood count and hemoglobin, decreased hematocrit, increased erythrocyte volume, and number of basophils. Monocytosis was observed at three measurement points. The etiopathogenesis of these reactive shifts in the blood system in response to 370 days of hypokinesia with head-down tilt should be viewed as a result of the combined effects of the adverse factors characteristic of these conditions, particularly the decrease in resistance to infection, and not only of hypokinesia per se.

A comparative analysis of the dynamics of blood parameters in subjects under conditions of a 370-day period of hypokinesia with head-down tilt and those found during a 1-year space flight attest to the continuance of physiological regeneration of the blood system in individuals under long-term exposure to hypokinesia or space flight.

PAPERS:

P1308(29/90)\* Sapova NI, Grozov VM.

***The effect of various pharmacological agents on general state, heart rhythm , and performance efficiency of operators.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 64; 1990.

Human Performance, Performance Efficiency, Cardiovascular and Respiratory Systems, Heart Rhythm

Humans, Males, Operators

Mental Tasks, Pharmacological Agents

Translation of Abstract: A study was performed on general state, cardiac rhythm (measured through rhythmocardiography) and performance efficiency of 10 healthy male subjects in a 3 - hour session involving 10 minutes of task performance with 5-minute breaks. A special keyboard device recorded parameters of performance level automatically. The task consisted of multiplication of three-digit numbers by three-digit numbers on paper. Five conditions were run, including a control (no drug), administration of Obzidan (Inderal), Platiphyllin (a drug derived from the groundsel plant, used as a cholinergic), and Seduksen (Valium), given orally in small therapeutic doses. In the control condition it was demonstrated that as a consequence of short-term hypokinesia, which induces bradycardia, increased sinus arrhythmia and drowsiness, there was a restructuring of blood supply and deterioration of task performance. Obzidan and caffeine increased alertness, bradycardia [sic] more pronounced than in the control condition, and improved performance efficiency throughout the experimental period. Platiphyllin led to increased performance efficiency only during the first hour of work. Seduksen decreased performance efficiency, primarily during the first hour of work.

Thus, changes in functional state due to various drugs to a significant degree determined how the operator feels and the effectiveness of his performance of relatively stressful work.

## HUMAN PERFORMANCE

P1342(29/90) Ioseliani KK, Khisambeyev ShR.

***Predicting mental performance of cosmonauts on long-term flights.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 236-237 .

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Human Performance, Mental Tasks,

Humans, Males, Cosmonauts

Space Flight, Long-Term, Equipment and Instrumentation, Pleven-87

**Abstract:** Introduction. One of the most important tasks of space psychophysiology is the timely, reliable, and valid prediction and assessment of the psychological performance of cosmonauts, especially on long-term flights. At present, data has been obtained from tests of mental task performance of the cosmonaut-physician on days 3, 143, and 192 of a flight, and also during the pre- and postflight periods. This research used the "Pleven-87" apparatus.

**Method.** The "Pleven-87" apparatus was developed by Soviet and Bulgarian specialists and provides an assessment and short-term prediction of mental performance on the basis of results of the following tests: "continuous computation at a stipulated tempo," "self-paced continuous computation," "complex sensorimotor reactions with psychological feedback," "conditioned motor responses," and "response to moving object."

**Results:** The data obtained demonstrate the retention of high psychological performance capacity throughout the flight. For the majority of parameters, the speed and accuracy of performance on computational/logical and sensorimotor tasks showed either stability or improvement over the course of the flight, which attests to mobilization of psychophysiological resources of the cosmonaut-physician during the flight. The single exception was an insignificant decrease in the integral score on computational/logical tasks on day 3 compared with the preflight level, reflecting the stage of warm-up during the period of acute adaptation to weightlessness. For comparison, we note that the overall score of the sensorimotor component on day 3 of flight exceeded preflight level by 1 unit (on a 9-point scale).

When computational and logical operations had to be performed at a stipulated rate (the most difficult of the tasks) the most striking aspect was the availability of a significant amount of extra time. It is important to note that throughout the long-term flight the amount of extra time was virtually constant in the cosmonaut-physician. This suggests a stable level of psychological performance capacity, the possibility of compensating for the adverse effects of flight factors through use of higher psychological functions, and allows prediction of the psychological performance capacity of the cosmonaut.

The results obtained on the cosmonaut-physician after landing show that during the initial period of adaptation to the Earth after the long-term flight, high level of psychological performance capacity persisted.

## HUMAN PERFORMANCE

Conclusions. The high prognostic validity, appropriateness, and information value of the set of instruments has been demonstrated, suggesting its promise for use in psychophysiological studies of the crews of orbital space stations.

## HUMAN PERFORMANCE

P1345(29/90) Salnytskiy VP, Shevchenko AG, Dudukin AV, Ryabov EV, Nikonov AV.  
***A technique of semi-full-scale simulation and its use inflight to increase psychological readiness of cosmonauts.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoj Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 271-273.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Human Performance, Psychological Readiness

Humans, Males, Cosmonauts

Space Flight, Man-Machine Systems, Equipment and Instrumentation, Semi-Full-Scale Simulation, Cosmonaut Training, Mathematical Modeling

**Abstract:** The state of development of manned cosmonautics today is marked by a great number of scientific and applied investigations that require cosmonauts to perform complicated and responsible operations starting on the first day in orbit and continuing throughout a flight. This requires stability of skills for controlling the spacecraft and high levels of physical and psychological readiness to perform various tasks. At the same time experience with medical support of manned space flights suggests that the first 2 weeks of flight (acute period of adaptation to weightlessness) is accompanied by functional disorders (subjective discomfort, spatial disorientation, disrupted motor coordination, and others), and in a number of instances decreases in psychological performance and in the quality of job performance. Thus, in training crews serious attention must be devoted to development of professional skills in the context of exposure to combinations of space flight factors in ground simulations. However, at present cosmonautics does not possess ground training simulators /research apparatus that could support the most complete simulation of dynamic, informational, geometric and psychological analogs of the mission task performance of cosmonauts on the one hand, and combinations of space flight factors on the other.

For this reason, we developed a theoretical rationale and design (blueprint) for the use of ground training simulators/research apparatus, telemetrically in contact with onboard devices for manual spacecraft control and information display systems. The methodology involves the following: the cosmonaut, at his work station of the spacecraft, sees on the television screen information concerning the state of the objects he is controlling transmitted along the radio-relay channel from the ground training simulation-research apparatus. On the basis of this information, he uses the control devices and transmits commands to the ground simulator along the telemetric channel to control the object. Thus a closed system of control is created in which the cosmonaut, the system for displaying information, and the control devices are on board the spacecraft, while the object being controlled, in the form of a mathematical model, and the means to translate this model into a visual display are on the ground.

This way of organizing an experiment supports the optimum combination of completeness of simulation of cosmonaut task performance conditions (actual space flight factors, informational and dynamic analogs of the model, and an actual control system) with safety and replicability.

As a result of our study, we identified statistically reliable changes (compared to baseline) in parameters of mission task performance and psychophysiological state of the cosmonaut in

## HUMAN PERFORMANCE

performance of the first experimental task set. We also noted disruption of performance state and decreased attention. When the control task set was repeated, characteristics of performance and state normalized and after 4-5 sessions reached baseline levels.

Our paper describes comparative analysis of experimental data obtained under actual flight conditions and in simulation experiments. The research performed showed that this method is promising as a means to facilitate psychological adaptation of cosmonauts to conditions of mission task performance, and for the development of promising systems of manual control and performance algorithms for contingency situations, study of psychological performance capacity of operators during the acute period of adaptation to space and during long-term exposure to weightlessness, evaluation of the efficacy of prophylactic countermeasures, etc. The paper is accompanied by video tapes made during our investigation.

## PAPER:

P1348(29/90) Lesnyak AT, Vorotnikova IYe, Rykova MP, Meshkov DO.

***Proliferative, suppressor, and cytotoxic activity of splenocytes of rats in the experiment on COSMOS-2044.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 320-321.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Immunology, Splenocytes, Proliferation, Suppressor, Cytotoxic  
Rats  
Space Flight, COSMOS-2044, Tail Suspension

Abstract: The immune system, whose functioning may alter under exposure to various factors, plays an essential role in maintaining physiological homeostasis. Numerous studies have established that space flight factors suppress immunity in humans. However, a detailed study of the mechanisms underlying the changes observed was only possible using animals on a COSMOS series biosatellite.

The goal of the current work was to study mitogen-induced proliferation and suppressor activity, and also natural cytotoxicity in splenocytes of rats spending 2 weeks in weightlessness on-board COSMOS-2044. A suspension of spleen cells was obtained from Wistar-SPF rats in flight, synchronous control, tail-suspension and vivarium groups (n=5 per group). The proliferative activity was measured in 2-, 3-, and 4-day cultures of splenocytes stimulated by low, optimal and high doses of PHA. Con A-induced suppressor activity was studied in an autologous test of suppression of PHA-proliferation. Natural cytotoxicity was studied on the basis of the capacity of killer cells to form conjugates and lyse target cells and also by membrane-toxic activity in an 18-hour test with K-562 and UAS-1 target cells labeled with <sup>3</sup>H-uridine.

Proliferative activity of rat splenocytes in cultures with a minimal dose of Con A was significantly altered only in the tail-suspension group, increasing with increasing duration of cultivation. With optimal dose of Con A on day 2 of cultivation, proliferation was lower in the flight and tail-suspension groups than in the synchronous and vivarium groups. On day 3 the parameter remained depressed in the tail-suspension group and on day 5 increased significantly in the flight and synchronous groups. When dose of Con A was high, there were low levels of proliferation in the flight group and tail-suspension group when cultivation lasted for 2 and 3 days, and in the tail-suspension group after 4 days. With stimulation by PHA, the proliferative response of splenocytes was depressed in flight rats. Activity of nonspecific suppressor cells was sharply depressed in the flight and synchronous groups. The functional activity of natural killers with respect to K 562 cells decreased reliably only in the tail suspension group, while for UAS-1 cells it was depressed in the flight and synchronous groups. The capacity to form conjugates and lyse target cells was depressed in the flight and synchronous groups.

Thus, exposure of rats to space flight for 2 weeks was accompanied by a partial depression of proliferative activity, suppression of the nonspecific suppressor cells, decrease in natural cytotoxicity with respect to one of the two lines of target cells tested, and disruption of the process of conjugate formation and lysis of target. The recovery of proliferative response when cultivation duration increased and the absence of depression of cytotoxic activity to K 562 targets attests to the reversibility of the changes. It should be noted that the reason for the identified immunological shifts was not merely weightlessness, but the entire set of factors characteristic of space flight, since a number of parameters were also depressed in the control groups. Thus, for example, proliferative activity decreased in the tail-suspension group, while suppressor and cytotoxic activity was diminished in animals in the synchronous control condition.

## PAPERS:

P1299(29/90)\* Kozyarin IP.

***A hygienic evaluation of certain moisture and carbon dioxide absorbers recommended for cleaning the air of pressurized environments***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina

24(3): 43-45; 1990.

[12 references; none in English]

Hygienic Evaluation, Microbiology  
Moisture and Carbon Dioxide Absorbers, Zeolite, Silica Gel  
Life Support Systems, Air Cleaning, Pressurized Environments

**Abstract:** To ensure that only hygienically acceptable quantities of moisture and carbon dioxide are present in a pressurized environment, these substances must be removed from the artificial atmosphere. This process takes place through the use of nonregenerative and regenerative methods using sorbents (zeolites and silica gel). The goal of this work was the hygienic evaluation of two samples of absorbers of carbon dioxide (KA-ShM and M-11) and moisture (silica gel KSM-6V), recommended for cleaning the artificial atmospheres of pressurized environments.

The study of absorber samples was conducted in two stages. The first stage entailed obtaining comparative data descriptive of the qualitative and quantitative composition of volatile components emitted by each sample of sorbents, as well as evaluation of their effect on atmospheric microflora. The goal of the second stage (bench tests) was to study the chemical composition of a set of gaseous products emitted by the sorbents studied separately and in combination. The experiment was performed using a test bench recirculation apparatus. In the first stage of the experiment, a weighed quantity of 0.5 kg of each substance was placed in hermetically sealed containers (exsiccators) with 8 liter capacity and after 1 hour air samples were removed through a tube for chemical analysis. A quick analysis method utilizing a UG-2 gas analyzer was used. Air (250-300 ml) was blown through for a period of 1 to 10 min. The air studied was analyzed for carbon monoxide, hydrogen sulfide, sulfur anhydride, chlorine, toluene, and hydrocarbons. A total of 57 air analyses were performed. The effects of sorbents on atmospheric microflora utilized the Koch method traditionally used in sanitary microbiology

The second stage of the research utilized a test-bench recirculation apparatus consisting of a glass tube 80 m in length and 50 mm in diameter with porous plates at the top and bottom (the bottom one was fixed). An electrothermometer was mounted inside the tube so that the temperatures to which the sorbents were heated could be recorded in the range of 70 to 300° C. The upper portion of the apparatus was hooked up to a compressor. Moistened air was blown through the absorber at a rate of 0.5-1.0 l/min/cm<sup>2</sup>. The order of the sorbents in the device from top to bottom was: layer of silica gel 100 mm thick, KA-ShM zeolite 20 mm thick, product M-11 (170 mm. thick). The temperature of the air entering the devices was 20-39° C, and moisture content on entry was a maximum of 15 g/m<sup>3</sup>. Two devices were used: the first was the main apparatus and the second was used to regenerate the sorbents. Heating (regeneration) of the sorbents occurred at a temperature of 160° C for 25 minutes. To investigate the gaseous products emitted by the groups of absorbers studied on day 1 of the experiment, physicochemical analysis was first performed on the air which had passed through the apparatus. For each sorbent separately, the chemical composition of the air was measured at the beginning of the study and 1 and 2 hours after the start of the experiment for 1, 3, 5, and 7 days. Composition of the air when all the absorbents were used in combination was studied analogously. At the same time volunteers assessed the odor of the samples. Subjects of both

## LIFE SUPPORT SYSTEMS

sexes, aged 18-37, with no disease affecting the olfactory organs participated. More than 60 observations were performed. The second stage of the research (regeneration) involved heating each sorbent and then the sorbents in combination at a temperature of 160° C, blowing air through them (after cooling), and then determining the physicochemical properties of the air and rating their odor.

The research demonstrated that the sorbents studied do not emit harmful volatile components such as carbon monoxide, hydrogen sulfide, chlorine, toluene and/or hydrocarbons into the air of experimental pressurized chambers. However, traces of sulfur anhydride were detected, evidently explained by its absorption by the sorbents during transportation and storage. The second study had analogous results with respect to physico-chemical parameters. The data show that these materials do not stimulate the development of atmospheric microflora regardless of exposure duration. On the contrary, as exposure increased the level of microbial contamination decreased. Thus, this parameter also indicated that sorbents may be recommended for use for this purpose.

The eight odor testing sessions established that the KA-ShM, M-11 and KSM-6V sorbents do not have a strong odor, either separately or in combination. This was true before and after regeneration. In all series of observations the volunteers described the odor of the sorbents as unidentifiable or resembling rubber with an odor strength rating of 1-2 [not specified how many points on the rating scale]. When the regeneration device was filled with a mixture of sorbents a smell of rubber was noted by all the volunteers. This phenomenon probably can be explained by the fact that the majority of tubes in the device were made of vinyl polychloride or ordinary rubber. When the sorbents were heated (regeneration) singly or in combination, certain volunteers reported the smell of alcohol, formalin, rubber, and milk, but the strength rating did not exceed 1-2.

Thus, on the basis of the results of the hygienic evaluation of absorbers of carbon dioxide (the zeolites KA-ShM, product M-11) and moisture (KSM-6V silica gel), one can conclude that by virtue of their physicochemical and sensory properties they can be recommended for cleaning and drying the air of pressurized environments.

Table 1. The effect of moisture and carbon dioxide absorbers on atmospheric microflora

Table 2: Results of rating of odor of volatile components emitted by moisture, and carbon dioxide absorbers

Table 3: Results of ratings of odor of volatile components emitted by a mixture of sorbents after heating and blowing air through them

P1304(29/90)\* Adamovich BA, Ratner GS.

***A methodology for evaluating and selecting a life support system during the early stages of design.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina

24 (3): pp. 56-57; 1990

[9 references; 1 in English]

Life Support Systems, Regenerative, Evaluation, Selection  
Theoretical Article  
Mathematical Modeling

Abstract: Optimization criteria for past life support systems based on consumable stores have utilized criteria such as initial weight, cargo weight for a single delivery, total weight, labor intensity, maintainability, reliability parameters, and development time and cost. However, provision of oxygen, water, and food to the crew of a spacecraft during a long-term flight is possible only if we design and implement a new type of regenerative LSS. Existing approaches to designing regenerative LSS are being analyzed and new directions are being explored. Thus, for example, it has been noted that, unlike previous systems, regenerative LSS cannot be reduced to a set of modular blocks, each of which reprocesses an element of the environment. Therefore a modular approach to the design of LSS structure will result in loss of the integral properties characteristic of the system as a whole. A new approach has been proposed that makes it possible to evaluate efficiency of heat-mass conversion. This approach treats the LSS system as a whole and utilizes minimax criteria of efficiency for designing systems that are optimal from the standpoint of cost benefit and thermomass analyses.

The authors consider the problem of evaluating and selecting rival LSS for spacecraft from the standpoint of higher order systems, i.e., from the standpoint of the goals of the space mission. Any spacecraft system, including the LSS as one of its most important components, must be evaluated first and foremost with respect to cost effectiveness, i.e., the contribution which, for example, the LSS will make to the cost effectiveness of the work of the spacecraft crew.

Here cost effectiveness should be taken to mean the difference between the benefit, expressed in monetary terms, accruing to the economy from the work of the spacecraft crew that can be attributed to the utilization of one or another LSS, and the expenditure associated with that system's development, manufacture, and insertion into orbit and utilization.

If the cost effectiveness of an LSS is considered from the standpoint of the crew, then it turns out that the maximum LSS effectiveness occurs, when the LSS:

- meets all the needs of the crew essential for life;
- is safe;
- is easy to maintain;
- requires minimum volume

Surprisingly, the crew is not affected by either the weight of the LSS or its energy consumption, as long as it satisfies the above conditions above..

When these conditions are satisfied the crew can devote its entire working day exclusively to obtaining information and producing materials for economic benefits, including scientific research.

## LIFE SUPPORT SYSTEMS

When it is actually designed, every LSS will undergo extremely rigorous evaluation with respect to crew safety and the capacity to produce all that is necessary for life (water, oxygen, and a portion of the food) in the required quantities. Thus, the efficiency function, i.e., the cost effectiveness of the LSS, may be represented as depending on only two parameters, the labor intensity of maintaining the LSS and the space it occupies, with limitations on the reduced mass, and development cost time .

The authors derived efficiency functions, through the use of equations relating these parameters and predictive estimates of life support parameters computed for an operating duration of 1 year and including blocks for regenerating water from atmospheric moisture, urine, and other waste products and wash water and blocks for regenerating oxygen from carbon dioxide. The authors argue that this approach to designing a LSS, while well justified, is presently impeded in its practical implementation by the relatively complex task of first determining the cost effectiveness attributable to decreasing LSS maintenance time or the space the system occupies.

They conclude that, at present, in the interests of optimal design, it seems desirable to use another approach, based directly on the experience of developers and designers of regenerative LSS, experience which has generated actual statistical data. In particular, the well known mathematical methods of Bayesian theory may be applied, making it possible to accept a solution under conditions of uncertainty based on *a priori* and *a posteriori* distributions of probabilities. Use of both approaches in combination is recommended

P1322(29/90)\*\*Ivanova IYe, Derednyayeva TA, Alekhina TP, Shaydarov Yul.  
***The higher plant component in man-rated biological (bioregenerative) life support system.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 40-43; 1990.

[18 references; none in English]

#### Functional Characteristics

Botany, Higher Plants, Wheat, Peas, Carrots, Beets, Cabbage

Life Support System, Bioregenerative, CELSS, Higher Plants-Man-Mineralization

**Abstract:** The goal of this experiment was to study the functional characteristics of a man-plants-mineralization life support system. Plants were cultivated in an airtight green house about 70 m<sup>3</sup> in size, with a growing surface of 15 m<sup>2</sup>. Wheat occupied 11.25 m<sup>2</sup>, peas 1 m<sup>2</sup>, carrots and beets 0.625 m<sup>2</sup> each, white cabbage 1.25 m<sup>2</sup>; and the seedbed? 0.25 m<sup>2</sup>. The plants were grown hydroponically with periodic addition of a nutrient solution. Cultivation of the wheat involved conveyor sowing with 9 age groups with 7-day intervals between harvests. Other vegetable crops contained from 5 to 8 age groups. Harvesting occurred on day 65 for wheat, and after from 53 to 77 days for the other vegetables. The wheat and vegetables received nutrient media from two different sources, one that was continuously present and another corrective solution added twice a week to support concentration of biogenic elements at the following levels (in mg/liter): N 50-80, P 30-50, K 100-150, Ca 100-150, Mg 20-30 (pH 5,6-5.8). At some points during the experimental period concentration of nitrogen increased up to 250 mg/liter, mainly due to ammoniated nitrogen generated by microbiological decay in the mineralization component. Air parameters were maintained at the following levels: temperature 22-25°, and relative humidity 55-70%, CO<sub>2</sub> concentration during preliminary cultivation was - 0.35-0.40%, and during the experimental period 1.0-1.2%, oxygen concentration was 20.0-23.0%. Illumination was continuous at 60-80 W/m<sup>2</sup> PAR above the vegetables and 125-185 W/m<sup>2</sup> PAR above the wheat. The plants were grown for a period of 6 months. Parameters studied included productivity and structure of the crop, consumption of the major biogenic elements and water, concentration of carbohydrates and vitamins in the edible portion of the plants. The schedule of events was as follows: days 1 - 35 - control period; days 35-60 presence of the mineralization component; days 60-90 presence of humans as well as the mineralization components, days 90-105 addition of algae to the other components. For the purposes of analysis the first 35 days (5 crops) were considered a control period and the subsequent 70 (10 crops) days were considered experimental.

Total productivity (yield) of the wheat plants increased. That of the peas remained the same, while that of other vegetables was between 10-40% below baseline in the experimental period. However, with the exception of carrots, production of useful biomass decreased during the experimental period. During the experimental period, the density of sowing increased on day 45 and illumination increased from 145 W/m<sup>2</sup> to 270 W/m<sup>2</sup> at the end of the experimental period leading to increased photosynthetic productivity of the plants. Productivity was maximal during days 70-100 of the experimental period, during which the plants were exposed not only to the products of mineralization and desiccation of organic wastes but also to the volatile wastes of humans and algae. However, when productivity was assessed from the standpoint of production of edible substance, wheat decreased virtually to zero during certain periods in the middle of the experiment. During the experimental period tillering of the wheat increased while the absolute weight of grain decreased.

Concentrations of sugars, cellular tissue, and ascorbic acids were measured in the edible portions of the vegetables. In addition, concentration of carotene was measured in the carrots. Experimental conditions had a significant effect on these components. Ascorbic acid increased by

## LIFE SUPPORT SYSTEMS

a factor of 2.5 in the carrots, and fructose and ascorbic acid by a factor of 2.2 in the beets, while glucose and sucrose decreased by nearly a factor of 2 in the same plants. In the pea, cellular tissue decreased by 13%. Growth in the closed system did not significantly affect plants' consumption of biogenic elements, with the exception of calcium, which in the wheat decreased by more than a factor of 2. Decrease in water consumption in the vegetables approached significance.

When solutions used in the wheat and vegetable experiment were compared with freshly prepared equivalent solutions, they were found to stimulate enhanced growth of radishes. Thus the system did not negatively influence the plants through the nutrient media.

In an additional experiment wheat plants were grown in a medium composed of pure salts and in one obtained from the system described above. No differences were found. The authors conclude that the fluctuations in the state of the wheat grown in the system were not due to the growth medium containing condensates of water-soluble gaseous elements in the atmosphere. This narrows the search for the factor negatively affecting the wheat crop to the inhabited atmosphere. The authors further conclude that their results suggest that the criterion of photosynthetic productivity for higher plants does not mirror the optimization of this component if production of edible matter is the chief concern.

Table 1: Productivity of plants in control and experimental conditions

Plant	Condition	Growth in plant biomass, g dry substance per 1 m <sup>2</sup> per day	
		total	edible
Wheat	Control	25.8	5.31
	Experimental	32.8	4.66
Peas	Control	12.8	3.46
	Experimental	12.9	2.29
Beets	Control	8.4	3.40
	Experimental	5.0	2.27
Carrots	Control	11.0	6.01
	Experimental	9.7	6.34
Cabbage	Control	16.0	14.37
	Experimental	14.2	12.86

Table 2: Concentration of sugars in the edible biomass of plants

Table 3: Consumption by plants of mineral nutrients and water

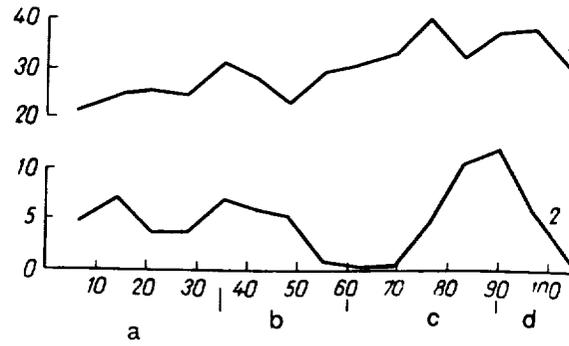


Figure: Dynamics of productivity of wheat plants

Abscissa - time (in days), ordinate - productivity (In g/m<sup>2</sup> per day), a - control period, b - inclusion of mineralization component, c - inclusion of humans, d - inclusion of algae. 1 - total biomass, 2 - edible biomass.

P1347(29/90) Ivanov IYe, Derendyayeva TA, Mashinskiy AL, Nechitaylo GS.

***The effect of space flight on the sowing and productive properties of seeds.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 307-9 .

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Developmental Biology, Plant Development, Genetics, Mutations  
Botany, Plants, Seeds, Lettuce, Dill, Radish, Garden Cress  
Life Support Systems, Space Flight, Long-Term, Mir, Radiobiology

Abstract: In cultivating plants on long-term flights, for example on a Mars mission, there must be a store of seed to produce vegetables for consumption. These seeds will be exposed to the set of space flight factors as well as undergoing natural aging. The literature and our own data show that this will significantly decrease germination and emergence rate and that chromosomal restructuring, multinuclear cells and other changes will occur. These changes are a function of the type of plant, duration of flight, and storage conditions on the spacecraft. These changes are undesirable, so special measures are required to prevent them. This means that we must study the effects occurring in long-duration exposure of seeds to space flight factors in more detail.

The research material was seeds of taxonomically various plants: lettuce (compositae family), dill (umbelliferae family), radish and garden cress (cruciferaefamily) exposed to space for 240 days on space station Mir. After return to Earth, for 28 days these seeds were cultivated in a hydroponic cultivation unit on the "Balkanin" granular salt-saturated substrate in a temperature controlled environment with environmental parameters maintained at: air temperature 21-23°C, relative humidity 50-60%, CO<sub>2</sub> concentration 0.03%, illumination intensity 30-40 W/m<sup>2</sup> in the photosynthetically active radiation zone. Illumination was constant around the clock, the area of the growing container was 0.05 m<sup>2</sup>. The seeds were sown in the following quantities: lettuce - 50, radish - 40, dill and garden cress - 80 seeds per container, based on the sowing standards for field conditions. After 7 days of cultivation, the germination rate was determined, the number of sprouts counted and then the plants were thinned. The final density of sowing was 16 radish plants, 20 lettuce and garden cress, and 25 dill plants per container.

The results of the research showed that the germination rate of the lettuce, radish, and cress seeds exposed to space was 10-15% below that of the control, which for the duration and storage conditions was not significant. The experimental dill seeds displayed a germination rate only 59% of control. The morphometric characteristics of the sprouting plants — height, number, size of leaves, and coloration — were no different from controls. When the yields of flight and control seeds were compared, it was found that flight plant yields were never lower than control and that in the case of garden cress yield was 27% higher than control. This effect may be considered the result of radiostimulation.

Study of the composition of the biomass of the experimental plants showed only a significant decrease (by 28%) in the specific content of ascorbic acid in the leaves of the garden cress compared to control. If one considers that yield of these plants was elevated by an almost

## LIFE SUPPORT SYSTEMS

identical figure, then the total amount of ascorbic acid produced was no different from control plants.

Germination dynamics of seeds as a function of duration and conditions of storage of seeds on Earth have been well studied. However, these results do not take into account the specific conditions of space flight and cannot be used directly in developing programs for using space greenhouses. With regard to conditions of space flight, an important new factor is the level of residual radiation in the area where the seeds are stored. Research must be extended to long-duration storage with parallel measurement of the total radiation dose of seeds.

## MATHEMATICAL MODELING

### PAPERS:

P1298(29/90)\*Kondrachuk AV, Sirenko SP.

***A model of the caloric response of the semicircular canal.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 40-43; 1990.

[11 references; 6 in English]

Neurophysiology, Semicircular Canal

Mathematical Modeling

Caloric Response, Space Conditions

**Abstract:** One theory of the mechanism underlying response to caloric irrigation makes reference to convection of the endolymph, which is associated with gravity. However, this response also occurs in space. Another potential mechanism is thermal expansion of the endolymph. This paper presents a mathematical model of the semicircular canals' response to caloric irrigation that reflects the expansion of the endolymph and allows determination of the conditions under which each of the two proposed mechanisms are dominant. The model describes a situation in which during caloric irrigation the deformation of bundles of receptor cells in the semicircular canals is determined by two flows: one determined by the expansion of the endolymph and the other by convective movement. Contributions of these two factors depend on parameters of the thermal stimulus (rate of warming, size and position of sources of heat relative to the canal and direction of gravity) as well as the parameters of the canal (viscosity of endolymph, radius of curvature and cross section, constant time, thermal conductivity, coefficient of thermal insulation, etc.). The direction of the first flow (either from the area being warmed or to the area being chilled) is determined by the relative temperature of the heat source, while the direction of the convection flow is also due to the orientation of the area being heated relative to the force of gravity. The model provides good agreement with experimental data.

Figure 1: Distribution of vectors of gravitational force and of the area being heated in the semicircular canals relative to the system of coordinates selected

Figure 2: Histogram of distribution of impulse frequencies in time when a portion of the semicircular canal is heated

Figure 3: Histogram of frequency of impulse with  $f=165^\circ$  and ratio of the angle of bending of the bundle of receptor cells to the coefficient of proportionality as a function of time

Figure 4: Histogram of frequency of impulse with  $f=180^\circ$  and ratio of the angle of bending of the bundle of receptor cells to the coefficient of proportionality as a function of time

## PAPER:

P1301(29/90)\*Gorozhanin VS, Lobkov VV.

***Hormonal and metabolic reactions of the human body to long-term fasting.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 47-50; 1990.

[18 references; 3 in English]

Metabolism, Endocrinology

Humans, Males

Nutrition, Fasting, Long-Term

**Abstract:** This work investigated the effects of long-term fasting on a spectrum of hormonal and metabolic parameters in healthy humans. Subjects were 14 male volunteers, aged 25-39, who fasted for 14 days. Access to water was unrestricted. They were also observed during a 14 day recovery period, during which daily calorie intake was gradually increased. Each day subjects took a 40-60-minute walk at a speed of 3-5 km/hour. Blood was taken from the ulnar vein at 9-10:00 in the morning 2 days before the fast began; on days 3, 7, and 14 of fasting; and on day 14 of recovery. Radio immune assay was used to determine concentrations of ACTH,  $\beta$ -endorphin, hydrocortisone, aldosterone, TSH, thyroxine ( $T_4$ ), triiodothyronine ( $T_3$ ) reverse triiodothyronine, STH, prolactin, insulin, S-peptide, glucagon, FSH, LH, testosterone, A+G prostaglandins,  $F_{2\alpha}$ -prostaglandins, cyclic GMP, histamine, cAMP, glucose, free fatty acids, PH and lactate. Concentrations of epinephrine and norepinephrine were also measured in blood and epinephrine, norepinephrine, dopamine, DOPA, metanephrine, normetanephrine, homovanillic acid, and vanillylmandelic acids were measured in daily urine. In six of the subjects hydrocortisone, STH, and insulin were measured every 2 hours around the clock. In three subjects blood was taken daily in the morning. Mean weight loss in the group was 8.7 kg.

The beginning of the fast was accompanied by an almost tenfold increase in plasma epinephrine and sharp increases in concentration of ACTH,  $\beta$ -endorphin, hydrocortisone, STH, aldosterone, glucagon, cAMP, cGMP and their ratio, free fatty acids, and lactate. On day 7, most of these parameters were elevated, but ACTH,  $\beta$ -endorphin and lactate had returned to normal. Plasma levels of  $T_3$ , prolactin, insulin, S-peptide, FSH, testosterone, histamine, glucose, and PH were all depressed on day 3, and dropped even further on days 7 and 14 of fasting. TTH,  $T_4$ , PGA+E, and  $PGF_{2\alpha}$  were depressed on days 7 and 14, while concentration of reverse  $T_3$  increased throughout fasting. Concentration of LH was elevated on day 7 and depressed on day 14. Norepinephrine levels were too low to be measured throughout fasting, and acetylcholine was elevated on days 7 and 14 by a factor of 2.5 and 3.3, respectively. Renal excretion of epinephrine increased through the fasting period, while excretion of norepinephrine and DOPA were unchanged and excretion of dopamine increased significantly on day 3 and then returned to baseline. Excretion of homovanillic and vanillylmandelic acids was depressed starting on day 3. Excretion of metanephrine was elevated throughout fasting and of normetanephrine was depressed on days 7 and 14. On day 14 of recovery, plasma concentrations of epinephrine, norepinephrine,  $\beta$ -endorphin, STH, acetylcholine, cAMP, cGMP, free fatty acids and excretion of epinephrine, and dopamine were elevated. Concentrations of  $T_4$ , prolactin, FSH, LH, testosterone, PGA+E,  $PGF_{2\alpha}$ , and excretion of metanephrine, homovanillic acid, and vanillylmandelic acid were depressed. The remainder of the parameters were at baseline.

The authors conclude that the pattern of changes in hormonal and metabolic reactions in fasting are closely coordinated, essentially supporting a unified mechanism serving to maintain homeostasis of energy utilization, shift to a fat-consuming type of metabolism, and economization on utilization of glucose and oxygen. The specific component of this mechanism is the "prevention of stress damage" subsystem including the GABA system of the brain, the

## METABOLISM

system of  $\beta$ -endorphins, prostaglandins, and antioxidants, and evidently the system of acetylcholine and cGMP. This subsystem is an inhibitory blocker of the activity of the majority of its components, which are elevated in stress, and serves to depress effects on the sympathetic adrenal and pituitary-adrenal system so as to limit energy expenditure as the body approaches fatal depletion of energy supplies.

Table 1; Concentration of hormonal and biologically active compounds during fasting

Table 2: Excretion of catecholamines, products of their metabolism and metabolic parameters of blood in fasting

P1305(29/90)\* Klimovich VV, Lukashik NK.

***Parameters of thiamine metabolism in tissues of rats exposed to hypokinesia.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 58-59; 1990.

[17 references; 7 in English]

Metabolism, Thiamin

Rats, Males

Hypokinesia, Immobilization Cages

**Abstract:** This work measured level of thiamin and diphosphothiamin and activity of transketolases in the tissues of rats maintained under conditions of limited motor activity. Subjects were 40 white male rats spending 15 days in immobilization cages. Control animals were kept in large individual cages. Animals ate traditional laboratory rations and received water ad libitum. Air temperature was maintained at 24-26°. After 15 days the rats were sacrificed. Blood was drained from the body and collected, tissue was rapidly excised and stored in liquid nitrogen. Activity of transketolases, and concentration of diphosphothiamin were measured in hemolysates of whole blood, homogenates of tissue from the liver and gastrocnemius muscle and in daily urine.

Activity of transketolase was unchanged in whole blood after hypokinesia. Concentration of the coenzyme form of the vitamin diphosphothiamin was also stable, evidently supporting stable functioning of transketolase in erythrocytes. No changes were noted after hypokinesia in transketolase activity in muscle tissue; however, there was a significant decrease in the level of the free form of the vitamin and an increase in diphosphothiamin, possibly suggesting that in hypokinesia the capacity of the muscles to utilize thiamin alters and they become less able to store thiamin. In the liver, there was a tendency for increased transketolase activity in subjects exposed to hypokinesia, and an increase in free and coenzyme forms of the vitamin. It is hypothesized that metabolism in the liver is relatively active during the 15-day period of hypokinesia. Experimental animals showed a drastic increase in thiamin excretion. These results support a position that limitations on motor activity are accompanied by depression of metabolic processes in muscle tissue, leading to decreased utilization of the vitamin and its enhanced excretion. During the 15-day period of hypokinesia, the need of tissues for the vitamin altered and the storage capacity of the liver supported a constant level of diphosphothiamin in blood, leading to a decrease in the free vitamin in muscle tissue, which in turn led to increased renal excretion of the vitamin.

## MUSCULOSKELETAL SYSTEM

### PAPERS:

P1291(29/90) Stupakov GP, Volozhin AI.

***The bone system of experimental animals under conditions of weightlessness: The effect of space flight on the skeleton of tortoises.***

In: M157(26/90) Stupakov GP, Volozhin AI.

Kostnaya Sistema i Nevesomost'; Костная Система и Невесомость

***[The Skeletal System and Weightlessness].***

Volume 63 In series: Problemy Kosmicheskoy Biologii,

Leningrad: Nauka; 1989.

Pages: 82-90.

Musculoskeletal System, Bones, Skeleton; Metabolism, Low

Tortoises

Space Flight, Short- and Long-Term, COSMOS-782, -605, -613, Soyuz-20

**Abstract:** The goal of experiments on tortoises was to determine the direction and severity of bone changes in space in animals with metabolic rates significantly lower than that of mammals. Experiments were performed on 30 *Testudo horsfieldi* Grey tortoises. Animals in the space flight group were maintained in metal cages and deprived of food throughout flights varying in duration (19, 22, 60, and 90 days). Animals in a synchronous group were kept in identical cages and deprived of food for matched periods of time. A vivarium control group was fed normally.

Animals in all groups were sacrificed 2 days after spacecraft reentry. The humerus and femur bones were freed of muscle tissue and stored at 5° C in 0.5% neutral formalin until strength testing, at which point the bones were placed in 10% formalin.

No later than 1 week after sacrifice whole bones were tested for static bending strength, or the distal epiphyses for compression strength. In calculations of the ultimate bending strength of compact substance of the diaphysis, the moment of inertia was computed under the assumption that the cross sections of bone and marrow canal were perfect ellipses. The distal epiphysis was tested for compression strength by applying pressure with a cylindrical indenter 1 mm<sup>2</sup> in cross section. Each epiphysis was tested in the medial and lateral areas and then the mean ultimate strength was computed. Bending strength was tested after the 22- and 60-day flights and compression strength after the 19- and 90-day flights. Computation of ultimate strength utilized the outer and inner dimensions of the bone in cross section as revealed by radiography of sagittal and frontal projections.

Mineral concentration in a unit volume of bone substance (mineral saturation), the ratio of the mineral and organic component by weight (ash content), and specific weight (density) were measured in a fragment of the diaphysis cut in the shape of a ring and in the distal epiphysis.

Results failed to reveal significant changes in the mineralization of bone tissue of the diaphysis. After 60-90 days of flight, density and especially mineral saturation showed a tendency to decrease. Ash content was unaltered. Thus the small decrease in quantity of bone substance in a unit volume was not accompanied by a decrease in degree of mineralization of bone structure.

Microradiography showed that the level of mineralization of bone tissue of the diaphysis after a 22-day space flight was close to that of the control group. Nor did the 90-day flight affect this parameter.

## MUSCULOSKELETAL SYSTEM

The development of slight osteoporosis in the epiphysis and metaphysis of the femur and humerus bones revealed by physical methods after flights lasting 60 and 90 days was confirmed by the microscopic studies. Figure 18 reveals thinning of the trabeculae of the spongy substance and widening of the vascular canals in the cortical layer of the metaphysis. There were no visually observable signs of increased absorption of bone tissue in the cortical layer of the diaphysis. However, morphometry of the vascular canals revealed that in control animals there was an asymmetric distribution of vascular canals by size, with the largest near the endosteum. This suggests relatively rapid restructuring of the cortical layer of long tubular bones. After flights of 19 and 22 days there were no substantial changes in distribution of vascular canals. However, the number of spaces bordering on trabeculae from the medullary cavity decreased, suggesting activation of resorption processes of the endosteum. After 60 days there was a very significant decrease in the relative number of the smallest vascular canals and an increase in the larger ones. After 90 days the number of canals of moderate size increased and the number of the largest ones was no different than control. After these two longer flights the total number of medullary spaces in the wall of the diaphysis normalized, probably due to development of resorption loci in the cortical layer of the diaphysis. It may be hypothesized that the shorter space flights induce increased absorption of only the most accessible bone trabeculae -- those bordering on the medullary cavity. After the 60-day flight the number of "medium-sized" canals, the majority of which were located in the intermediary zone of the cortical layer, increased. After the 90-day flight the resorption process also affected the zone of the wall of the diaphysis near the outer surface of the bone, where the majority of small canals are located. The continuing resorption of bone trabeculae from the area of the medullary cavity led to seeming normalization of the number of medullary cavities within the wall of the diaphysis.

In control animals the mineral saturation, ash content, and density of the compact substance were not highly correlated with ultimate bone strength. Evidently this was due to the lack of substantial individual differences in these parameters. In control animals ultimate strength was 15.24 kfs/mm<sup>2</sup>, while in animals undergoing 22- and 60-day flights this parameter was 14.18 and 15.19 kfs/mm<sup>2</sup> respectively. Thus the strength of the compact substance of the diaphysis of the femur and humerus was unaltered after 22- and 60-day flights.

In control animals ultimate strength of spongy substance of the distal epiphysis of spongy bones was highly correlated with mineral saturation and density, but not with ash content ( $r=.86$ ,  $0.92$ , and  $0.21$ , respectively). Thus, in tortoises, strength of spongy substance is largely a function of amount of bone substance in a unit volume and not of the ratio of mineral to organic components. For comparative purposes animals in the 19- and 90-day flight conditions were placed in a single group and analogous correlations computed. In this group ultimate strength of spongy substance was depressed by 20% compared to control. At a given level of mineral saturation, bone strength was lower for flight tortoises than for control subjects. The regression constant of mineral saturation - strength regression equations differed significantly in the two groups.

The authors conclude that space flights lasting 60-90 days evoke slight osteoporosis in the epiphysis and metaphysis of long tubular bones of tortoises without affecting level of mineralization of surviving microstructure. This is similar to the situation for rats. The difference lies in the rate of development of dystrophic processes. If in rats the loss of bone mass from spongy structure after 19 days may reach 20%, then in tortoises after 60-90 days it reaches approximately 4-8%. This difference may be associated with different rates of metabolic processes. A further species difference involves the fact that the decrease in strength of spongy bone in rats is a function of severity of osteoporosis, while in tortoises it is associated with additional changes. It is possible that these changes occur at lower structural levels and are reversible. In rats (active animals with high metabolic rates) these changes

## MUSCULOSKELETAL SYSTEM

show up after relatively short periods of weightlessness, and in tortoises only after longer periods.

Further interspecies simulation studies are recommended.

Table 8: Groups of tortoises used in flight experiments

Spacecraft	Duration, days	Number of animals		
		Flight	Synchronous	Vivarium
COSMOS-782	19	4	2	4
COSMOS-605	22	2	2	2
COSMOS-613	60	2	-	4
Soyuz-20	90	2	2	2

Table 9: Characteristics of bone tissue in tortoises

Group	Diaphysis			Epiphysis			
	mineral sat., g/cm <sup>3</sup>	ash content, %	density, g/cm <sup>3</sup>	mineral sat., g/cm <sup>3</sup>	ash content, %	density, g/cm <sup>3</sup>	density, g/cm <sup>3</sup>
Femur Bone							
Control	1.168	60.7	1.923	0.354	57.4		0.613
Space flight, days							
19&22	1.192	61.5	1.958	0.346	59.1		0.591
60&90	1.175	61.1	1.865	0.326	56.1		0.580
Humerus Bone							
Control	1.174	60.9	1.911	0.413	58.0		0.710
Space flight, days							
19 & 22	1.163	60.7	1.929	0.418	59.8		0.708
60 & 90	1.150	61.2	1.881	0.387	57.5		0.686

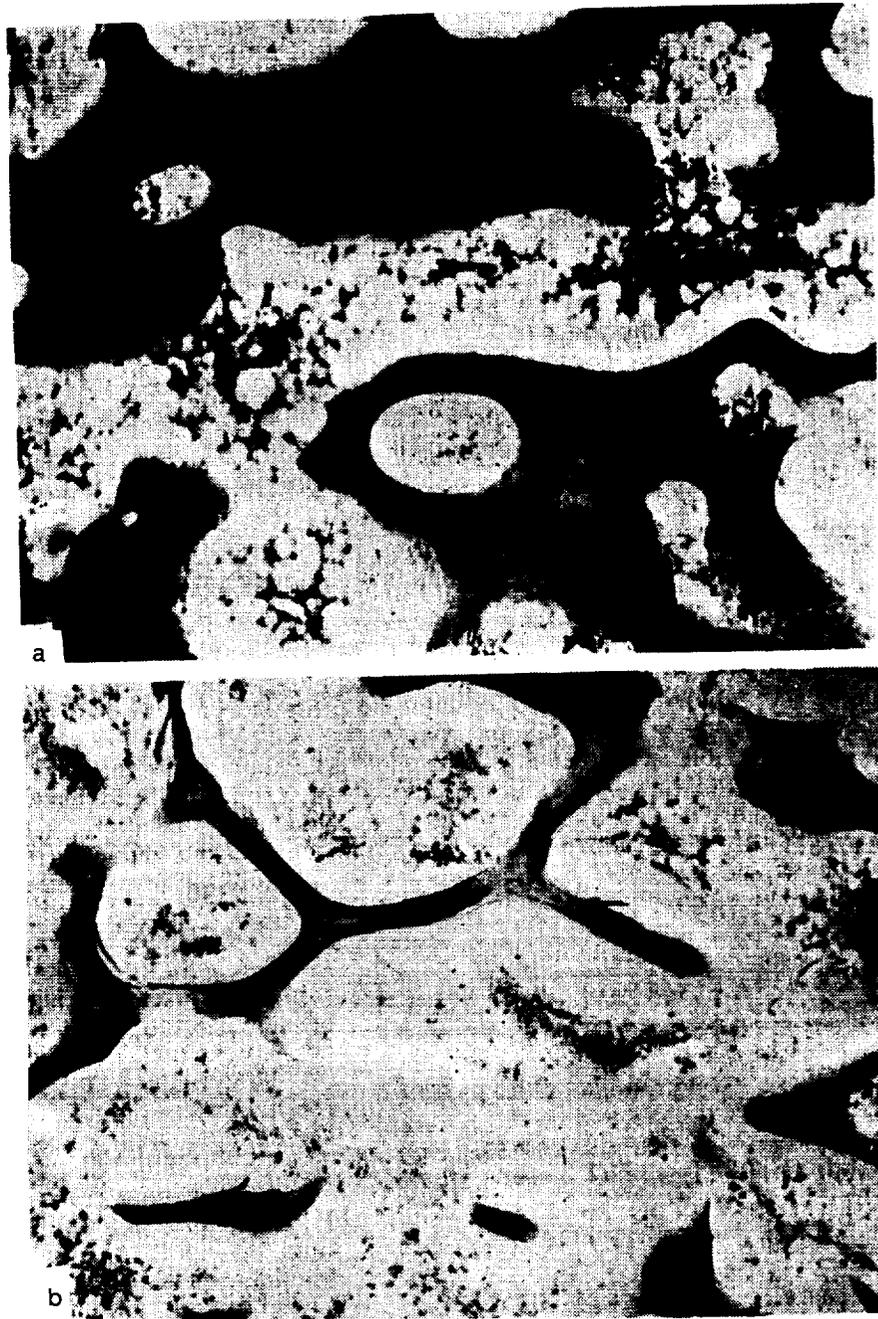


Figure 18: Distal metaphysis of the humerus bone of a tortoise  
a - control, normal structure of the spongiosa of the metaphysis, b - flight, 60 days (widening of the spongiosa of the metaphysis)

# MUSCULOSKELETAL SYSTEM



Figure 18 (continued) c - flight, 60 days (cortical layer with widened vascular canals); d - diaphysis of the humerus bone (normal structure of cortical layer of the diaphysis); e - diaphysis of the humerus bone (flight 60 days). Unaltered structure of the cortical layer of the diaphysis

## MUSCULOSKELETAL SYSTEM

P1313(29/90)\*\* Oganov VS, Cann C, Rakhmanov AS, Ternovoy SK  
***A computer tomographic investigation of the musculoskeletal system of the spine in humans after long-term space flight.***  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
24(4): 20-21; 1990.  
[11 references; 6 in English]

Musculoskeletal System, Bones, Spine, Computer Tomography, Muscle Density; Mineral Loss  
Humans, Cosmonauts  
Space Flight, Long-Term, Salyut-7, Hypokinesia with Head-Down Tilt

Abstract: Loss of weight loading on the musculoskeletal system during space flight is considered the major cause of the losses of calcium that have been observed in cosmonauts and astronauts.

In ground-based studies with volunteers undergoing long-term bedrest, it was established that 4 hours per day spent in a "standing" position or 3 hours of controlled walking were sufficient to prevent increases in calcium in the urine, which typically accompany this type of hypokinesia. However, physical exercise in a horizontal position did not have a significant effect on loss of minerals from bone tissue. These data, and also the fact that Soviet and American space crews suffered losses in the heel bone, despite adhering to an exercise program in flight, indicated the need to investigate other portions of the skeleton, with greater clinical significance than the heel bone, particularly the spine.

The mineral density of spongy bone of the lumbar vertebrae was measured in cosmonauts with the aid of quantitative computer tomography before and after long-term (5, 7 months) flights on the Salyut-7 space station. In addition, the mineral density of the anterior and posterior components of the vertebrae were measured as were the volume and density of the back muscles (iliocostalis, erector spinae, and interspinalis), which were isolated from the bones and subdural fat. The reproducibility of results of measurements of the mineral density of bone tissue was 1.6%, the reproducibility (measurement error) of measurements of muscle density was 0.15%, while measurement error for muscle volume at the level of the first and second lumbar vertebrae was 1.1%. Measurements were made one month preflight and also on days 20-27 postflight. Student's t test was used to determine significance.

After long-term flights, two of the four cosmonauts did not display statistically significant changes in mineral density of spongy tissue in the central portion of the vertebral bodies; the third displayed a significant decrease in this parameter; and the fourth a significant increase. The mineral density of the weight-bearing bodies of the vertebrae was depressed in two cosmonauts and averaged  $-2.5 \pm 3.0\%$  (not statistically significant) for the group as a whole. Density decreased by  $7.8 \pm 1.7\%$  ( $p < 0.01$ ) in the posterior portions of the vertebrae. Back muscle volume decreased by a mean of 4.4% ( $p < 0.01$ ), while the density of the muscles decreased by 0.4%. This level of density decrease would correspond to an additional loss of 3% muscle mass (for the measured volume), if it is assumed that muscle tissue is replaced by fat tissue. If muscle tissue is replaced by extracellular fluid, then the additional calculated loss of muscle mass would be 7.7%.

In a series of ground-based simulation studies using long-term (up to 1 year) hypokinesia with head-down tilt, changes in the mineral density of spongy tissue of the lumbar vertebrae were in opposite directions in different subjects. A reliable decrease in mineral density was noted in only 10% of the subjects.

Thus, the results of computer tomography of the human spine after long-term flights are consistent with the results of analogous studies after long-term hypokinesia with regard to the trabecular bone of the vertebral bodies. In both cases the decrease in the mineral density of

## MUSCULOSKELETAL SYSTEM

these zones was noted in only a portion of the individuals studied, while the rate of loss was significantly slower than what would be expected theoretically on the basis of existing ideas about the high level of metabolism in trabecular bone tissue of the spine.

The absence of changes in the mineral density of spongy tissue in the vertebrae of certain cosmonauts postflight and in subjects after hypokinesia with head-down tilt can be explained by the efficacy of the prophylactic measures used or by the functioning of protective mechanisms within the musculoskeletal system, for example, torsion effects compensating for elimination of weight loading through the vertebral disks exerting pressure on the vertebrae.

At the same time, as the cited data show, physical exercise performed by the cosmonauts during flight also failed to completely prevent adverse changes in the back muscles and those components of the vertebrae (spinous and transverse processes) that are insertion sites for muscles. The rate of bone and muscle atrophy did not exceed 1-2% per month. However, the decrease in volume of back muscles was much smaller than that which occurred in volunteers after a 120-day period of hypokinesia with head-down tilt without the use of prophylactic countermeasures.

The fact that mineral density of spongy bone of the lumbar vertebrae increased in approximately 30% of the subjects studied remains difficult to explain. Furthermore, after hypokinesia the increase in mineral density was more pronounced in subjects who did not perform physical exercise as a prophylactic countermeasure (120-day hypokinesia with head-down tilt), or only began to exercise during month 5 of bedrest (370-day hypokinesia with head-down tilt). This phenomenon should undoubtedly be the subject of a special analysis. Of particular interest here is the tendency for the concentration of minerals in the lumbar vertebrae to increase in some patients undergoing long-term immobilization as a result of cerebrospinal trauma, which has been reported by American researchers.

The data obtained attest to the fact that the magnitude of changes in bone tissue and skeletal muscles in cosmonauts is not a function of flight duration. A great deal of variability among individuals in changes in parameters indicative of state of bone tissue (from negative to positive) was also noted, even in members of a single crew.

The use of such an accurate noninvasive method as computer tomography has for the first time made it possible to establish individual levels of decrease in mineral density of vertebrae and the site of these decreases after long-term flights. These data are of interest from the point of view of estimating the risk of osteoporosis and decreased bone strength developing under conditions of weightlessness. Along with pre- and postflight measurements, it would be desirable to study the dynamics of bone metabolism during space flight. Complex (multimethod) experimental studies (simulations) of the interrelationship among structural, physical/chemical, and biomechanical properties of bone tissue in response to decreased gravitational loading of the musculoskeletal system have also taken on extreme importance.

## MUSCULOSKELETAL SYSTEM

Table 1: Results of quantitative computer tomography of the spine in cosmonauts after long-term space flights (change in % of preflight level)

Parameters	Cosmonaut			
	1	2	3	4
Mineral density of the lumbar vertebrae:				
- whole vertebra	-6.1	-0.3	-2.3	-10.8
- body of the vertebra	-4.6	+2.9	+1.8	-10
- transverse and spinous processes	-8.1	-3.7	-7.5	-11.9
- spongiosa	+1.9	+12.4	+1.7	-10.2
Back muscle volume	-0.8	-4.3	-6.5	-5.8

## MUSCULOSKELETAL SYSTEM

P1314(29/90)\*\*Il'ina-Kakuyeva Yel.

***Morphohistochemical investigation of the skeletal muscles of rats in an experiment on biosatellite COSMOS-1887.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 22-25; 1990.

[21 references; 9 in English]

Musculoskeletal System, Skeletal Muscles, Morphohistochemical Analysis, Fast-Twitch; Slow-Twitch

Rats

Space Flights, COSMOS-1887

**Abstract:** Biological material for this experiment was the skeletal muscles of 5 Wistar rats sacrificed 2 days after completion of a 13-day space flight (flight group), 5 rats participating in a synchronous control condition, and 5 rats in a vivarium control. Muscles studied came from the fore and hindlimbs and included the slow-twitch soleus, fast-twitch gastrocnemius (medial portion), quadriceps of the femur, and biceps of the brachia. The material was weighed, frozen and used for preparation of sections in a cryostat. In addition, sections were embedded in plastic for histological study. Histochemical methods were used to identify glycogen, phospholipid, activity of succinate dehydrogenase (SDH) not attached to NAD,  $\alpha$ -glycerophosphate dehydrogenase (GPDH), and NAD-H<sub>2</sub>-dehydrogenase. Concentration of substrates and enzyme activity were estimated visually. Identification of muscle types was performed on cross sections of muscles after estimate of the activity of ATPase myosin in them with preincubation in an acid and neutral medium. Computer morphometry was used to determine the cross sectional area of muscle fibers and the percentage representation of type I and type II fibers. Muscle sections were stained with hematoxylin and eosin. Microcirculation was studied in muscle cross sections embedded in histological plastic. Identification of functioning capillaries was based on staining of erythrocytes with iron hematoxylin and count of their number per 200 muscle fibers. After identification of ATPase activity in them, the total number of capillaries and muscle fibers in a 1 mm<sup>2</sup> area was counted and the capillarization ratio determined. When it was determined that no differences existed between the synchronous and vivarium control conditions, the two groups were merged for the purposes of analysis.

Muscle mass was no different in flight and control rats. A significant 7% decrease was noted in IIC fibers of the quadriceps in the flight group. In the slow-twitch soleus, although mass did not change, there was significant atrophy in all three types of fibers - IA, II and intermediate, with decreases of 42, 19.5, and 20% below control, respectively. Failure of mass to change was due to edema of the interstitial tissue, with the endomysium swelling, filling with neutrophils and mononucleated cells. The lumens of all vessels were enlarged. Many fibers in the edemic zone were disintegrating and undergoing phagocytosis by macrophages. In two of the animals, there were islands of muscles not subject to edema, in these the "triangular" fibers were very atrophied.

No significant morphological changes were noted in the fast-twitch femoral quadriceps and brachial biceps of flight animals. However, in the central portion of the gastrocnemius there were areas of necrotic change in muscle fibers for all animals. Many fibers lost their polygonal shape and became rounded. The endomysium was somewhat enlarged and full of mononuclear cells. Differences were noted between flight and control group in percentage of type I and type II fibers in fast-twitch muscles. It was difficult to count fibers in the soleus due to the pathologies. However, where a count was possible it was determined that there was a significant increase in intermediate type fibers and a decrease in type IIA fibers.

## MUSCULOSKELETAL SYSTEM

No intergroup differences were found in the total number of capillaries in the muscle. However, there was a significant increase in the number of functioning capillaries in the soleus and gastrocnemius muscles of the flight group. All muscles of flight rats showed a decrease in activity of NAD-H<sub>2</sub>-dehydrogenase, and an increase in activity of GPDH in the soleus. Glycogen and lipid concentrations were at control level in fast-twitch muscles and significantly depressed in the pathologically altered soleus.

In discussing their results the authors attribute the pathological edema found in the soleus muscle to the immediate effects of return to normal g, since such effects are not noted when subjects are studied 4-6 hours after reentry. The edema is associated with microcirculatory effects, since increased number of functioning capillaries noted here after 2 days, also does not occur immediately postflight. The edema prevented observation of muscle restructuring that might have been observed in the soleus, which has been found to be more sensitive than fast-twitch muscles to microgravity.

Table 1: Mass of muscles in animals of different groups (grams)

Muscle	Group		
	Vivarium	Flight	Synchronous
Soleus	0.1532	0.1687	0.1484
Gastrocnemius	1.7430	1.6963	1.7280
Quadriceps of femur	2.6910	2.5903	2.5264
Biceps of brachium	0.2014	0.2070	0.2149

Table 2: Cross-sectional area of muscle fibers (in mm<sup>2</sup>) in animals of various groups

Muscles	Fiber Type	Group		
		Vivarium	Flight	Synchronous
Soleus	IA	2808.5	1627.4*	3073.9
	II	2582.9	2077.4*	2730.9
	intermed.	1924.6	1537.7*	2138.0
Gastrocnemius	I	1651.3	1720.4	1555.7
	IIA	2269.9	2156.5	2230.7
	IIB	3759.5	3693.6	3755.8
	IIC	1512.2	1431.5	1481.6
Quadriceps of femur	I	1274.7	1375.4	1231.7
	IIA	2491.3	2447.4	2390.2
	IIB	4688.7	4624.7	4774.1
	IIC	1416.4	1310.8*	1302.4
Biceps of brachium	I	942.2	1021.2	975.1
	IIA	1529.7	1545.8	1592.5
	IIB	2454.4	2435.7	2520.5
	IIC	933.0	896.5	924.4

\* difference between flight and control statistically significant

## MUSCULOSKELETAL SYSTEM

Table 3: Number of functioning capillaries per 200 muscle fibers

Muscle	Group		
	Vivarium	Flight	Synchronous
Soleus	180.8	257.6*	184.6
Gastrocnemius	150.2	197.8*	140.8
Quadriceps of femur	136.0	142.4	128.8

\* Difference between flight and control groups statistically significant

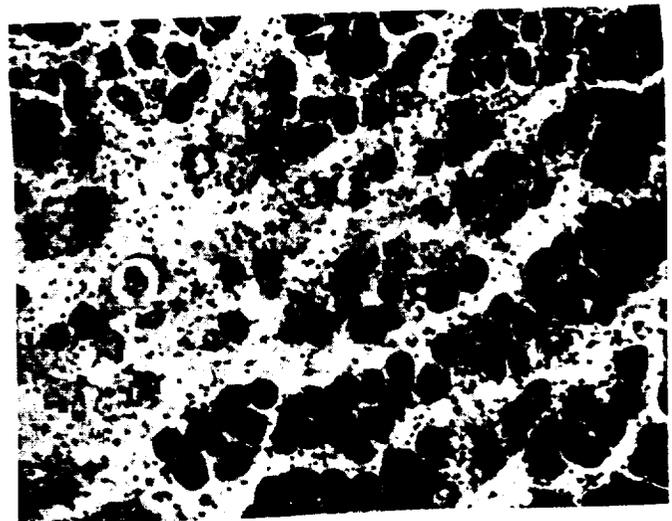
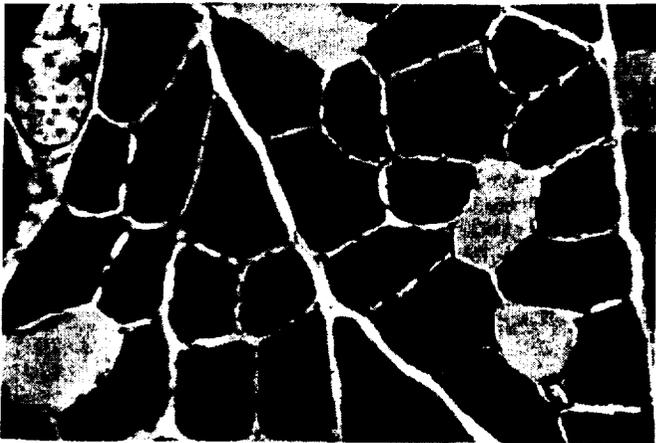


Figure 1: Gastrocnemius muscle: distribution of ATPase myosin activity after preincubation in a 4% solution of paraformalin

Figure 2: Soleus muscle (2 days postflight): marked interstitial edema, mass destruction of muscle fibers

Stained with hematoxylin and eosin: Ob. X 3.5: oc. X 10.

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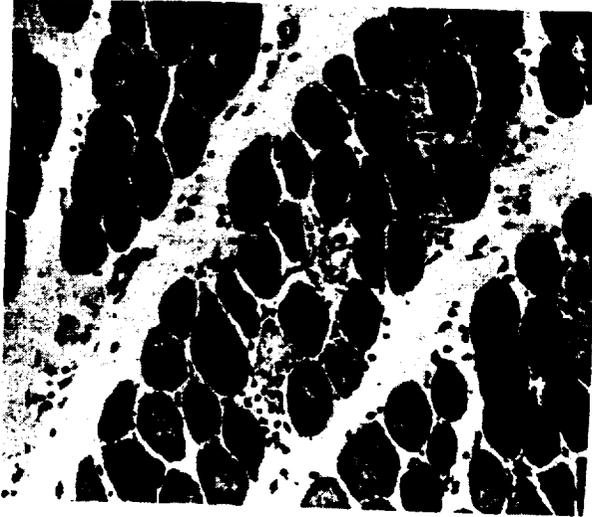


Figure 3: Gastrocnemius muscle (day 2 postflight): focus of mass destruction of muscle fibers and local interstitial edema.  
Stained with hematoxylin and eosin: Ob. X 3.5; oc, X 10.

## PAPERS:

P1295(29/90) Ul'yanskiy LS, Ivanov VT, Mikhaleva II, Sudakov KV.

***Delta-sleep peptide as a modulator of cardiac activity: Theoretical recommendations for practice.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina,  
24(3): 23-28; 1990.

[24 references; 4 in English]

Cardiovascular and Respiratory Systems, Cardiac Activity, Protective Effects  
Rats, Rabbits

Neurophysiology, Parasympathetic Nervous System, Vagus Nerve, Enzymology, Delta-Sleep Peptide, Psychology, Stress, Immobilization Effects

Abstract: In earlier works the authors established that the delta-sleep peptide has an antistress effect and increases survival of animals typically dying of cardiovascular disorders under conditions of emotional stress. This suggests that delta sleep peptides may directly affect cardiac activity. The present paper describes special investigations of the effects of delta-sleep peptide on cardiovascular function in intact animals and those exposed to emotional stress.

The first experiment investigated the effects of delta-sleep peptide [DSP] on the nature of vascular response in rats undergoing acute emotional stress. The stress situation involved immobilization and aperiodic electric shock to the skin alternating with electric stimulation of the ventromedial hypothalamus. Characteristic response to the latter stimulus in animals susceptible to stress is pressor vascular reactions. In animals during the first hour of stress before treatment with DSP, 100% responded by a marked pressor reaction to stimulation of the ventromedial hypothalamus. After introduction of DSP, such a response was absent in 60-80% of the cases during the first hour of stress. In a control group (no stress?) pressor response occurred in 50% of the cases. As exposure to stress continued, level of pressor responses in animals treated with the peptide first dropped and then increased.

Other experiments showed that the effects of DSP are due to central mechanisms, since its introduction into the brain ventricle blocked the avoidance response when areas associated with negative emotions were stimulated in the brain. It was still not clear if the effects of DSP on the stability of cardiovascular function were associated only with these central effects or whether there was a direct effect on the heart as well.

When DSP was injected intravenously in 9 unstressed rabbits in a dose of 60 nM/kg, it decreased heart rate by 15%. Since atropine eliminated this effect, DSP evidently works by increasing vagal tone. This effect was studied directly in 16 anesthetized rabbits. In these animals, the vagus nerve was stimulated electrically after administration of DSP. DSP increased the negative chronotropic effect after stimulation of the vagus in the majority of the animals. The effect peaked 30 minutes after administration of the peptide.

Effects of DSP were studied on the sympathetic regulation of cardiac rhythm in 6 rabbits. The sympathetic nerves were severed bilaterally in anesthetized rabbits, leading to decreased heart rate. When the cervicothoracic ganglion was stimulated, heart rate increased. Injection of DSP attenuated the heart rate response to stimulation of the ganglion. The effect peaked 1 hour after injection. Thus DSP leads to increased parasympathetic and decreased sympathetic effects on cardiac activity. In another experiment when antiserum to DSP was injected, heart rate increased, the negative chronotropic effect of stimulation of the vagus nerve was attenuated, and the positive chronotropic effect of stimulation of the cervicothoracic ganglion was enhanced. The shift in favor of parasympathetic over sympathetic influence is associated by the authors with the stress-protective effect of DSP.

Experiments were performed on 45 isolated rabbit hearts perfused with Tyrode's solution. Under control conditions, heart rate was relatively stable for 40-45 minutes. Introduction of DSP did not lead to significant changes in heart rate. Introduction of acetylcholine decreased heart rate, and additional DSP decreased heart rate still further under two slightly different experimental conditions. When norepinephrine was added to the perfused isolated hearts, heart rate increased, and when DSP was added under these conditions the effect of norepinephrine was substantially attenuated. Thus DSP enhances the negative chronotropic effect of acetylcholine and attenuates the positive chronotropic effect of norepinephrine.

An additional study was performed on the effect of DSP and its deficit on electrical stability of the heart of 22 anesthetized rabbit with severed vagus nerves and excised cervicothoracic ganglia to exclude extracardial effects. Effects of DSP on threshold for ventricular fibrillation and its precursors were studied in 14 animals. DSP was associated with increased threshold for repeated extrasystoles, paroxysmal ventricular tachycardia, and fibrillation. The effect persisted for 2 hours. DSP antiserum led to the opposite effect, lowering the thresholds. The capacity of DSP to enhance parasympathetic neural effects and increase the electrical stability of the heart suggests it would protect the heart and have an antiarrhythmic effect in stress.

The effect of DSP on electric stability of the heart was studied in 7 emotionally stressed animals and on the disruption of cardiac rhythm in 12. Emotional stress was produced by immobilization combined with electrical stimulation of centers of the hypothalamus associated with negative emotion. Threshold of short-term fibrillation was determined to investigate electrical stability without having to use defibrillators for repeated experiments. Stimulation occurred through the use of bipolar electrodes. Emotional stress produced sinus tachycardia and reduced electrical stability. Under stress thresholds for fibrillation and its precursors decreased. Intravenous administration of DSP to stressed animals normalized the threshold for fibrillation and its precursors.

To further clarify this relationship, heart rate and extrasystoles were studied in stressed animals before and after administration of DSP. DSP was found to decrease the frequency of or even eliminate ventricular extrasystoles. Effects lasted as long as 3-5 days in the majority of subjects, but in the remaining animals no effects were observed.

The authors conclude that DSP has a marked effect on cardiac activity and its regulation, prolongs the effects of the vagus nerve and depresses effects of sympathetic nerves on the heart, and accordingly affects cholinergic and adrenergic mediators. DSP blocks pressor vascular reactions to direct electrical stimulation of the ventromedial hypothalamus and thus increases survival of animals exposed to acute emotional stress. DSP normalizes electrical stability of the heart and has an antiarrhythmic effect on ventricular extrasystoles occurring in stress. The authors recommend study of the clinical potential of this substance in situations of stress.

Figure 1: Various vascular reactions to stimulation of the ventromedial hypothalamus in rats under conditions of acute emotional stress and administration of DSP

Figure 2: Enhanced negative chronotropic effect in stimulation of the vagus nerve after administration of DSP

Figure 3: Attenuation of the positive chronotropic effect of norepinephrine on the isolated heart of a rabbit after administration of DSP

Figure 4: Decreased electrical stability of the heart in experimentally induced stress and its normalization through use of DSP

P1303(29/90)\* Stolbkov YuK, Maslova YeP.

***Nystagmus in individuals with asymmetrical afferentiation of the otoliths.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3):53-56; 1990.

[9 references; 3 in English]

Neurophysiology, Nystagmus

Humans, Patients

Otolith Asymmetry

**Abstract:** In an experiment on pigeons it was found that if simultaneous stimulation of the semicircular canals and otoliths resulted in asymmetry of the neuronal activity of paired structures of the brain receiving otolith afferentiation, there would be opposite changes in duration of opposite nystagmus. The goal of this work was to investigate whether this law held true for humans. A total of 23 subjects aged 9 to 45 were tested. These subjects suffered from unilateral nerve deafness, unilateral chronic purulent otitis or neurinoma of the acoustic nerve. All subjects would be expected to show asymmetrical patterns of otolith afferentiation. Subjects were rotated in darkness in the horizontal plane at positive angular acceleration of  $10^\circ/\text{sec}^2$ , followed by 2 minutes of constant angular velocity and negative angular acceleration at the same rate as the positive. Vestibular rotational nystagmus was recorded during positive acceleration and postrotational nystagmus during negative acceleration. During rotation subjects were asked to position their heads in different ways with respect to the axis of rotation. When the head was in a central position the rotation axis passed between the labyrinths, and in eccentric position it was displaced with respect to the interaural line either backward (position 1) or forward (position 2). In all cases each labyrinth was at an equal distance from the axis of rotation. When the subjects had their heads in eccentric position they were affected by centrifugal force (0.5 g) as well as angular acceleration. In all conditions the horizontal semicircular canals were aligned with the rotation plane. Nystagmic parameters measured through electronystagmometry with binocular leads included duration of nystagmus. Reactions with head in central and eccentric positions were compared. Only differences greater than 1 second were considered. A total of 21 subjects were tested in position 1 and 23 in position 2.

Of the four subjects with acoustic neurinoma, three showed asymmetric reactions with head in central position. Subjects with neurosensory hearing loss and chronic otitis showed asymmetry in 8-12% of the cases. Nineteen out of 23 subjects displayed asymmetry of some sort when their heads were eccentrically positioned relative to the rotation plane. The authors conclude that the principles underlying interaction of the two vestibular subsystems observed in pigeons are applicable to humans.

Table 1: Frequency of occurrence of various types of change in vestibular rotational and postrotational nystagmus

Table 2: Duration of nystagmus in various position in patients with peripheral vestibular disorders

P1318(29/90)\*\* Dmitriyev AS, Taits MYu, Dudina TV, Kandybo TS, Yelkina AI.  
***The role of glucocorticoids in postvibrational shifts of inhibitory mediation in brain structures.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 32-33; 1990.

[14 references; 3 in English]

Neurophysiology, Inhibitory Mediation, Brain Structures  
 Rats, Male  
 Endocrinology, Glucocorticoids, Vibration Effects

Abstract: Experiments were performed on 100 male Wistar rats maintained on a standard vivarium diet. Animals were subjected to vibration on a vibration stand with frequency 10 Hz, amplitude 1 mm, and vibrational acceleration of  $2 \text{ m/sec}^2$  over the course of 2 hours. Hydrocortisone acetate was administered intraperitoneally in a dose of 2 mg/kg 18-20 hours before vibration. This dose evoked a 2-3-fold increase in the level of glucocorticoids in blood plasma. The animals were sacrificed. All studies were performed on the left side of the brain. Activity of the neuromediator system was estimated from rate of neuronal uptake of a series of neural mediators (instead of labile acetylcholine, its precursor choline was used). The methodology for determining rate of uptake and receptor binding of corticosterone was adapted for trace quantities of tissue (5-10 mg). Brain structures studied were the parietal cortex, mediobasal hypothalamus, lateral vestibular nucleus, locus ceruleus, and raphe nucleus. All radioactive markers had high specific activity. A 1% homogenate of tissue was prepared in a decalcified medium. After incubation the "coarse" synaptosomal fraction was isolated on nitrocellulose filters. Receptor binding of corticosterone was estimated from the difference between total and non-specific binding. Rate of uptake of neuromediators and level of receptor binding of corticosterone was measured on a counter and expressed in the number of decays per minute per mg wet tissue. Level of cAMP was also measured.

Increased blood glucocorticoids induced by administration of hydrocortisone acetate led to a decrease in receptor binding of  $^3\text{H}$ -corticosterone in the hypothalamus, due both to decreased number of binding sites and to the fact that the majority of receptors were occupied with the unmarked hormone. Under these conditions the receptor binding of corticosterone increased by a factor of three in the parietal cortex, in spite of hypercorticosteroidemia, due most likely to the increased need for adaptation hormones under extreme conditions. In addition there was substantial activation of GABA, norepinephrine and serotonin (i.e., inhibitory) mediation. Inhibitory mediation and increased level of cyclic nucleotides led to decreased uptake of choline in this structure. Short-term vibration after the hormone was administered led to a decrease both in inhibitory and excitatory (cholinergic) mediation in structures specific to this factor (parietal cortex and lateral vestibular nucleus). Nonspecific structures displayed only a tendency for the rate of certain neuromediation processes to decrease. In animals with induced hypercorticosteroidemia exposed to vibration, there was a tendency for noradrenergic and dopaminergic mediation to increase in structures such as the locus ceruleus and raphe nucleus. The increase in cAMP in systems specifically and nonspecifically involved in adaptation to vibration suggests that all of them have been activated. The authors suggest that the fact that interactions among the mediator processes in various central nervous system structures are a function of level of glucocorticoids in the organism should be considered when countermeasures are developed for motion sickness.

## NEUROPHYSIOLOGY

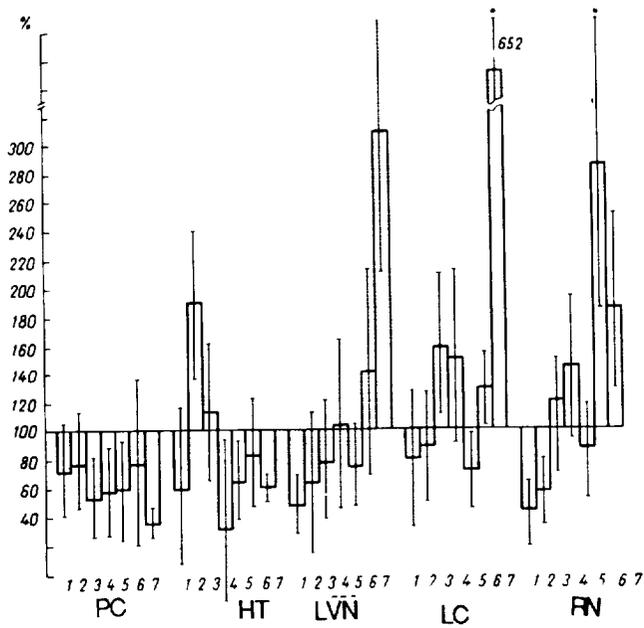


Figure: The effect of 2 hours of whole-body vertical vibration and administration of hydrocortisone acetate on the rate of neuronal uptake of choline (1), serotonin (2), norepinephrine (3), dopamine (4), GABA (5), reception of corticosterone (6) and level of cAMP (7) in the parietal cortex (PC), mediolabial hypothalamus (HT), lateral vestibular nucleus (LVN), locus ceruleus (LC), and raphe nucleus (RN). Data are expressed in percent of control. \* -  $p \leq 0.05$

P1325(29/90)\* Krotov VP, Simonov LG, Trombovetskiy YeV.

***Epidural and subdural recording of intracranial pressure in response to postural tests.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 53; 1990.

[10 references; 5 in English]

Neurophysiology, Body Fluids, Intracranial Pressure, Equipment and Instrumentation  
Rabbits  
Postural Tests

**Abstract:** The goal of this study was to compare measurements of epidurally and subdurally recorded intracranial pressure in 6 rabbits subjected to postural tests. Intracranial pressure was measured using a tensometer implanted in anesthetized rabbits. After removal of soft tissues, an 11 mm opening was drilled in the skull in which was placed a plexiglass plug secured with acryloxide. A sensor was secured within the plug so that its sensitive surface was at the level of the inner surface of the bone. The first measurement was made 2-4 days after implantation. The first trials were made without penetration of the dura mater. Animals were tested while the angle of the body to the horizontal changed from +75° to -30°. For the second series, the sensor was removed from the plug and a portion of the dura mater removed. after which the sensor was again inserted in its previous position and the same tests performed. Thus, in the first series of tests, intracranial pressure was measured epidurally, while in the second it was measured subdurally. The results of both series of tests were compared.

Significant differences were not found in measurements of the two types, although subdural pressure always measured higher than epidural. Both types of pressure measurements responded in the same way to the postural tests. The authors conclude that epidural measurement of intracranial pressure does not introduce significant error compared to subdural measurement and is preferable due to the lack of need to penetrate brain tissue.

**Figure:** The nature of changes in epidural and subdural measurements of intracranial pressure in response to postural tests in animals.

## NEUROPHYSIOLOGY

P1334(29/90) Bayevskiy RM, Bogomolov VV, Tazetdinov IG.

***Assessment of autonomic homeostasis in the operational medical system for monitoring the health of cosmonauts.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health  
Pages 16-17.

Neurophysiology, Autonomic Homeostasis, Psychology, Stress

Humans, Cosmonauts

Space Flight, Operational Medicine, Equipment and Instrumentation, Cosmonaut Monitoring System

**Abstract:** As is well known, the complex effects of several factors during long-duration space flights may lead to the development of such specific changes as physical deconditioning, decreased orthostatic tolerance, vestibuloautonomic problems, and psychological stress. Physicians providing operational medical monitoring of cosmonauts have focused on predicting and preventing these changes. However the development of such changes is the result of disruption of processes of adaptation to the environment and especially stress and overstress of the regulatory systems. For this reason, along with the traditional operational monitoring of such parameters as heart rate and blood pressure, liver size and body weight, and orthostatic and exercise tolerance, added significance should be attached to psychoemotional state and general well-being of the cosmonauts, monitoring of the state of mechanisms regulating physiological functions, particularly autonomic regulation, especially for long-term flights.

During the last decade, space medicine has accumulated experience in evaluating autonomic homeostasis on the basis of data from mathematical analysis of cardiac rhythm. This method makes it possible to obtain data on the status of the sympathetic and parasympathetic nervous systems, about their balance, and the activity of subcortical neural centers on-line over communications channels. Here the circulatory system acts as an indicator of the adaptive reactions of the human organism as a whole.

Research on long-term space flights has shown that, along with intensified activity of the sympathetic nervous system characteristic of the acute period of adaptation, during the first months of flight there is a gradual displacement of autonomic homeostasis in the direction of relative dominance of the parasympathetic system. This new steady state, however, is subject to cyclic fluctuations with clear short-term intensification of the sympathetic component of autonomic homeostasis during months 4-6 of flight as a function of individual differences in regulation. We hypothesize that this is associated with the shift to a stage of relatively stable adaptation requiring some degree of mobilization of regulatory mechanisms in support of restructuring of various physiological systems at a new level of functioning.

At the same time, the degree of activation of the sympathetic autonomic nervous system during performance of responsible operations, for example EVAs, serves as an indicator of the cosmonauts' general state, their neuropsychological stress and physical performance capacity. Mathematical analysis of cardiac rhythm during exercise makes it possible to monitor the onset of activation of adrenergic systems. This information is of great significance for optimization of the training process.

## NEUROPHYSIOLOGY

Thus, assessment of autonomic homeostasis must occupy an important place within the system of operational medical monitoring of cosmonauts, since this method enables identification of the very first, nonspecific, presymptomatic shifts in the regulatory mechanisms, which are suggestive of the probable development of specific health problems.

## NEUROPHYSIOLOGY

P1336(29/90) Gorgiladze GI, Maveyev AD.

***The effect of weightlessness on eye movement responses.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 51-52.

NOTE: THIS IS THE TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO ADDITIONAL INFORMATION ABOUT THIS WORK.

Neurophysiology, Eye Movement Response

Humans, Cosmonauts

Space Flight, Salyut-6, -7

**Abstract:** Spontaneous and evoked eye movement responses were studied in members of the crews of Salyut-6 and Salyut-7 during space flight and in the rehabilitation period. Electrooculograms were recorded at rest, as well as during active head movement and optokinetic stimulation.

In the preflight study nodding of the head in the frontal plane under conditions of gaze fixation evoked high-amplitude compensatory eye movements in the same rhythm as the nodding. In the dark, aside from compensatory movements, there were rapid jerky low amplitude eye movements. After cessation of head nodding, the eye movements immediately ceased. In weightlessness eye movements in response to head nodding underwent substantial changes. First, there was suppression of the slow compensatory eye movements. Second, nystagmic movements in opposite directions occurred. When head nodding stopped, eye movements did not disappear immediately, but persisted for some time. In the postflight studies, on day 2 postflight, head nodding again evoked compensatory eye movements in the dark, as well as during gaze fixation. However, there was only partial recovery of the initial reaction. Immediately after return to Earth, one cosmonaut displayed clear spontaneous nystagmus in the dark at a frequency of 2 beats/second. With gaze fixation, instead of the spontaneous nystagmus, there arose slow, high amplitude eye movements. Optokinetic stimulation was associated with suppression of eye movement reactions, asymmetry and disruption of normal alteration of rapid and slow components of nystagmus.

The research performed identified changes in vestibular functions in space flight and during the postflight rehabilitation period. Such changes attest to the development of vestibular asymmetry and disruption of the gaze fixation mechanism in response to space flight factors.

## NEUROPHYSIOLOGY

P1351(29/90) Karkishchenko NN, Dimitriadi NA.

***Anticonvulsants as protective agents in space motion sickness.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 82-83.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Space Motion Sickness

Rats, Humans

Pharmacological Countermeasures, Anticonvulsants

Abstract: On the basis of a hypothesized similarity between the neurochemical mechanisms underlying heightened susceptibility to convulsion in epileptics and the development of vestibuloautonomic disorders in motion sickness, it was argued that it would be desirable to study the protective effects of anticonvulsants in prevention and treatment of motion sickness. In experiments on rats, we developed a (patented) model for initial screening of such substances. It was demonstrated that a number of preparations (diphenin [phenytoin], valproic acid, chloracon [Benzylamide  $\beta$ -chlorpropionoamide], and glycine) administered prior to vestibular stimulation, depressed development of analgesia in exposure to complex acceleration. These results are evidently associated with the effect on high-affinity GABA receptors. In further research using male volunteers with depressed tolerance of statokinetic loading, we evaluated the effects of certain drugs on development of vestibuloautonomic disorders in motion sickness induction. Significant increase in subjects' tolerance for the effects of complex acceleration analogous to that experienced in space were recorded after use of diphenin and valproic acid. A smaller improvement occurred after use of sodium hydroxybutyrate. Improvements took the form of decrease in autonomic and EEG parameters, and reduction of motion sickness symptoms. The results obtained were confirmed by the results of experiments on animals. The use of anticonvulsants for preventing motion sickness, especially in space, is considered promising.

## NEUROPHYSIOLOGY

P1353(29/90) Polyakov BI, Smirnova TM, Speranskaya MS.

***Psychophysiological characteristics of people susceptible and resistant to motion sickness.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 262-263.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Motion Sickness, Susceptibility  
Humans, Males, Individual Differences  
Psychology, Psychophysiological Parameters

**Abstract:** Psychological and neuroautonomic testing of healthy males, aged 21-45, with high (H), moderate (M) or low (L) resistance to motion sickness induced by Bryanov's method, revealed 15 parameters distinguishing among the groups using 2 discriminant functions. Six of these parameters reflect different aspects of initial psychological state: L and neuroticism scale of Eysenck, L and K test of the MMPI, and tests 10 and 16 in Cattell. Nine parameters reflect autonomic reactivity: changes in P wave amplitude of the EKG, maximal amplitude and alpha-index of the EEG while exercising (holding legs at a 45° angle for a minute), change in systolic and diastolic pressure, respiration rate, alpha index and GSR while performing mental work (word formation), P wave amplitude in emotional stress (negative evaluation of mental performance). Analysis of the interrelationship among the identified parameters showed that for group H, there was a high correlation between the various parameters of autonomic reaction, but no significant correlations between autonomic parameters on one hand and psychological parameters on the other. In group L, all significant correlations reflected among autonomic parameters were not significant. In group M, correlations were found both within the groups of parameters for psychological and autonomic status, as well as between groups. The difference in the structure of correlation clusters suggests that individuals resistant to motion sickness show more developed mechanisms supporting coordination among physiological systems. These mechanisms in turn are weakly related to psychological status. As resistance to motion sickness decreases, the association between autonomic reactivity and psychological status increases and the intercoordination among various physiological systems in reactions to stress also decreases. It is possible that the degree of interdependence of psychological and physiological functions is one of the determinants of individual differences in susceptibility to psychosomatic pathologies, in particular motion sickness.

## PAPERS:

P1300(29/90)\*Novoselov VG.

***Hygienic aspects of the use of calorie-deficient diets enriched with wild plants.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3):45-47; 1990.

[3 references; none in English]

Survival, Botany, Wild Plants, Biological Effects, Human Performance  
Humans, Expedition Members, Males  
Nutrition, Deficient Diets

**Abstract:** Wild plants may be considered an additional food source when individuals are compelled to survive on their own in the taiga, mountains, or swamps. This work studied the biological effects of calorie-deficient diets enriched with wild plants and investigated ways that these plants could be used as food supplements. Studies were performed on expeditions in the Northern Ural Mountains in 1986 and 1987. Marching time was 14 days in 1986 and 6 days in 1987. The routes were difficult, passing through swamps and mountainous taiga far from inhabited areas. Each expedition group consisted of seven apparently healthy male volunteers, aged 21 to 44 years. Half of each group received a traditional well-balanced diet containing 2866 (study I) or 4425 (study II) calories. The second group was given a calorie-deficient diet of 1486 or 457 (survival ration kit) calories consisting of traditional foods. The second group received dietary supplements consisting of wild plants. For the 1986 expedition these included: common lady's mantle, garden sorrel, Siberian cow parsnip, woodland angelica, garden burnet, fireweed, Iceland moss, and boletus mushrooms. Supplements for the 1987 expedition included common lady's mantle, garden sorrel, Siberian cow parsnip, woodland angelica, garden burnet, common St. John's wort, prickly rose, narrow-leaved cattail, European meadow sweet, strawberries, cloudberry, honeysuckle, red currants, blueberries, birch fungus, usnea (a lichen), cedar nuts, and boletus, russula, and yellow brown boletus mushrooms. Before the start of the expedition and after its completion, parameters indicative of the health and performance of the subjects were investigated. During the expedition, time and motion studies were performed. Recipes for preparing the wild plants were devised and tested.

Use of wild plants significantly increased the weight and caloric content of the low-calorie diets. Nonetheless subjects in the second group lost more weight and found the expedition more difficult than those in group 1 (receiving traditional non-deficient diets). Performance parameters were found to decrease only in the first study, although the subjects in the second study received fewer calories from their standard rations. Possibly this was due to the shorter duration of the second expedition. Subjects in group 2 displayed biochemical changes in their blood characteristic of deficient diets, including slight decreases in blood glucose and urea. Urine analyses revealed that subjects in group 2 had superior vitamin status to those in group 1. All other hematological and biochemical parameters and also parameters obtained through provocative tests of the respiratory and cardiovascular systems were equivalent in the two groups. The author believes that the wild plant supplements made it possible for group 2 subjects to avoid the adverse changes usually accompanying deficient diets combined with strenuous physical exertion. Subjects in group 2 did not report feeling hungry after meals, but did become hungry again sooner than those in the first group. Some of the plants, e.g. lady's mantle, were very bland in taste and led to increases in demands for salt and other spices. The author recommends the use of the most tasty wild plants on the trail, even before arriving at camp. He suggests that to avoid poisoning and ecological damage, and save time only the plants most common for a given area be used as food in survival situations. Only the berries and young shoots of certain plants should be eaten raw. Many cooked plants require thorough chewing.

PAPERS:

P1333(29/90) Akhapkina VI, Goncharov IB.

***Prospects for improving pharmacological support of space flights.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages 15-16 .

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Neurophysiology, Pharmacological Countermeasures, Nootropic Drugs, GABA, GHBA  
Humans, Cosmonauts  
Operational Medicine, Space Flight

Abstract: Drugs are the simplest and most accessible way to provide medical aid in space flight. However their use in the practice of space medicine requires special research and special caution. Drugs used in space must not only possess high pharmacological efficacy but also must be safe for use in situations requiring rapid and accurate psychomotor reactions and retention of the capacity to orient oneself rapidly in complex circumstance and make responsible decisions under conditions of stress, and be physically and chemically stable.

The most appropriate structural basis for developing special purpose drugs capable of increasing the resistance of the nervous system to extreme factors and thus expanding the adaptive potential of the body are the biogenic amines -- GABA and GHBA ( $\gamma$ -hydroxybutyric acid). The goal is to control changes in the spectrum of pharmacological action of GABA-ergic drugs so that they produce only the essential form of neurotropic activity without any undesirable side effects. A number of drugs based on GABA have been developed, of which the nootropic drugs are of most interest. In addition to a purely nootropic effect they have tranquilizing, psychostimulating, anticonvulsive, antihypoxic, and adaptogenic actions, which substantially increase the indications for their use. In experimental and clinical physiological studies, it has been established that the adaptation facilitating effect is common to all nootropic drugs derived from GABA. They support both immediate and long-term adaptation to extreme factors.

One prospective direction for expanding the pharmacological action of nootropic drugs involves separating them into optic isomers. Each of these will be potentially useful in medical practice to the extent that it has unique properties of pharmacological action and meets the requirement for high specificity and maximum safety.

## OPERATIONAL MEDICINE

P1340(29/90) Komarova LM.

### ***Do we need a physician on the crew for the Mars mission?***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health  
Pages 94-96.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Operational Medicine, Crew Composition, Physician  
Humans, Cosmonauts  
Space Flight, Long-Term, Mars Mission

Abstract: The issue of the participation of a physician in space flights has been discussed by many specialists in space medicine. In each case, the inclusion of a physician in the crew must be justified, with the deciding factors being duration, distance, and complexity of the flight, size of crew, and degree of risk.

The success of the manned mission to Mars, scheduled to take place in the beginning of the 21st century, will depend on the possibility of ensuring the safety of the crew as evaluated by the acceptable degree of risk or probability of successful return to Earth. At the present time, it is not possible to quantitatively evaluate the danger of a flight to Mars, due to the inadequacy of our knowledge of the actual conditions under which humans will work on such a mission and the possible changes in their psychophysiological status under these conditions. However, qualitative analysis shows that the risk is great.

The relevant characteristics of a flight to Mars include its long duration (from 18 months to 3 years), the enormous distance (minimal distance 56 million km, transmission time on the order of 10 min), complete "isolation" of the crew from Earth (with respect to possibility of an emergency evacuation, replacement of a sick cosmonaut, or provision of assistance), and the unparalleled complexity of the flight program. The conditions under which the cosmonauts will live and work, psychosocial factors, long-term effects of weightlessness, changes in the force of gravity, danger of radiation effects and others take on decisive significance for the flight. From the medical point of view, the support of crew safety in flight entails, first and foremost, maintaining the life and health of the cosmonauts and the necessary supporting conditions. It is essential to take the following factors into account:

- as the flight program becomes more complex and flight duration and crew size increase, the probability of functional disorders, disease, and injuries occurring in cosmonauts also increase, i.e., the significance of potential clinical problems in flight increases;

- medical diagnosis on long-term flights will be impeded by altered physiological reactivity, limited possibility for performing diagnostic procedures, and transmitting and exchanging information with Earth (including medical consultations);

- clinical practice shows that the primary information for establishing diagnosis is obtained by physicians while interviewing and examining the patient. According to Maloney such data constitutes 95% and to Eggstein 70% of the relevant information, while clinical

## **OPERATIONAL MEDICINE**

instruments produce 20% and laboratory studies 10% of the requisite data. According to Hegglin, the respective percentages are 50, 30 and 20;

- due to the complexity of the Mars mission, its crew (according to current estimates, no fewer than 4 members) will consist of highly qualified specialists with experience with space flight, i.e., people of middle age with limited adaptive potential;

- the ability to provide medical aid to the crew, i.e., all the measures that reinforce and support physical and psychological health, including prophylaxis, diagnosis, treatment, and rehabilitation, is an absolute necessity for ensuring flight safety.

Considering the problems listed and the characteristics of long-term flight, one may conclude that it is essential to include a physician on the crew of the Mars mission, since timely and effective medical aid will substantially improve the safety of the flight.

## PAPERS:

P1337(29/90) Grigor'yev LS, Smirnova AV, Voronkov Yul, Myasnikov VI.

***Some new approaches to the problem of medical occupational selection.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 55-57.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Personnel Selection, Cosmonaut Selection, Human Performance, Equipment and Instrumentation  
Humans, Cosmonauts, Twin Studies  
Operational Medicine, Medical Factors, Neurophysiology, Genetics

Abstract: With the increasing role of the human factor in the development of manned cosmonautics, the problem of human tolerance of space flight factors takes on particular practical significance. The first practical stage of this process is medical occupational selection, after which a large variety of steps are taken, including use of prophylactic and corrective measures, to prepare the cosmonaut for flight. Future prospects for cosmonautics increase the importance of this first stage is increasing, and thus the need to find new and promising principles and methodological approaches to permit us to increase the efficacy of selection.

One of these principles may involve, in addition to clinical diagnosis, conduct of studies directed at identifying the possibility of development of maladjustment and the specific characteristics maladjustment is likely to have in a given individual. On long-term flights, we may expect the development of asthenic states or neurosis-like responses as a result of deviations from the normal level of sensory and social information individuals normally obtain in their daily activities on Earth. Since the process of asthenization, like the course of other adaptive processes, is determined by the functioning of the nervous system and neurohumoral regulation, the next aspect of the selection process must be directed at the functioning of the central nervous system. Successful progress in fundamental and clinical neurophysiology can provide all the prerequisites for advances in the practice of cosmonautics. This would involve mass introduction of computerization of neurophysiological research, particularly in the area of electroencephalography, which radically increases the information generated by this method.

The next important selection principle relates to assessment of the potential predisposition to disease and involves the use of the findings of medical genetics and related disciplines, such as neurogenetics, genetic psychology, biochemistry, immunogenetics, and others. It seems desirable to us to use genetic methods to study the significance of genotype-environment relationships in the formation of the functional characteristics of the CNS that support the specifics of individual tolerance to the effects of destabilizing factors. This approach is based on the unassailable argument that, all else being equal, the less an individual displays an initial predisposition to develop dysfunctional states, the lower the actual probability of their occurrence.

Finally, requiring candidates to perform tasks related to actual mission performance requirements under a range of conditions (from monotony to intense stress) constitutes an important general approach with the capacity to increase the efficacy of selection methods.

Validity of these principles and approaches was tested in twin subjects performing operator tasks using computerized methods of analysis of EEG and motor potentials of the brain. A number of interesting properties in addition to those already known through twin studies were identified. The maximal similarity between twins was noted in the following characteristics: preferred technique or tactic for performing operator tasks, dynamics of skill development, tolerance of monotonous work conditions, topographic specifics of patterns of EEG synchronization during performance, specifics of premotor potential in the performance of fine motor tasks, characteristics of autonomic "arrangement" of the tasks performed, and others. The high similarity in efficiency and EEG parameters was also noted in the simultaneous performance of more than one task, especially under conditions close to individual performance limits. The maximal correspondence (cross-correlation) of quantitative EEG parameters during task performance occurred when a skill had already been acquired. These preliminary results already make it possible to assume that genotype-related characteristics of performance will have high diagnostic validity for medical occupational selection.

P1352(29/90) Ioseliani KK, Narinskaya AL, Tereskhina SA.

***On psychological selection of cosmonauts for repeated flights.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

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Pages 234-236.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Personnel Selection, Cosmonaut Selection, Space Flight, Repeated Flights, Psychology, Human Performance

Humans, Patients, Age Differences

Hypokinesia With Head-Down Tilt

Abstract: Issues of psychological selection of cosmonauts for repeated flights have not been sufficiently studied. There is no data on psychological criteria and certification requirements for allowing an individual to fly more than once. The nature of the function relating the dynamics of psychological performance capacity to duration of the interval between flights is unknown. One of the most important problems -- whether individuals should be allowed to fly again if there are health problems which have a psychological effect (atherosclerosis, initial symptoms of high blood pressure, etc.) has not been solved.

We performed a study in which weightlessness was simulated by two periods of exposure to hypokinesia with head-down tilt with varying intervals between them (condition 1: 30-day hypokinesia, 30-day recovery, 30-day hypokinesia; condition 2: 30-day hypokinesia, 10-day recovery, 30-day hypokinesia). Subjects included were 13 people aged 26 to 55: the young individuals (n=8) were apparently healthy and the older individuals (n=5) showed incipient atherosclerosis and borderline high blood pressure.

To evaluate psychological performance and the status of the major psychological functions we used a set of instruments: "continuous computation at a fixed rate," "proof-reading test" (variant with letters), "working memory," "arithmetic counting," "determinator," a questionnaire for self-rating of general state and mood (Grol and Heider), and a scale of situational anxiety (C. Spielberger).

The younger individuals did high quality, reliable work throughout the study. Their work was marked by a high level of initial readiness, rapid warm-up, rapid development and restructuring of the required cognitive skills, even and stable rate of work, and accurate performance of stressful mental work under conditions of time pressure. The maintenance of this high level of task performance was also correlated with rather stable parameters of subjective state and situational anxiety.

The older people with health problems displayed fluctuations in performance parameters. There was some inhibition of mental processes; activity and flexibility were significantly diminished. Some members of this group tried to work as rapidly as possible, but because of frequent fluctuations in the rate this could not be achieved leading to decrease in their mental efficiency. Under conditions of time pressure, the members of this group experienced difficulties performing the more difficult tasks. The parameters of self-ratings and situational anxiety were unstable.

## PERSONNEL SELECTION

Analysis of the material suggested that for apparently healthy young individuals the issue of a second flight after completion of a rehabilitation period should be decided on the basis of their individual psychological traits. Older people with incipient atherosclerosis and borderline high blood pressure should not fly a second time.

## PAPERS:

P1302(29/90)\* Yevdokimov VI.

***Risk factors for the occurrence of neuroses and psychosomatic illnesses in flight crews.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 50-53; 1990

[9 reference; 2 in English]

Psychology, Neuroses, Psychosomatic Illness

Humans, Flight Crews

Aviation Medicine, Risk Factors

Abstract: This paper describes a study of the factors fostering psychological personality disorders, neurotic states, and psychosomatic illnesses in flight crews. A total of 121 patients underwent comprehensive clinical psychological examinations. Of these, 24 were found to have symptoms of asthenic states and reactions. An additional 97 suffered from psychosomatic illnesses. In the majority, the symptoms of the illnesses hampered their job performance. A total of 165 subjects were used as a control. The psychological examination involved the PAT (projective aviation test) consisting of 10 pictures of aviation situations, about which subjects are asked to make up a story. Stories were rated on five dimensions: flight motivation, confidence in success, activity, discipline, and anxiety. The second test used was the "standardized method for studying personality (SMSP), a 566 question personality inventory, yielding a graphic profile with ratings on 13 scales.

The study identified two groups of individuals with inadequate strategies for psychological adjustment to extreme conditions of professional activity, which could be considered risk factors for the occurrence of psychogenic diseases. Group 1 contained 71% of the neurotic subjects and 61% of those with psychosomatic problems. In the control group there were 11.5% of such subjects. These subjects were marked by lack of confidence, indecisiveness, an inflated sense of duty, tendencies to check and recheck what they had done, and to self-analysis. Ordinary obstacles were responded to as insurmountable, causing them to operate at the upper extent of their capacities and fostering constant tension. According to their commanders their worst fault was a tendency toward indecisiveness in a crisis. Their personality inventory profiles showed high levels of anxiety and depression, and impulsivity, and their projective stories involved characters under pressure from those around them. Their stories showed much higher levels of expectation of failure and anxiety, and low professional motivation.

The second group contained 21% of the neurotic patients, 27% of those with psychosomatic problems, and 13.3% of the controls. These subjects were marked by impulsivity, poor social adjustment, extreme stubbornness, and inability to take orders. These were the subjects that their superiors tried to get rid of. They were described by their superiors as unconscientious, undisciplined, and prone to conflict and were subject to accidents and near-accidents. On the personality inventory these subjects showed high impulsivity, rigidity, and depression. Their profile was similar to that of individuals with psychopathic traits. Their stories tended to contain conflicts, with bold decisive heroes who were often thwarted by their social environment or physical objects. They were less disciplined and had less faith in success than controls.

The authors conclude that early diagnosis of inadequate psychological adjustment (risk factors) in the form of asthenic tendencies and a tendency to nonconformist behavior will facilitate initial prevention of neuroses and psychosomatic illnesses in flight personnel.

Figure 1: Personality profile of cadet L: Diagnosis neurotic state

Figure 2: Personality profile of pilot K: Diagnosis, mild psoriasis of left calf

P1306(29/90)\* Terelyak Ya, Kobos Z (Poland).

***Psychological determinants of time to complete flight training.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(3): 59-60; 1990

[9 references; all in Polish]

Aviation Medicine, Flight Training, Human Performance  
Humans, Flight Personnel  
Psychology, Test Scores

Abstract: Correlations were computed between time to complete flight training and a number of scores on psychological tests for 20 candidates for the Aviation Officer Training Institute. Tests were administered during selection and included: assessed reactivity and lability of the nervous system using a temperament-assessment instrument, neuroticism, and extroversion on the basis of response to a multiphasic personality inventory. During training and after solo flights, simple reaction time and psychomotor coordination were measured. Time to complete training was measured on the basis of total time and number of flights with instructor before first solo flight.

There was a negative correlation between reaction time and training time, and between reactivity and neuroticism. Number of errors made in simple reaction time tests was positively correlated with time to perform psychometric tasks and number of flights before solo flight.

Table: Spearman correlation coefficients between results of psychological investigation of training time and number of flights before solo flight.

P1341(29/9) Zaprisa NS.

***Dynamics of parameters of communicative activity in the system for psychological analysis of cosmonaut functional status.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 232.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Human Performance, Functional State

Humans, Cosmonauts

Psychology, Psychodiagnosis, Speech Analysis

Abstract: Many years of experience with psychodiagnosis based on speech behavior allows us to assert that communicative (speech) activity (in all its variants) is a relatively stable personality trait.

Parameters of "speech activity" in radio-communications session were recorded using instruments and involved identification of the duration of "pure" speech and duration of pauses (here we are not referring to the rhythmic features of speech, but to periods of speaking and being silent), taking into account the duration of the communications session.

Psychologists' need to attend to features of speech behavior (psycholinguistic characteristics of the structure of utterances, prosodic features of speech, emotional reactions), and also the features of the specific communication situation (conditions and specifics of activity or other features of the speech situation) in real-time, has made it necessary to target a certain limited set of parameters of "speech activity," as reflecting the most significant manifestations of "communicative potential" or individual communicative style.

The stability of parameters of communicative activity may serve as one criterion of stability of functional state, provided that communications situations are identical in all instances observed and that there are no external constraints on how the communication is to be organized. However, these conditions are rarely observed in actual communications sessions. This seeming contradiction does not preclude the possibility of using these parameters for diagnostic purposes. Averaging the quantitative values of each parameter for a day and a week of flight equalizes the various "variables" in the communicative interactions. At the same time, the variability of individual parameters of communicative activity allows us to assess the level of communicative creativity, reflecting the capacity for adaptive restructuring of one's own behavior.

The use of parameters of "speech activity," along with psycholinguistic and social psychological characteristics of the individual, increases the reliability of systems of psychodiagnosis in evaluating and predicting the state of cosmonauts in flight.

P1343(29/90) Myasnikov VI, Ivanov AA.

***A multimethod evaluation of the psychophysiological state and behavior of humans undergoing a 370-day period of hypokinesia with head-down tilt.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

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Pages 250-251.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Psychology, Psychophysiological State, Human Performance  
Humans, Males  
Hypokinesia With Head-Down Tilt, Long-Term, 370-Day

Abstract: Soviet space medicine has accrued a great deal of experience in performing long-term (up to 1 year) simulation experiments to study the characteristics of the psychophysiological adaptation of humans to a set of extreme environmental and occupational factors (wintering at the "Vostok" station, 1 year's experiment in a ground-based sealed life support system) as well as from performance of actual long-term flight experiments (366-day space flight of cosmonauts V. Titov, and M. Manarov on space station Mir). The experimental data generated by these studies suggested the major goal of the present experiment — to identify the principles underlying changes in psychophysiological state and productivity of humans under conditions of long-term (up to 370 days) monotony and highly restricted motor activity.

The research was performed on 10 volunteers - apparently healthy men, aged 30 to 42. The participants were divided into 2 subgroups: the first (n=5) engaged in a systematic program of physical exercise throughout the experiment. The second subgroup (n=5) began the exercise program on day 120 of the study. Personality testing instruments (Eysenck, Strelau, Cattell, MMPI, and others), tests of higher-order psychological functions, emotions, and characteristics of autonomic response (GSR, HR, BP, etc.) were used to study the characteristics of the subjects' adaptation to the experimental conditions. Testing with these instruments occurred with frequency of at least once a month.

Comparison of results of simulations and flight experiments showed both common and distinctive features in the characteristics of psychological adaptation of the subjects to extreme conditions. The duration, homogeneity, and monotony of the physical and social environment, similar for all studies, had significantly greater effects in the field experiments due to the greater "aggressiveness" of environmental factors (remoteness, autonomy of the isolation group, etc.).

Multimethod psychophysiological assessment of the state and behavior of volunteers during a period of hypokinesia with head-down tilt lasting 370 days revealed a transient, statistically significant disorders in the subjective and sensoriperceptual areas, a decrease in the productivity of psychological activity, and a decrease in the quality of visual/motor coordination. The research on the personality aspects of psychological adaptation to a 370-day period of hypokinesia showed that its manifestations were different in different people, especially in the area of emotions and mood and to a lesser extent in parameters of productivity of psychological performance. This accords with the results of medical monitoring of the psychological state and performance of cosmonauts on long-term flights.

The data obtained should be considered for further adjustment and improvement of ways and means for psychological prophylaxis and optimization of the occupational performance of the operator with application to the goals of manned Mars missions.

P1344(29/90) Myasnikov VI, Polyakov VV, Zhukova OP, Ponomareva II,[USSR], Momand AA [Afghanistan], Aleksandrova AA, Stoilova I [Bulgaria].

***The study of cosmonauts' sleep in flight on space station Mir.***

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 251-252.

NOTE: THIS IS A TRANSLATION OF A PUBLISHED ABSTRACT. WE HAVE NO FURTHER INFORMATION ABOUT THIS WORK.

Psychology, Neurophysiology, Sleep Patterns, Adaptation  
Humans, Cosmonauts  
Space Flight, Mir

**Abstract:** Introduction: Experience with medical support of manned flights on space stations Salyut and Mir has shown that changes in sleep are one of the earliest and most frequent manifestations of the process of psychological adaptation of humans to extreme factors. The first experiment in Soviet cosmonautics to study the phase structure of human sleep was performed jointly on space station Mir by cosmonauts from the USSR, Bulgaria, and Afghanistan using the Son-K device.

**Method:** Sleep was studied through simultaneous recording of electrophysiological parameters (electroencephalography, electrooculography, electromyography, and electrocardiography) on magnetic tape of the Son-3 device (Bulgaria) followed by automated processing of the data in the Pravets computer. Immediately after waking the cosmonauts responded to a questionnaire rating the quality of their sleep. A total of 16 sleep periods(pre-, in- and postflight) were studied.

**Results:** Analysis of the data showed that changes in the phase structure of sleep occurred throughout the acute period of adaptation to weightlessness. The severity and direction of these changes were subject to individual differences. Thus, in the Bulgarian cosmonaut, the duration of sleep and time to fall asleep did not differ from baseline. Adaptive restructurings manifested themselves in a statistically significant increase in stage 4 slow sleep, up to 42% (normal =23%), a decrease in REM sleep to 6.5% (compared to 24%) and a decrease in the number of cycles completed from a norm of 4-5 to 1-2 with increase in their duration to 120-180 minutes (norm 60-90 minutes).

Features of the stage structure of sleep in the Afghan cosmonaut on day 5 of exposure to weightlessness included increase in time to fall asleep (up to 26-28 minutes) and a high percentage of phase 1 slow sleep (35.9%). These characteristics were typical of his baseline parameters. Difficulty in falling asleep and lightness of sleep in weightlessness were noted in his subjective evaluations.

For the Soviet cosmonaut, duration of sleep in the baseline period was within the boundaries of the norm and amounted to 463 minutes. Inflight, duration of sleep gradually increased and by day 191-192 had reached 600-660 minutes. The period required to fall asleep at this time had increased to 99 minutes, which corresponded to the subjective assessment of "difficultly falling asleep." A statistically significant increase in duration of stage 1 slow sleep was noted on days 71 and 138, at which point it was 31.2% and 41.2%. On day 191-192, delta-sleep

(stages 3 and 4) increased to 22.6%. REM sleep progressively increased in weightlessness from 9.8% (on day 71) to 20.3% on day 192.

Conclusions: Objective data on the phase structure of sleep combined with subjective evaluation of sleep adequacy is an important diagnostic criteria expanding understanding of functional reserves during a cosmonaut's adaptation to conditions of long-term space flight, especially during acute adaptation to weightlessness.

## PAPERS:

P1309(29/90)\* Zagorskaya YeA, Klimovitskiy VYa, Melnichenko VP, Rodina GP, Semenov SN.  
*The effects of low-frequency electromagnetic fields on physiological systems.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
 24(3): 3-11; 1990.

[116 references; 24 in English]

Neurophysiology, Endocrinology, Regulatory Systems, Hematology  
 Review Article  
 Radiobiology, Electromagnetic Fields, Low Frequency

Abstract: The authors reviewed the literature on the effects of low frequency electromagnetic fields and came to the following conclusions. Despite certain inconsistencies in the data in the literature, there is evidence attesting to pronounced response of the physiological regulatory systems — neural and endocrine — to low frequency constant and intermittent magnetic fields. Although data on reactions of the cardiovascular system are contradictory, the changes occurring here may be pathological in nature. In all probability these changes are due to neurotropic properties of the electromagnetic fields and their influence on the functional status of the regulatory systems, particularly the hypothalamus. To some extent the state of regulatory mechanisms is also a function of the response of white blood cells to magnetic fields.

Early response of the regulatory systems (hypothalamus and pituitary) to constant and intermittent low frequency magnetic fields trigger reactions of the endocrine glands and organs affected by these glands, leading to stimulation of a branching chain of metabolic processes. Thus the nature and intensity of the response to electromagnetic fields include, first and foremost, the neuroendocrine system, the physical-chemical reactions of whose cells evidently are more labile than those of other tissues.

At the same time it is possible that the direct effects of electromagnetic fields themselves cause changes to develop in the state of cellular and mitochondrial membranes, altering tissue and vascular permeability and disrupting enzyme activity. An increase in the level of  $\text{Ca}^{2+}$  in cell cytoplasm, changes in activity of the adenylate cyclase system and in the level of cAMP - each of these leads to a number of reactions related to cell metabolism. Alteration of the concentrations of these compounds under the influence of low density constant magnetic fields would substantially modify transmission of hormonal information to the cell in all components of the endocrine system, leading to disruption of hormonal regulation in the body as a whole. Here, changes occurring in response to exposure to electromagnetic fields in the status of regulatory mechanisms will be compounded by the primary disruption of cell structure induced by the direct effect of the field. The severity of total harmful effects of the field is a function of duration of exposure and field intensity.

P1319(29/90)\*\* Katasonov SN, Shishkina SK, Maltseva IO, Ryabova TYa.

***Study of changes in the electrical parameters of the skin of irradiated rats.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 34-35; 1990.

[5 references; 2 in English]

Skin, Electrical Parameters, Prognostic Indicator

Rats

Radiobiology,  $\gamma$ -Irradiation

**Abstract;** The goal of this study was to investigate whether severity of radiation effects could be estimated from electrical parameters of the skin and whether these parameters can be used as a new type of biological indicator of severity of irradiation effects. The authors studied dynamics of electrical parameters of the skin in laboratory rats under normal conditions and after irradiation. Subjects were 85 female Wistar rats. Electrical parameters were measured using a special instrument. The method allowed determination of the equivalent electrical resistance of areas of the skin. This parameter was measured at 6 points in each animal. Both control and experimental animals were tested for 3 days in a baseline period. Then experimental subjects were irradiated with  $\gamma$ -radiation for  $^{137}\text{Cs}$  in doses of 8.3 and 15 Gy (dose rate 0.30 Gy/min). Control animals went through a dummy irradiation procedure. Electrical parameters were measured for 26 days after treatment for dose of 8.3 Gy and up to the day after death for the higher dose. Statistical processing utilized the Wilcoxon-Mann-Whitney test for ranked data.

In the norm, electrical skin parameters were found to vary considerably from day to day in the same sample of rats. Under dummy irradiation procedures, the stress of restraint led to a short-lived (30-minute) decrease in skin resistance. In the irradiated rats this decrease was not as marked, and the difference was significant for a number of points. Beginning on day 2 skin resistance increased markedly in irradiated rats, peaking on day 7, at which time it was from 2.2-7.8 times higher than the corresponding value for the control group. On days 8-12, resistance decreased, reaching new peaks on days 13-15 and 20-21. Periods of increased resistance preceded and periods of decreased resistance coincided with periods during which the animals died. Analysis of individual data confirmed this pattern. At the higher dose of radiation, electrical skin resistance changed drastically 1 day after treatment. Subsequently resistance continued to increase, peaking immediately before each animal's death. Skin resistance the day after death was at control level.

The authors conclude that electrical parameters of skin are promising for use as indicators of biological effects of irradiation.

Figure 1: Dynamics of electrical resistance of skin of rats irradiated at a dose of 8.3 Gy

Figure 2: Dynamics of electrical resistance of skin of rats irradiated at a dose of 15 Gy

P1320(29/90)\*\* Lobacheva GV.

***Research on audiogenic reactions of rats after ultraviolet-irradiation of their eyes.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(4): 36-38; 1990.

[11 references; 1 in English]

Neurophysiology, Audiogenic Seizures

Rats, Females

Radiobiology, Ultraviolet-Irradiation, Eyes

**Abstract:** This study attempted to evaluate the effect of ultraviolet-irradiation of the eyes on the central nervous system. The CNS parameter selected was the tendency of rodents to have an epileptic like seizure after exposure to a loud noise. Subjects were female Wistar rats. Female rats are more susceptible to audiogenic stimulation. Intensity of the sound used to provoke reactions was 96 dB for 90 seconds. Motor excitement was rated as a level 1 seizure. A stuporous state in which the animal fell on its stomach and clonic spasms occurred was considered a level 2 seizure. Falling on the side with clonic spasm was considered level 3, and falling on the side with tonic tension of the muscles was defined as a level 4 seizure. In addition, three types of reaction were identified: type A involved a single phase of phase of motor excitation followed by inhibition as exposure continued. Type B was defined as two-phase excitation. in which the first excitation period is followed by inhibition and then a second excitation period. This type was common for seizures of levels 2, 3, and 4. Type C also involved a single phase of excitation and was also associated with level 2, 3 and 4 seizures.

Preliminary studies to determine baseline parameters were also used to divide subjects into roughly equivalent control and experimental groups with 21 and 20 subjects each. Seven days after the baseline study the control and experimental animals were anesthetized and then both eyes of the experimental animals were irradiated with ultraviolet in the range of 290-310 nm, with maximum emission at 302 nm in a dose of 10 kJ/m<sup>2</sup>. For ultraviolet keratoconjunctivitis, the biologically effective dose is 1.74 kJ/m<sup>2</sup>. Repeated testing of audiogenic effects in an echo chamber was conducted during the development of acute inflammatory reaction (day 3) and in the initial period of developing corneal opacity (day 7) and a remote period (day 35). Mean values were computed excluding animals showing inhibitory reactions. Data were tested using the Wilcoxon-Mann-Whitney statistic.

Almost all animals in both groups belonged to type B. Only one animal, in the experimental group, belonged to type A. Compared to control, experimental animals showed a slight decreases in number belonging to type B. Experimental animals displayed a prolonged latent period for level 1 seizure to occur. Duration of the first phase of excitement was the same in control and experimental groups, and duration of the intermediate inhibitory phase was higher in the experimental group. The treatment was associated with decreased duration of levels 1, 3, and 4 seizures and increased duration of level 2 seizures.

The authors conclude that ultraviolet irradiation of the eyes is associated with a general tendency of inhibitory process of the CNS to be enhanced and excitatory processes to decrease.

Table: Parameters of seizure activity in rats before and after irradiation of the eyes with ultraviolet radiation

Figure: Dynamics of parameters of seizure activity in control and experimental rats

P(29/90)\*\* Malakhovskiy VN, Stemparzhetskiy OA, Bokk MI.

***Physiological properties of posture (balance) maintenance in dogs during immediate response to radiation.***

Kosmicheskaya Biologiya i Aviakosmicheskaya.

24(4):38-40;1990.

[10 references; 2 in English]

Musculoskeletal System, Neurophysiology, Balance

Dogs

Radiobiology,  $\gamma$ -Irradiation

**Abstract:**The goal of this study was to investigate a number of posture maintenance parameters in dogs during the period of initial response to irradiation and to identify those that correlate with disruption of sensorimotor coordination and performance of purposeful acts. Subjects were outbred male dogs subjected to  $\gamma$ -irradiation in doses of 10 and 80 Gy at a dose rate of 1.7 Gy/min. In one of the experiments, 5 hours after 10 exposures to radiation at intervals of 5 minutes, the area of a passive vector stabilogram was recorded. Other measurements included maximal muscle effort and state of sensorimotor coordination. In the stabilogram study, after the animal had grown accustomed to the platform of the device, a stabilogram was recorded over a period of a minute. Maximal muscle tension and state of sensorimotor coordination were measured in the irradiated animals over a period of 1 month after irradiation. The procedure involved jumping over a barrier of increasing height and walking on a bar of decreasing width. Animals irradiated at 10 Gy jumped the barrier from a tensometric platform, making it possible to note both an increase and decrease in the power of the thrust. Before and after irradiation at this dose the responses of the animal were studied while it was compelled to shift its position to compensate for horizontal rotation of the platform on which it was standing. The following parameters were measured: amplitude of displacement of projection of the center of gravity, duration of maximal displacement, total time for postural reaction to displacement to occur, speed of recovery of postural equilibrium.

Immediately after radiation, animals displayed significant motor excitation making stabilography difficult. After 1-3 hours had elapsed episodes of motor excitation were observed and were followed by vomiting. On the whole, motor and behavioral activity were diminished, muscle tonus and readiness to change posture were minimal. After irradiation at 80 Gy, the period of initial excitement was much shorter. Vomiting began during irradiation and ended after 1-2 hours, followed by maximal decrease in motor activity. During this period ataxia, tremor and staggering were noted. Disruption of motor coordination and maximal strength of jump were the same at both doses, reflecting gradual increase in disruption between 30 minutes and 3-4 hours after irradiation. Stabilograph data did not provide enough information compared to behavioral recording. For this reason the procedure involving rotation of the supporting platform was introduced. This method was tried only with animals irradiated at 10 Gy. Of the parameters listed above, the one providing most information was the time required to regain postural equilibrium. This parameter showed good correspondence with capacity to perform purposeful action requiring maximal muscle strength and high sensorimotor coordination. This suggested that this parameter has potential for evaluating performance capacity.

Figure 1: Characteristic postural reaction to a single disturbance

Figure 2: Maximal height of barrier jumped over, minimal width of bar crossed, strength of push, area of vector stabilogram in dogs after irradiation

Figure 3: Mean values of parameters of a stabilogram of dogs irradiated at a dose of 10 Gy after pulsed displacement of a supporting platform

P1327(29/90)\*\* Bugrov SA, Davydov BI, Tikhonchuk VS, Soldatov SK, Osokina TF.  
***The protective action of mexamine in microwave irradiation of rats.***  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
24(4): 55-56; 1990.  
[10 references; 5 in English]

Biological Effects, Survival

Rats, Female

Radiobiology, Microwave Irradiation, Radioprotectors, Mexamine, Serotonin

Abstract: Mexamine, 5-methoxytryptamine hydrochloride, a radioprotective substance close to serotonin in chemical structure and pharmaceutical action, has been shown to protect animals from the effects of ionizing radiation and hypoxia. In this experiment its protective effect with respect to microwave irradiation was investigated. Subjects were 230 outbred female rats irradiated in an anechoic chamber at 2.4 GHz for 3 minutes. The coefficient of reflection did not exceed 3-4%. Specific absorbed dose was 90.1 W/kg in one case and 105 W/kg in the other. Mexamine hydrochloride was administered intraperitoneally in doses of 1, 5, and 15 mg/kg. After 5 or 20 minutes or 1 or 2 hours, they were irradiated. Control animals were given isotonic saline. Survival over the course of 1 day was assessed.

Irradiation by these microwaves led to hyperactivity and periodic convulsions. Animals died either during irradiation or on the first day after it. Those surviving the first day generally survived. When mexamine in a dose of 15 mg/kg had been administered 20 minutes or 1 hour after irradiation, survival rates were 71 and 88% as opposed to 35% in the control. When the drug was administered 2 hours before irradiation, no benefit was seen. When it was administered 5 minutes before irradiation, survival decreased to 6%. This latter effect is explained by the fact that after 5 minutes mexamine has increased oxygen consumption by the tissues but has not yet decreased body temperature sufficiently. Curves of mexamine elimination and its protective effect show good correspondence.

Figure: Association between protective effect of mexamine under exposure to microwave irradiation, its elimination, and survival of animals

## REPRODUCTIVE SYSTEM

### PAPER:

P1326(29/90)\*\*Serova LV, Apanasenko ZI, Ivanovna SYa, Chelnaya NA.

***The effect of hypergravity on mammals during the period of delivery and birth of offspring.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

23(4): 54-55; 1990.

[3 references; 2 in English]

Reproductive System, Delivery, Lactation, Developmental Biology, Psychology, Maternal Behavior

Rats, Female, Pregnant, Neonates

Hypergravity, Centrifugation

Abstract: This work observed the effects of 2-g centrifugation on mothers and offspring during the period of delivery and nursing. Subjects were female Wistar rats centrifuged starting on day 13 of pregnancy until birth (day 23). Subsequently animals were centrifuged until day 7 of the lactation period (condition 1) or returned to normal gravitational conditions (condition 2). Parameters of reproductive function, weight and maturity of offspring, and weight of visceral organs were recorded.

No significant differences were observed in reproductive function or maternal behavior. Until day 7 after birth, six neonates each were left with four mothers exposed to centrifugation before and after delivery. Of these seven died during this period, mainly on day 1. The same number of neonates were left with each of four mothers returned to normal g after delivery. In this condition, a total of six neonates died. Thus postnatal death rates were virtually identical. Some of the rats born on the centrifuge displayed signs of vestibular dysfunction, such as running in circles. Rats centrifuged prenatally and then returned to 1-g did not display significant differences from control in rate of growth. Those remaining at 2-g after birth displayed significantly lower weight on day 7 of life. However, no developmental lags were noted. Juvenile rats in condition 2 showed no difference from the control in weight of liver, kidneys, myocardium, spleen, brown fat, or thymus. The mothers in this group had lower body and liver weight than controls, while thymus weight was elevated compared to those in condition 1, but not control mothers. Results demonstrated that it was possible in principle for animals to bear and successfully nurse offspring while exposed to hypergravity of 2-g. While neonates showed some delay in weight gain under these conditions, they were fully viable and developed normally.

Table: Weight of body and organs of neonate rats 7 days old

Grp	n	Body wt, g	Organ weight, mg					Fat	
			liver	kidneys	myocard.	thymus	spleen	white	brown
1. Vivarium	18	16.8	524	199	104	35.5	129	10.9	106
2. Synchronous	18	14.9	473	183	88	32.2	104	7.9	95.4
3. 2-g - 2-g	16	12.4	388	143	60.5	27.7	63	7.5	67
4. 2-g - 1-g	17	15.3	471	171	81	30.6	95	11.8	81
p(1-3)		<.0.001	<0.001	<<0.001	<0.001	<0.05	<0.001	<0.05	<0.001
p(1-4)		<0.05	<0.01	<0.01	<0.001	--	<0.001	--	<0.001
p(2-3)		<0.001	<0.01	<0.001	<0.001	--	<0.001	--	<0.01
p(2-4)		--	--	--	--	--	<0.001	--	--
p(3-4)		<0.001	=0.001	<0.001	<0.001	--	<0.001	<0.001	<0.05

**PAPER:**

P1310(29/90)\*\* Gazenko OG, Grigor'yev AI, Bugrov SA, Yegorov VV, Bogomolov VV, Kozlovskaya IB, Tarasov IK.

***Review of the major results of medical research during the flight of the second prime crew of the Mir Space Station.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

23(4): 3-11; 1990.

[16 references; none in English]

Space Biology and Medicine, Operational Medicine, Habitability and Environmental Effects, Microclimate, Atmosphere, Microbiology, Cardiovascular and Respiratory Systems, Musculoskeletal System, Neurophysiology, Motor Effects, Nutrition, Metabolism, Endocrinology, Body Fluids, Adaptation, Radiobiology, Hematology, Immunology, Psychology

Humans, Cosmonauts

Space Flight, Long-Term, Mir, Second Prime Crew, Prophylactic Countermeasures

**Abstract:** The flight of the second prime crew on the Mir-Soyuz-TM-Progress-Kvant complex took place between February 6, and December 29, 1987. The crew commander Yu.V. Romanenko (CC-2) spent 326 days in space; the flight engineer, A.I. Laveykin (FE-2-1) served as a crewmember for more than 175 days and then was replaced by flight engineer A.P. Aleksandrov (FE-2-2), who spent 160 days in flight.

During the second prime crew's stay on the space station complex, the international Soviet-Syrian visiting crew worked on board the station for 7 days. During their stay, the second prime crew was visited by seven Progress cargo spacecraft, which brought scientific equipment and instruments, fuel, food, water, and other consumable materials. Crewmembers also set up and used the unique equipment of the Kvant module to perform scientific experiments. Aside from the extensive research program, cosmonauts Yu.V. Romanenko and A.I. Laveykin performed 3 EVAs (April 11, and June 12 and 16, 1987) with a total duration of 8 hours and 48 minutes. During the first (unplanned) EVA, the crew performed technical work to enable the Kvant module to dock with the space station. The objective of the second and third EVAs was installation of a solar panel.

The scientific program included study of the Earth's natural resources, and meteorological, astrophysical, geophysical, and biomedical investigations.

Operational medical support measures during this flight were directed at supporting the crew's health and work capacity to ensure successful completion of the flight program. This was achieved through adequate living conditions, medical monitoring and more thorough examinations of the cosmonauts, along with a comprehensive set of prophylactic countermeasures to prevent the adverse effects of long-term space flight factors. Psychological monitoring and support of the crew was also provided.

The major portion of the scientific medical program involved continuation and further development of research on the phenomenology and mechanisms of changes in various physiological systems during and after long-term space flight.

#### **GENERAL DESCRIPTION OF FLIGHT CONDITIONS ON THE MIR SPACE STATION**

**Microclimate Parameters:** Throughout the flight temperature, humidity, and atmospheric parameters (total barometric pressure, partial oxygen and carbon dioxide pressures) of the inhabited modules were maintained within established, hygienically acceptable standards, close

to conditions on Earth. For the most part, the cosmonauts' subjective assessments coincided with the objective environmental monitoring data. The temperature-humidity conditions that were maintained most of the time (mean air temperature of 22-25° C and relative humidity of 37-66%), and the use of flight suits with a heat protection factor of around 1 CLO provided the cosmonauts with comfortable conditions for low to moderate exertion. This was confirmed by their relatively low consumption of water and the absence of excessive perspiration or thirst.

**Sanitary and Chemical Status of the Atmosphere:** The sanitary and chemical status of the atmosphere of the inhabited space station modules was assessed through gas chromatographical analysis of air samples, collected on sorbents and returned to Earth. As a result of analyses of the samples, organic substances belonging to the following classes were identified and measured:

- aliphatic and aromatic hydrocarbons
- alcohols
- complex esters
- ketones
- aldehydes
- halogenated hydrocarbons.

These substances are volatile human metabolites and products emitted by nonmetallic materials used in the spacecraft interior and onboard apparatus. Analysis of the results obtained showed that the major contributors to "pollution" of the atmosphere of the inhabited modules were acetone, acetaldehyde, ethanol, and ethylacetate. These contaminants did not have downgrade the quality of the atmosphere, which was evaluated as satisfactory.

Investigation of the station microecosystem enabled identification of specific zones where microorganisms - gram negative bacteria (including opportunistically pathogenic enterobacteria), spore-forming bacilli and mold fungi, predominantly representatives of *Penicillium* — developed. These microorganisms may have medical significance, and under some conditions are capable of causing biodegradation of polymer materials. During the second prime crew's time on the station, problems associated with the state of its environment were precluded by preliminary and inflight measures.

Personal hygiene measures included systematic sanitary treatment of the skin, hair, mouth, utensils and the interior surfaces of the spacecraft. For this purpose, the crew was supplied with "wet wipes" for daily hygiene, "wet towels" and "dry towels" for wiping the body and head after exercise and when changing underwear, "oral hygiene products" and also toothpaste and chewing gum, hair care products, a set of toilet articles, wipes for cleaning dishes and the interior of the station, and detergent in packets.

Radiation conditions on the Mir station were assessed as quiet throughout the flight of the second prime crew. The total radiation dosage for the crew in month 11 of flight was 7630 mrad, and for the other two members of the crew (flying 5-6 months) total dosage was 3580-4310 mrad.

The prescribed diet completely satisfied the cosmonauts' metabolic needs, contained all the essential nutrients, and maintained crewmembers' nutritional status at a satisfactory level. The mean daily caloric consumption was 3100-3200 calories. Freeze-dried products, which were rehydrated inflight, comprised 65% of the total diet.

Potable water was brought from Earth or regenerated directly from condensate of atmospheric moisture, consisting primarily of moisture emitted by the cosmonauts themselves. Both hot and cold water were used.

The proportion of regenerated water consumed was 69%. Total water consumption averaged about 1.85 liters per man per day (not counting water in food and metabolic water), which was adequate for daily inflight fluid requirements.

The prime crew's work-rest schedule followed a 24-hour cycle with 2 days off per week (generally, Saturday and Sunday). The nominal duration of a work day was 8 hours 30 minutes. Eight to 9 hours were assigned for sleep, with 2 hours for exercise.

Throughout the flight there was some variation in the cosmonauts' workload from week to week, due to differences in the various stages of the flight program. Thus, during the initial period (first 2 weeks of the flight) the workload was planned to be reduced by 50% of the standard level to accommodate adaptation to weightlessness. The initially unsuccessful docking with the Kvant module entailed an unforeseen EVA, and was marked by shifts in work periods and curtailment of the scheduled sleep period to 4-5 hours. Subsequent periods of overwork were episodic in nature and adequately compensated by additional free time and days off. During the final stage of the flight, the duration of a working shift was curtailed somewhat so that time could be devoted to prophylactic countermeasures and preparations for reentry.

Psychological support measures were directed at maintaining the crewmembers' positive emotional state and readiness for work and correcting any observed shifts in state caused by psychologically significant flight factors.

The psychological support system covered the following areas: transmission of nonwork-related information (daily retransmission of radio and television broadcasts and music); material for leisure activities (music and videotapes, movies, periodicals, books); and ground support.

The set of prophylactic countermeasures utilized during the flight of the second prime crew was directed at stabilizing health, maintaining high work capacity, and preventing physiological disturbances during long-term space flight, reentry, and the postflight period. The basis for the prophylactic measures was physical training on the onboard exercise machine (an improved multifunction machine of the "treadmill" type, with a system of tension and fixed cords and an onboard bicycle ergometer), use of a set of expanders and constant loading suits.

Conditioning exercise schedules for both exercise machines followed a microcycle consisting of 3 exercise days and 1 day of rest (3 + 1 cycle). The energy expenditure on physical training during a cycle with two exercise periods per day was 1400-1520 calories.

In accordance with the flight program, the second prime crew began exercising on the onboard apparatus at the end of the first week of flight and gradually increased the amount and rate of exercise; by the end of the first month they had attained the planned level of two daily exercise sessions with respect to amount, rate, and nature of exercise. The recommended "traversed distance" of locomotor exercise on the treadmill was 3600-3730 m with a mean rate of about 125 m/minute; stipulated workload on the bicycle ergometer was 21,100 kgm, with a mean exercise rate of 800 kgm/min.

The cosmonauts demonstrated a responsible attitude toward performance of training exercises and toward specialists' recommendations. The training program was individualized to conform with the flight program and each cosmonaut's level of conditioning.

On the whole, the conditioning exercises performed by the cosmonauts were close to recommended levels in nature and sequence throughout the entire flight (Figures 2, 3), and even occasionally exceeded planned levels in some parameters (e.g., rate). This facilitated retention of high work capacity in flight and a favorable course of readaptation postflight. The

program of prophylactic countermeasures required cosmonauts to wear special constant-loading suits (daily, for not less than 8 hours).

During the final 2-3 weeks of the long-term flight a conditioning cycle using lower body negative pressure [LBNP] (-10 mm Hg, increasing up to -45 mm Hg) was introduced in order to stimulate neuroendocrine mechanisms for regulating vascular tonus, fluid volume receptors, and fluid retention, and prevent orthostatic intolerance during reentry and readaptation. The LBNP schedule during the final stage of Romanenko's 326-day flight included 5 preliminary and 2 final conditioning sessions during the days preceding the conclusion of the flight. The cosmonaut followed an LBNP regimen close to the one recommended (Figure 4), and continued to feel well; blood pressure and heart rate parameters underwent only moderate fluctuations.

The set of prophylactic measures also included ingestion of fluid-electrolyte supplements during the last day of the flight, and use of a special prophylactic anti-g suit during reentry and in the initial postflight period.

### RESULTS OF MEDICAL RESEARCH IN- AND POSTFLIGHT

**General Description of Crew State:** According to their self-ratings, all three prime crew cosmonauts felt well throughout the flight. The sensation of blood rushing to the head experienced during the first days of the flight gradually diminished and disappeared in approximately 1 week. One crewmember experienced vestibuloautonomic discomfort at the beginning of the flight. Occasionally, after particularly demanding work, cosmonauts noted fatigue near the end of the work day, which was dispelled by a night's sleep. After EVAs, the cosmonauts noted muscle fatigue, and moderate pain in the arm muscles and shoulder girdle. This pain disappeared over the course of 1-2 days.

Neuropsychological status was marked by adequate adaptive reactions. All crewmembers were highly motivated to fulfill the flight program. Intragroup cohesiveness was high. Emotional responses were appropriate. The main component of the cosmonauts' psychoneurological states was task orientation.

As a rule, sleep lasted 7-8 hours and accorded with physiological requirements. During some periods, there were indications of difficulty falling asleep, lightness of sleep with frequent waking, or shifts of the sleep period to the "morning phase." These periods were short-lived (2-5 days); the cosmonauts did not take soporifics. The work capacity of all three prime crew cosmonauts was maintained at an adequate level throughout the flight.

After completion of the flight (at the landing site and during the immediate postflight period) the cosmonauts' state was satisfactory and did not differ significantly from that observed after other long-term flights. After leaving the spacecraft, the cosmonauts were able to walk unassisted; however, they noted an increased tendency to fatigue, lack of confidence when they walked, and a sensation of increased body weight. One cosmonaut experienced an episode of vestibuloautonomic discomfort while walking during the first few hours postflight.

Deviations [from the norm] in the cosmonauts' functional state during the initial stages of readaptation were analogous to those observed earlier in cosmonauts returning after flights lasting many months. However, for the majority of clinical parameters, symptoms were less severe than those after space flights of equal or shorter duration. The rate of recovery of physiological systems during the postflight period was relatively rapid in all cosmonauts of the second prime crew and the course of readaptation was favorable.

The medical problems leading to replacement of one member of the second prime crew arose during month 3 of the flight, when the flight engineer manifested cardiac rhythm irregularities

in response to emotional and physical stress. During an EVA (April 11, 1987) the flight engineer, while under marked neuroemotional stress, registered a series of atrial extrasystoles with episodes of trigeminy. While performing graded physical exercise on the treadmill soon after the EVA, he displayed marked tachycardia incommensurate with the exercise level and a significant number of isolated supraventricular extrasystoles. Utilization of a number of medical measures, adjustment of the prophylactic program, and stringent organization of the work-rest schedule led to gradual normalization of cardiac rhythm during exercise.

Intensive medical observation and monitoring during two subsequent EVAs (June 12 and 16, 1987) did not reveal any disruption of cardiac rhythm in the flight engineer; hemodynamic parameters measured at rest and during functional tests reveal no abnormalities. However, at the end of June, supraventricular extrasystoles were again noted during exercise, although the cosmonaut himself did not experience any associated sensations. Throughout the entire flight, he felt well and his performance was adequate.

Analysis of the cardiac rhythm irregularities displayed by the flight engineer could not eliminate the possibility that these symptoms would continue or worsen under conditions of long-term (up to 11 months) flight, especially given the need for daily intensive physical exercise or the possibility of stress-inducing situations. Such disruptions of cardiac rhythm had never been observed in the practice of space medicine. This introduced some uncertainty in predictions of the health status of the cosmonaut during the remainder of the flight, and ultimately it was decided to replace him during the visit of the next visiting crew.

Postflight cardiological examination of this cosmonaut revealed no organic changes in his myocardium, nor was any further disruption of cardiac rhythm during exercise noted. In all likelihood the cardiac rhythm irregularity in flight resulted from neuroautonomic dysfunction, which may have been an aspect of the cosmonaut's idiosyncratic response to long-term exposure to space flight factors. On the whole, the course of readaptation displayed by this cosmonaut revealed no substantial differences from those of other cosmonauts completing long-term flights.

**Anthropometry:** The weight of the cosmonaut who spent 11 months in flight varied within a range of +0.6 kg to -2.1 kg. One of the other cosmonauts showed a decrease in weight (0.6-3.4 kg) and the other a decrease followed by an increase of 2.4 kg. Calf volume decreased predictably, with deficit varying within the limits of 5-18% during the flight, but not exceeding 12% at the end of the flight. In all cosmonauts, torso length (height sitting) increased by 10-25 mm, with the increase occurring mainly during the first month of flight; subsequently, this parameter decreased insignificantly.

**Motor Function:** Postflight research on the motor system revealed changes in all components of the motor function in the prime crew cosmonauts. However, these were not severe, falling within the range of values noted previously after flights of similar or lesser duration, and showed clear dependence on the amount, type, and rate of exercise performed during flight.

Changes in the speed-strength properties of the antigravity muscles and increase in the electromyographic cost of standing were less severe in the crew commander who exercised twice a day, than in the other crewmember, who exercised only once a day for 2 months, mainly on the treadmill.

Disruption of coordination and posture (time to regain postural equilibrium after being pushed off balance and amplitude of corrective electromyographic response) during the early readaptation period was maximal in the crewmember who limited locomotor exercise on the advice of physicians.

The crew commander, who completed the longest flight, showed the least deviation in the motor function postflight. Recovery of functional state of the motor system was relatively rapid in all three crewmembers, especially the commander.

**Cardiovascular System:** Changes in bioelectric activity of the myocardium (standard 12-lead EKG), occurred mainly in the repolarization phase and involved diffuse decrease in T waves (by 13-64%) primarily in the left chest leads, and in one cosmonaut in the legs. These changes were accompanied by various T wave changes. On the basis of EKG data from exercise tests, these deformations were treated as functional and due to autonomic/metabolic shifts.

Hemodynamic changes in cosmonauts at rest during the long-term flight were cyclic and subject to individual differences.

General principles underlying these changes in flight included a tendency for diastolic blood pressure to decrease and for derived values (from phlebogram parameters, using A.S. Melen'yev's method) of pulmonary artery pressure to increase. Bloodfilling of the jugular veins fluctuated and cardiac output tended to decrease in two and increase in one crewmember. The commander, who spent the longest time in space, showed oscillations in hemodynamic parameters under conditions of relative rest. However, these fluctuations were close to those observed preflight.

When impedance plethysmography was performed on the cosmonauts during flight, a number of parameters showed general tendencies to alter:

- decrease in the tonus of cerebral vessels and development of asymmetry of tonus with signs of impeded venous outflow, as indicated by the appearance of pronounced venous waves;
- decrease in tonus of arm vessels, decrease in pulsed perfusion and increased tonus of calf vessels (Figure 12).

It should be noted that, in addition to the general principles described, each cosmonaut showed idiosyncratic characteristics in his hemodynamic response to flight. However, in general, the response of the circulatory system to flight in all crewmembers can be assessed as appropriate.

The provocative lower body negative pressure (LBNP) test was accompanied by appropriate hemodynamic responses, which did not differ significantly from baseline. LBNP tended to normalize the tonus of brain vasculature, as had been the case in the majority of previous cosmonauts. In one crewmember, application of LBNP did not have a normalizing effect on vascular tonus of cerebral vessels. In response to the LBNP test, another cosmonaut displayed a sharper increase in heart rate than he did preflight (up to 101 per minute in flight; no greater than 85 per minute preflight).

The research performed showed that throughout a 326-day flight -- the longest space flight on record -- the circulatory system retained a high level of functional stability with respect to specific flight factors.

Graded exercise tests on the treadmill during flight involved four stages (from walking to fast running) performed on no-load operation with energy cost of approximately 100 calories and total duration (including final walking stage) of 11 minutes. In two crewmembers, heart rate response to exercise either did not differ from preflight or gradually decreased. In one crewmember (first engineer) at the end of month 3, heart rate reached 200 beats per minute during slow running and extrasystoles were noted on the EKG.

A two-stage graded exercise test on the bicycle evoked appropriate cardiovascular responses. Endurance was either good or satisfactory. These parameters were closest to baseline in the commander.

Coronary blood flow and appropriateness of response to strenuous physical exercise (70 kgf) were evaluated by ultrasound doppler cardiography. At the end of month 1 and beginning of month 2 of flight, the reaction to this test was the same as preflight in one cosmonaut, while in the other two the increase in effective coronary blood flow in response to exercise was attenuated. When this same test was performed in one subject in month 7, there was less change in this parameter than preflight. Analogous effects were observed in previous flights. The effective coronary blood flow in exercise during flight cannot be considered inadequate to the metabolic needs of the myocardium, since the parameter did not increase significantly after exercise. The phenomenon may be due to opening of the reserve capillaries of the myocardium and increased perfusion of the heart muscle at rest, creating a physiological reserve of oxygenated blood.

Ultrasonography of the visceral organs was performed pre- and postflight for the liver, spleen, kidneys, lungs, and prostate and of the liver and lungs in month 8 of flight. During flight there was an increase in the size of the liver and in blood filling of the lungs. Postflight changes in configuration and size of the liver, blood filling of the lungs and increased kidney size were maintained for 3 days, but had normalized after 7. The most likely reason for these changes is fluid redistribution.

### POSTFLIGHT BIOCHEMICAL AND LABORATORY ANALYSES OF BLOOD AND URINE

Postflight study of hormonal status revealed enhanced activity of the hypothalamus-pituitary-adrenal and sympathetic-adrenal systems, manifested in blood concentration of hydrocortisone that was 1.5 to 3 times higher than preflight, elevation of blood epinephrine and norepinephrine lasting 1 week, increased excretion of free and bound epinephrine, norepinephrine, dopamine, and their methylated derivatives. At the same time, concentration of ACTH increased in only one cosmonaut, while in the others this parameter was depressed postflight.

Concentration of growth hormone in the blood in the first days of the recovery period was altered in all cosmonauts. Two displayed a decrease in the follicle-stimulating hormone (FSH) in blood, while the third manifested a decrease in concentration of luteinizing hormone (LH). The reactions of the gonadotropic hormones were probably due to the inhibiting effects of prolactin, the concentration of which was elevated in two crewmembers.

In the first 3-5 days after reentry, diuresis was somewhat depressed, while fluid consumption was elevated in all members of the prime crew. This is a typical reaction after long-term space flight. An appreciable decrease in renal excretion of the major electrolytes (sodium, potassium, chlorine) was also observed, as was activation of the renin-aldosterone system, fostering fluid and electrolyte retention.

Blood potassium decreased in all crewmembers, but to a greater extent and for a longer period after the longest flight; the cosmonaut completing this flight also showed a longer period during which aldosterone was elevated.

Serum levels of total ionized calcium were elevated on the day of reentry and elevated renal excretion persisted for several days in all cosmonauts.

The cosmonaut exposed to space for 326 days displayed decrease in levels of calcitonin, which decreased calcium in plasma, while level of parathyroid hormone remained normal or slightly elevated.

On the whole, changes in the electrolyte components of body fluids and in the activity of the hormonal systems regulating fluid-electrolyte metabolism during readaptation were similar in the prime crew cosmonauts to those previously observed after long-term space flight. These changes are primarily determined by general dehydration, losses of potassium and calcium, and secondary processes in the hormonal system regulating fluid-electrolyte metabolism, which serve to restore the volume and composition of body fluids. Changes in potassium metabolism, in contrast to those noted in calcium metabolism, may be a function of duration of exposure to weightlessness.

Monophoton absorptiometry data, obtained only from the cosmonaut completing the 326 day flight, showed a 5.6% decrease in mineral density of the tibial diaphysis. It should be noted that this change was not greater than those observed in cosmonauts after shorter flights. Severity of effects appear to be heavily influenced by the amount and schedule of physical exercise.

Concentrations of energy substrates and intermediate products of metabolism, as well as activity of certain enzymes in blood serum, were measured to gain knowledge about energy supply postflight. During the first few days after reentry, all three cosmonauts manifested signs that energy production was using mainly a carbohydrate substrate with a substantial increase in proportion of glycolytic and anaerobic conversion. This was demonstrated by elevated levels of serum glucose (6-8 mmole/l), lactic and pyruvic acids. These are metabolites of carbohydrate metabolism, which accumulate in blood when there is an increase in conversion of glucose through glycolysis and retarded utilization of these metabolites by the tissues. Concentration of pyruvate in blood was highest after the longest flight. One cosmonaut displayed a hormonal response to hyperglycemia, and the others showed increased blood insulin.

In the study of the dynamics of the substrates of fat metabolism, it was observed that concentration of blood triglycerides (the most important form of available energy storage) decreased in two cosmonauts and increased in one. Unlike results after previous flights, concentration of free fatty acids in blood was depressed in two crewmembers.

During the first hours after reentry, the peripheral blood of all three prime crew cosmonauts showed depression of reticulocytes by a mean of 27%. Subsequently (as early as days 9-11 of readaptation), the quantity of reticulocytes gradually increased. As after previous long-term space flights, on days 3-11 of readaptation, all prime crew cosmonauts showed a decrease in hematological parameters: concentration of hemoglobin decreased by 4-14%, quantity of erythrocytes by 13-30%, and hematocrit by 2-5%.

During the first days postflight, all prime crew cosmonauts displayed decreased glycolysis rate and concentration of ATP in erythrocytes. Study of the redox system of erythrocytes revealed decreases in the concentration of reduced glutathione, which may be related to decreased synthesis or activity of oxidized forms leading to increased rate of oxidative processes in the cell. This could result in activation of free radical processes and oxidative destruction of membranes.

Shifts in metabolic status were correlated with changes in the membranes, including increased concentrations of free cholesterol and its esters and decreased concentrations of phospholipids, as well as changes in the ratios among phospholipid fractions and cholesterol. During early readaptation after long-term flight, destabilization of the membrane components led to

substantial metabolic shifts, decrease in deformability of cells, and increase in membrane rigidity.

None of these results revealed any new phenomena or any evidence that changes progressed as duration increased to 326 days.

After completion of space flight, the T- and B-systems of immunity, synthesis of humoral mediators, allergic status and autoimmune shifts were studied. As after previous long-term flights, all cosmonauts displayed a decrease in antiviral resistance. The functional activity of natural killers was depressed in all cosmonauts. These cells also showed decreased capacity to bind to target cells.

Study of humoral mediators, which regulate the immune system, revealed decreased synthesis of interleukin-2 by lymphocytes in two cosmonauts and decrease in endogenous  $\alpha$ -interferon in one. No changes were noted in  $\gamma$ -interferon. The majority of changes observed on day 1 and 7 postflight had normalized after 14 days. Two cosmonauts showed signs of sensitization to formaldehyde, one of the constant trace components of pressurized environments.

No dysbiotic shifts were found during or after flight in any cosmonaut. Intestinal bacteria were stable. Decrease in lactoflora was less pronounced than during previous flights. These results suggest that the prophylactic measures taken (use of "eubiotika-bifidum bacterine" and personal hygiene measures) were effective.

The most important result was that, given the prophylactic measures employed, increasing duration of flight to 326 days (3 months longer than any previous flight) had no ill effects on health or performance. It is also important that postflight examination revealed no new functional shifts or progression of existing ones, that have not been observed previously.

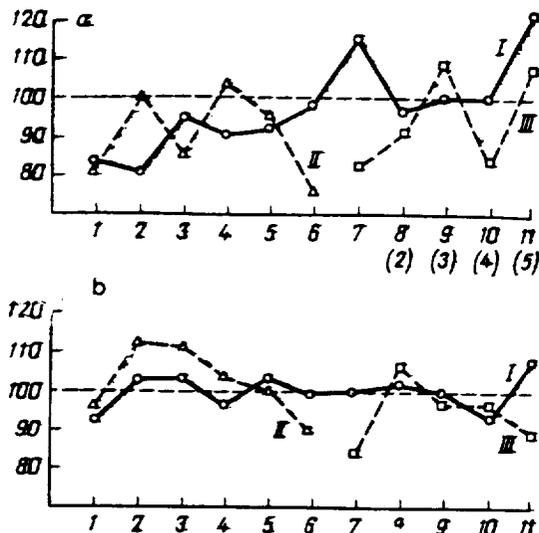


Figure 1: Amount (a) and mean rate (b) of locomotor exercise performed in flight  
 Abscissa: flight duration (months); ordinate: parameters (in % of recommended): I - 326 day flight, II - 175-day flight, III — 160 day flight

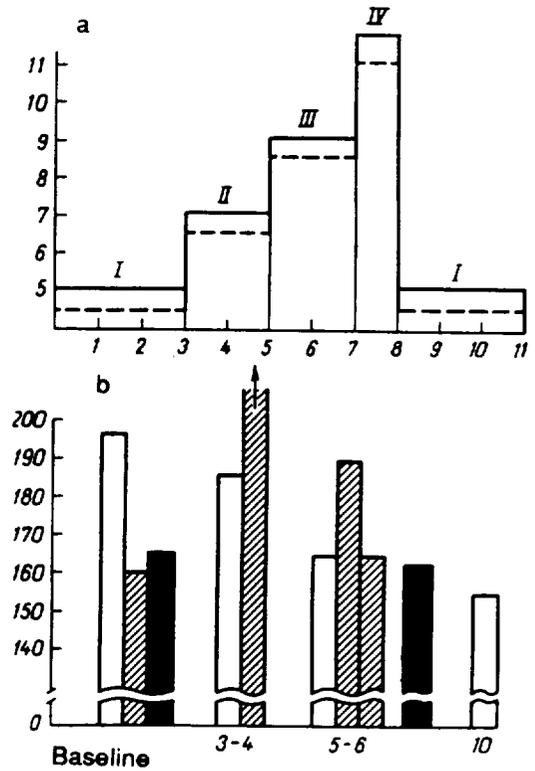
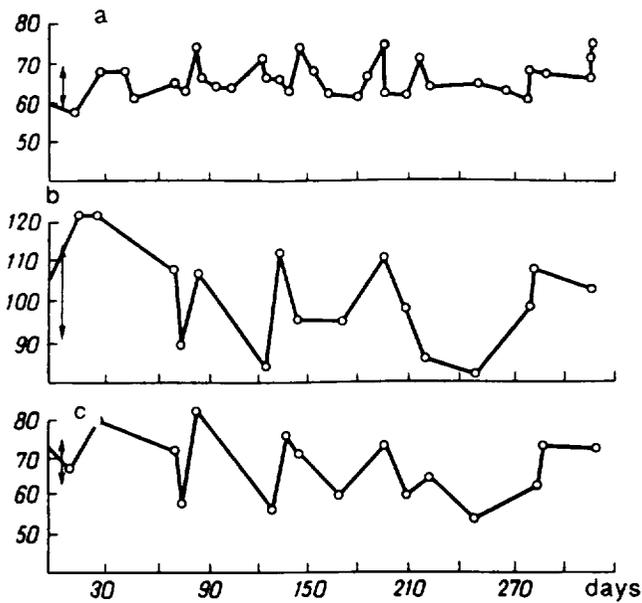


Figure 2: Changes in parameters of circulation in a cosmonaut at rest during a 326-day flight  
 a - heart rate per minute, b - cardiac stroke volume (in ml), c - cardiac output (in l/min).  
 Arrow indicates limits of parameter fluctuations preflight

Figure 3: Diagram of stepped locomotor exercise (a) on treadmill and maximal heart rate (b) in exercising cosmonaut  
 Solid and broken heavy lines - exercise loading (upper and lower limits). a - abscissa - time (in months); ordinate - exercise loading (in km/hr): I - walking, II-IV running. b - abscissa - duration of flight (in months); ordinate - heart rate per minute; white bars - 326-day flight, hatched bars - 175 day flight; black bars - 160-day flight

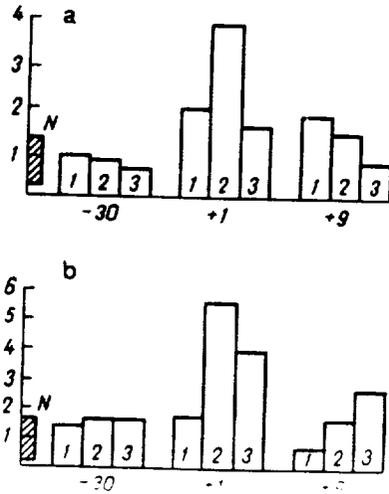


Figure 4: Parameters of activity of the sympathetic-adrenal system in cosmonauts pre- and postflight

a - concentration of epinephrine (in  $\mu\text{g/l}$ )k N - normal values. 1 - 326-day flight; 2 - 175-day flight; 3 - 160-day flight. Days of study -30: 30 days before flight; +1, +9 days postflight

## MONOGRAPH:

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Trudy XXIII Chteniy Posvyashchennykh Razrabotke Nauchnogo Naslediya i Razvitiyu Idey K.E. Tsiolkovskogo: Sektsiya "Problemy Kosmicheskoy Meditsiny i Biologii" Mediko-Biologicheskiye Problemy Obespecheniya Kosmicheskikh Poletov v Svete Idey K.E. Tsiolkovskogo

Труды XXIII Чтений Посвященных Разработке Научного Наследия и Развитию Идей К.Э. Циолковского: Секция «Проблемы Космической Медицины и Биологии» Медико-Биологические Проблемы Обеспечения Космических Полетов в Свете Идей К.Э. Циолковского

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## Contents

FP Kosmolinskiy. K.E. Tsiolkovskiy on periodic phenomena and certain issues in the study of human biological rhythms

VG Tristan. Subjective time in physical culture and sport in light of the ideas of KE Tsiolkovskiy (10)

NG Ozeretskoy. The ideas of K.E. Tsiolkovskiy on possible forms of life in space (15)

IV Polyakov, AA Timofeyev. Critical issues in a systems approach to organization of automated systems for medical support of operations controlling a computer complex (20)

PV Akent'yev, Yel Rogov. Investigation of operator performance in a system of group interaction (25)

ML Kolomiyeviskiy, VYe Anisimov. On the rehabilitation of flight personnel with cardiorespiratory diseases (29)

EV Lapayev, AA Ma'yanovskiy, LA Kustova, VF Zhivalo, N Baklanova. Multimethod evaluation of immune status in humans exposed to chemical factors (37)

LZ Gorokhovskiy. Development of the ideas of K.E. Tsiolkovskiy on the biomechanics of human movement in space (40)

YeP Tikhomirov, VG Samokhin, AYu Stoklitskiy. A case study in the use of a space suit to create a pressure gradient along the human body in order to control blood redistribution (47)

VB Malkin, BA Zolotnik. On the psychophysiological characteristics of cosmonauts (52)

## SPACE BIOLOGY AND MEDICINE

LI Voronin, YuV Katayev. On the development of the ideas of K.E. Tsiolkovskiy in the area of simulating space flight conditions on the ground (56)

AY Merkio. Evolution of gravity response in plants (61)

RS Laurinavichyus, PF Kenstavichene. The significance of the force of gravity for formation and growth of callus tissue in arabisopsis (65)

Yel Kuznets, VN Novosel'tseva, LV Savel'yeva. Maintenance of thermal homeostasis in humans during space flight from the standpoint of physiological engineering (71)

GF Vorob'yev, TA Bondareva, YuS Ilyushin, II Misetskaya, VI Polyakova, LI Tyuneyeva, OV Tishchuk, VI Chadov, AS Tsivilashvili, AS Yarov, PT Yastrebov. The partial pressure suit as a means of supporting life and performance of crews of flight vehicles at high altitudes (76)

IV Smirnov. A model of perception of external information (83)

BI Balkin, VV Kustov, GG Kruglikov. A comparative description of the biological effects of Lunar soil, obtained by the unmanned Luna-16 station from the maria and highlands areas of the Moon (91)

OA Dzhaliashvili, VA Zakharov. The rehabilitation of the visual system in operators controlling flight vehicles (95)

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**PLENARY SESSION I**

Co-chairs: Grigor'yev AI, Ponomarenko VA

Grigor'yev AI, et al., (Moscow). Medical results of the flight of the fourth prime crew on space station "Mir"

Bugrov SA, et al. The problem of occupational health in aviation medicine

Il'in YeA, et al., (Moscow). Some results of research on biosatellites COSMOS-1887 and -2044

**SECTION I AEROSPACE PHYSIOLOGY AND MEDICINE**

**Session 1.1: Medical Support of Space Flight**

Co-chairs: Stupakov GP, Yegorov AP

Alferov IV, et al. (Moscow). Medical support of prime crews on space station "Mir"

Akhapkina VI, Goncharov IB (Moscow). Prospects for improving pharmacological support of space flights

Grigor'yev AI, et al. (Moscow). Major results of medical research on a 1-year space flight

Kotovskaya AR, et al. (Moscow, Star City). Human endurance of +G<sub>x</sub> acceleration on space flights lasting from 8-366 days

Polyakov VV, et al., (Moscow). A comprehensive evaluation of gastrointestinal function during space flight

Serov IV et al. (Moscow) Shaffar L, et al., (Nice, France). Production of interleukin-2 — a major mediator of immunity —and expression of interleukin-2-receptors by lymphocytes in cosmonauts after space flights on "Mir"

**Session 1.2 Problems of Adaptation in Flight and Simulations**

Co-chairs: Pestov ID, Agadzhanian NA

Kovalenko YeA, et al., (Moscow), Vatssek A (Brno, Czechoslovakia), Khaaze G (Konigsbruck, Germany). Oxygen homeostasis as a functional manifestation of the adaptive properties of the body

Batenchuk-Tusko TV, et al., (Moscow). Dynamics of central venous pressure in weightlessness

Bondarenko RA, Tikhonov MA (Moscow). The concept of limiting physiological functions in the system of criterial evaluation of endurance of gravitational loadings

Vashchenko VI, et al., (Leningrad). On certain interrelated intracellular changes in conformation of DNA of lymphocytes and immune status in subjects exposed to acceleration

Voronkov Yul, et al., (Moscow). Evaluation of endurance of repeated exposure to simulated space flight factors as a function of whether or not adaptation has been completed

Il'yinskaya YA, et al., (Moscow). Increasing human endurance of LBNP through the use of electric stimulation of muscles

Koshcheyev VS, et al., (Moscow), Novak L, et al., (Brno, Czechoslovakia). Some characteristics of thermal regulation in humans under conditions of hypokinesia with head-down tilt

Mikhaylov VM (Moscow), Baranskiy S, et al., (Warsaw, Poland). An apparatus for evaluating and correcting human performance

Pokrovskiy AV, et al., (Moscow). Increasing the orthostatic tolerance of the human circulatory system under exposure to simulated space flight factors

Shaov MT, Shaova LG (Nal'chik), Kovalenko YeA (Moscow). Oxygen conditions and impulse activity of brain neurons in hypoxia and adaptation to it

Popov IG, Latskevich AA (Moscow). Blood amino acids in cosmonauts on flights varying in duration

B uravkova LB, Morukov BV (Moscow). Dynamics and diurnal rhythms of excretion of intracellular mediators of hormonal effects during long-term hypokinesia in humans

Madan-Prilipko LV (Kishinev). The effects of dietary protein deficiency and certain extreme factors on endocrine status

Melnik BE, et al. (Kishinev). The role of MSH in the manifestations of the adaptive reaction of ACTH functions in hypokinesia

Tikhomirova PA, Potapov PP (Yaroslavl'). Carbohydrates and lipids in the blood serum and liver in repeated exposure to 30-day periods of hypokinesia

**Session 1.3 Clinical and Experimental Studies**

Cochairs: Voronin LI, Voronkov Yul

Goncharov IB, et al. (Moscow). Extreme (emergency) medicine, problems and prospects in medical technology

Zakharov VP (Moscow). The expert-diagnostic significance of mitral valve prolapse in fighter pilots

Kozlovskiy AP, et al. (Moscow). Prospects for using expert systems in flight certification examinations

Kondrakov AV, et al. (Moscow). Rehabilitation of flight personnel with cardiac rhythm disorders

Lapayev EV, et al. (Moscow). The effect of repeated exposure to radial acceleration on certain parameters of immune status in humans

Mel'nik KP (Moscow). Clinical evaluation of the morphofunctional status of the kidneys in fighter pilots

Smirnov VS, et al. (Leningrad). Characteristics of the immune status of flight personnel

**Session 1.4 Simulation of the Effects of Long-Term Weightlessness**

Co-chairs: Morukov BV, Kopanev VI, Kiselev RK

Popova IA (Moscow). Evaluation of metabolic status in humans exposed to real and simulated weightlessness

Ivanova SM, et al. (Moscow). The effects of long-term hypokinesia with head-down tilt on biochemical parameters of erythrocytes and the functional status of their membranes,

Morukov BV, et al. (Moscow). Mineral metabolism in humans exposed to a 370-day period of hypokinesia with head-down tilt

Oganov VS, et al. (Moscow). Mineral density of human bones in simulated weightlessness

Karyak YuA, Kozlovskaya IB (Moscow). The effect of a 120-day period of hypokinesia with head-down tilt on the contractile properties of the triceps of the calf in humans

Kuznetsov SL, Stepantsov VV (Moscow). Results of histochemical and electron-microscopic studies of muscle tissue in long-term hypokinesia

Vil'-Vil'yams IF, et al. (Moscow). Human endurance of +G<sub>x</sub> acceleration in an experiment with a 370-day period of hypokinesia

Machinskiy GV (Moscow). The use of the "Fiziotest" equipment complex for supporting physical performance in humans under conditions of limited motor activity

Lobanchuk VI, et al. (Moscow). Adaptive changes in the circulatory function during long-term hypokinesia

Konstantinova IV, et al. (Moscow). The human immune system during a 1-year period of hypokinesia with head-down tilt and long-term space flights

Kalendarova MP, Polyakov VV (Moscow). Results of hematological research during long-term weightlessness and hypokinesia

Zhidkov VV, Larina ON (Moscow). Characteristics of concentrated mass-circulatory parameters of protein metabolism in humans during long-term hypokinesia with head-down tilt

Ignat'yeva-Dzidziguri MO, Butnev VYu (Sukhumi), Goncharova IB, Larina IM (Moscow). Diurnal rhythms of hormonal functions of the human sex glands under conditions of long-term hypokinesia

Kurkina LM, Zablotskaya IV (Moscow). Cyclic nucleotides after long-term exposure to weightlessness and hypokinesia with head-down tilt

Markin AA. Lipid peroxidation: 1-year space flight and its ground-based simulation

Mosyakina LI (Moscow). Transport forms of blood lipids under conditions of long-term hypokinesia with head-down tilt

## **SECTION II: PSYCHOPHYSIOLOGY OF WORK UNDER EXTREME CONDITIONS**

### **Session 2.1: Psychological Adaptation, Stress, and Regulation**

Co-chairs: Myasnikov VI, Bodrov VA

Davydov GA, et al. (Moscow). High-altitude stress and cosmonaut training

Volvich VG, et al. (Moscow) Study of psychological adaptation of the members of "Metelitsa," a female scientific-athletic expedition to the Arctic

Senkevich YuA, et al. (Moscow). A medical/psychological classification system of basic models of the structure and occupationally significant personality traits of the professional operator

Estevez M, et al. (Havana, Cuba), Myasnikov VI, et al. (Moscow) Functional interactions among cardiac rhythm and other behavioral parameters under conditions of rest and stress

Ioseliani KK, Khisameyev ShR (Moscow). Prediction of psychological performance of cosmonauts on long-term flights

Zhevzhik AI, Palamarchuk AM (Moscow). Physiological reactions of pilots under conditions of pronounced psychological stress

Kozlov VV (Moscow). Characteristics of psychological regulation of joint performance by pilots

**Session 2.2 Operator Performance, Reliability of the “Man-Machine” System, and the Problem of Safety**

Co-chairs: Ponomarenko VA, Lapa VV

Salnitskiy VP et al (Moscow). A method of semi-full-scale simulation and its use in flight to increase the psychological readiness of cosmonauts for work

Anikeyev NF, et al (Moscow). Ways to increase flight safety when the human operator suddenly loses the capacity to work

Shol'tsev I, et al (Prague). A methodology for investigating psychophysiological reactions of humans in response to operator tasks under laboratory and field conditions

Grigor'yeva LS, et al. (Moscow). The use of methods of computerized EEG analysis to study neurophysiological mechanisms of exploratory (search, retrieval?) and automated actions

Yepishkin AK (Moscow). Emotional reactivity and prediction of level of tracking performance in operators under stress

Nechayev AP, et al (Moscow), Sykora Ya, et al (Prague). The study of the characteristics of operator performance under conditions of isolation

**SECTION III: SPACE BIOLOGY**

**Session 3 1 Cellular Biology**

Co-chairs: Tairbekov MG, Mitashov VI

Tairbekov MG (Moscow) Gravitational mechanisms of cells

Delone NL, Antipov VV (Moscow). Cytogenetic aspects of the study of the mechanisms of physiological adaptation to space flights

Blum RK, et al (Riga), Ivanova SM (Moscow). Structural/functional properties of the erythrocyte membranes of primates after space flight and in a ground-based synchronous condition

Luchinskaya NN, et al (Moscow). The effect of weightlessness on growth of oocytes and development of guppies

Besova NV, Savel'yev SV (Moscow). Morphological changes in the ultimobranchial gland of caudate amphibians under space flight conditions

Sidorenko LA, Chel'naya NA (Moscow). The effect of a 135-day space flight on the blood profile and marrow of rats

Mitashov VI, et al (Moscow). Characteristics of regeneration of the limbs and lens of newts in space flights

**Session 3.2 Systemic Physiological Responses**

Co-chairs: Lapin BA, Korolkov VI

Serova LV (Moscow). Compensatory-adaptive potential of mammals under conditions of weightlessness and hypergravity

Truzhennikov AN, et al. (Moscow) The effect of space flight on the functional systems of primates flown on COSMOS series biosatellites

Shlyk GG, et al (Moscow), Kolpakova NF, et al. (Sukhumi). The state of higher nervous activity in monkeys during flight on biosatellite COSMOS-2044 and in a ground-based control condition

Yakushin SB, et al. (Moscow). Neuronal activity of the vestibular structures of the brainstem and cerebellum in monkeys during space flight

Durnova GN, et al (Moscow). The reparative process in the bones of rats under conditions of inadequate loading of the musculoskeletal system

Popova IA (Moscow). The modifying effect of weightlessness on the reparative processes in rats (based on results of biochemical analyses of blood)

Krasnov IB, et al. (Moscow), Polyakov IV (Voronezh). Morphological aspects of rats' adaptation to increased and relatively decreased gravitational force

Oganov VS, et al. (Moscow) Siladi T et al. (Debretsen, Hungary). Contractile properties and composition of myofibril proteins of skeletal muscles in rats after a 13-day space flight

**SECTION IV: RADIATION SAFETY OF SPACE FLIGHTS**

**Session 4.1 Radiation Safety**

Co-chairs: Kovalev YeYe, Tikhonchuk VS

Bugrov SA, et al (Moscow). Problems of radiation safety in space flight under combined exposure to ionizing and nonionizing radiation

Kovalev YeYe, et al. (Moscow). Problems of supporting radiation safety of a manned Mars mission

Fedorova NL, et al (Moscow), Urmancheyeva TG, et al (Sukhumi). The effects of ionizing radiation on behavioral reactions and physical performance of monkeys

Ul'yanova VA, et al (Moscow). Development of radiation damage and recovery in the hemopoietic systems of mice after repeated exposure to neutrons and  $\gamma$ -radiation in equivalent doses

Vasilev G, et al (Sofia, Bulgaria), Burakevich AL, et al. (Moscow). Radiation physics results of the Soviet-Bulgarian "Dose-B" experiment on space station "Mir"

Grigor'yev YuG (Moscow). Magnetic deprivation and approaches to evaluating the physiological effects of combinations of low intensity physical factors

Shtemberg AS, Osipova YeYu (Moscow). Dynamics of higher nervous activity disorders in rats undergoing prolonged irradiation

**Session 4.2 Effects of Heavy Charged Particles and Radioprotectors**

Co-chairs: Antipov VV, Chertkov KS,

Abramov MM, et al. (Moscow). Multifactor analysis of the efficacy of radioprotectors under conditions of combined exposure to hypoxic atmospheres and irradiation

Antipov VV, et al (Moscow), Fedorov VP (Voronezh). General principles of the manifestations of radiocerebral effects after combined exposure to space flight factors with extreme intensities

Atamanova OM, et al (Moscow), Tkach VV et al. (Simferopol'). Study of the antiradiation properties of cerebrospinal fluid of cattle in an experiment

Fedorenko, et al. (Moscow). Structural changes in neurons in experimental animals *in vivo* and *in vitro* under exposure to  $\gamma$ -rays

Nevzgodina LV, Maksimova YeN (Moscow). Major approaches to study of biological effects of heavy ions of galactic cosmic radiation

Gerasimenko VN, et al (Moscow). Cytogenetic effects of heavy charged particles in the cells of humans and animals

**SECTION 5 PROBLEMS OF HABITABILITY**

**Session 5.1 Physical-Chemical Life Support Systems**

Co-chairs: Sinyak YuYe, Kurmazenko EA

Vasilenko II, et al (Belgorod), Sinyak YuYe (Moscow). Liquid phase purification of wash water and condensate of atmospheric moisture

Gaydadyov VB, et al (Moscow). Development of electro dialysis of the technology of regeneration and mineralization of water

Grishayenkov BG, et al (Moscow). Intensification of the process of synthesis of formaldehyde as the first stage in obtaining carbohydrates from organic wastes

Zagibalova LB, et al. (Moscow), Georgitsa FI, et al (Kishinev). The generic composition of microflora from regenerated water obtained by various methods of water supply to spacecraft and a rapid method for assessing them microbiologically

Kurmazenko EA (Moscow). Aggregates of life support systems: Theoretical principles and practical design methods

Lebedeva TYe, et al (Moscow). Prospects for utilizing immobilized cells or enzymes to complete the purification of the water and air in pressurized cabins

Pak ZP, et al (Moscow). Hygienic evaluation of potable water obtained from highly mineralized water through electrochemical processing

**Session 5. 2 Weightlessness and Biological Life Support Systems**

Co-chairs: Shepelev YeYa, Gitelzon II.

Ananikova AA, et al (Moscow). The use of electrodialysis in a system to correct the salt composition of culture fluids of micro-algae in a biological life support system

Antonyan AA, et al (Moscow). Biochemical evaluation of seeds of certain vegetable plants after long-term storage under space flight conditions

Ivanova IYe, et al (Moscow). The effects of space flight factors on the growth and productive qualities of seeds

Meleshko GI, et al (Moscow), Shetlik i (Prague). The effect of space flight conditions on the pigmentation system of one-celled algae

Smirnova MN, et al. (Moscow). Study of the effects of microgravity on the composition of microflora in an "algae-bacteria-fish" ecosystem

Sychev VN, Levinskikh MA (Moscow). Study of one-celled algae on space flights

Chernova LS, Mashinskiy AL (Moscow). A microbiocenosis of higher plants in space flight

**Session 5.3 Hygienic Problems in the Formation of Artificial Living Environments for Spacecraft**

Co-chairs: Sysoyev AB, Lentsner AA

Berlin YuA, et al (Moscow). An experimental rationale for selecting the optimal skin cleaning agents for operators

Kravchenko TI, et al (Kiev). Prediction of the sanitary/chemical characteristics of nonmetallic materials used in pressurized environments

Pashin SS, et al (Moscow). Results of a comprehensive evaluation of outgassing on nonmetallic materials

Savina VP, et al (Moscow). An evaluation of the activity of lipid peroxidation on the basis of levels of peroxidation products in blood and exhaled air of humans

Surovtsev NA (Moscow). Development of methodological approaches to hygienic regulation of exogenous chemical compounds similar to human waste products in the artificial atmosphere of pressurized chambers

Sysoyev AB, et al. (Moscow). Sanitary and hygienic support of manned space flights

Viktorov AN, et al (Moscow). Microflora of the cabins of manned spacecraft and the problems of biodegradation of the structural materials used in them

Lentzer AA, et al (Tartu), Liz'ko NN (Moscow). Lactoflora of the human digestive tract on space flights

Liz'ko NN (Moscow). Bacterial therapy in the prevention of stress-induced dysbacteriosis

**Session 5. 4 Physiological and Hygienic Issues of Human Habitation of a Hyperbaric Environment**

Co-chairs: Genin AM, Leybovich LI

Bragina MP, et al (Moscow). Anti-microbial protection of deep sea diver crews

Zakharov YuV, et al (Nikolayev). Selection of rational configurations and equipment for the major and emergency life support systems for divers in deep-sea chambers

Leybovich, et al. (Nikolayev), Sysoyev AB (Moscow). Formation of a compression schedule that maintains the required level of noise in the barochamber

Pavlov BN, et al. (Moscow). Basic principles for creating hyperbaric systems for performing research on laboratory animals

Titkov SI, et al (Leningrad). The effect of long-term exposure to hyperbaric conditions on the status of the major functional systems in humans

**SECTION 6: INFORMATION PROCESSING SUPPORT OF RESEARCH**

Co-chairs: Bayevskiy RM, Shakin VV

Kholin SF, et al (Moscow). The unified system of information support of research for the "Medilab" project: Structure and functions

Funtova II, et al (Moscow). An automated medical technology complex for the on-line monitoring of the functional status of cosmonauts in flight

Gorlov VG, Nosovskiy AM (Moscow). Methodological approaches to the development of mathematical models for predicting functional physiological status

Gushen VI, Yefimov VA (Moscow). An approach to developing computerized psychological tests

D'yachenko AI (Moscow). Mathematical models in oscillatory mechanics of respiration

Yakimenko AO (Moscow). Mathematical modeling of life support systems

**PLENARY SESSION 2 CONCLUSIONS OF THE CONFERENCE**

Co-chairs: Gazenko OG, Bugrov SA

**Round Table 1: Problems of Biomedical Support of the Mars Mission**

Participants: Kholin SF, Viktorov AN, Vikhrov AI, Gushchin VI, Sokolov AI, Apatov AM

**Round Table 2: Problems of Philosophy of Science in Space Medicine and Biology**

Participants: Gyurdzhian AA, Kurashvili VA, Engel'gardt LT, Manakin AV

**Satellite symposium: "Space Motion Sickness" Principles and Countermeasures  
Basic Mechanisms of Motion Sickness in an Altered Gravitational Field**

Symposium organizer: IB Kozlovskaya

### ***Economics of Space Measured by Terrestrial Standards***

Article in: *Ekonomika i Zhizn'* (Economics and Life)

Translation: USSR Cosmonauts A Solov'yev and A Zbalandin answer readers' questions from on board space station Mir. [Editors' note: This is apparently only one of a number of question and answer sessions between Mir cosmonauts and the public. These interviews not only served as public relations devices for the space program, but also were considered part of psychological support measures designed to combat cosmonauts' feelings of isolation.]

Reader: How can one speak of the economics of the space program, when the state gives it all the resources it requests?

Cosmonaut: That isn't the case. We have not had such a system for a long time. Moreover, even in the so-called era of stagnation [days of Brezhnev and his successors], the resources invested in the space program had clear limits. Today space programs have to be ratified and the sources of financing are strictly limited.

Reader: Please tell us what a man-hour in space costs and what benefits your flight is bringing our economy.

Cosmonaut: Every day a cosmonaut spends in orbit costs 50 thousand rubles. This includes the use of the space station itself, the operation of ground monitoring and control facilities, in short, everything that makes space flight possible. As for benefits, that is far from being a simple question. For the time being, unfortunately, our manned space program is most frequently operating at a "loss". We hope that the large number of experiments in technology (materials science) and biotechnology that we are conducting, as well as the active utilization of the "Crystal" module, which we are expecting in June, will enable us to show a profit. However, we don't want to count our chickens before they're hatched. When we land, we will get all the data together and will certainly publish the information on the pages of this journal.

Reader: The economics of space is a component of the economics of the nation. But here is a paradox: what we produce in space is by and large competitive, while what we produce on Earth is not.

Cosmonaut: We see no paradox here. Space technology was created and is being created with a view toward nontraditional approaches to the study of the Earth, and the solution of many important economic and scientific problems. The benefits of each ruble invested in space will be increased manifold.

It is a true saying that the miser pays twice. If we try to save money in space, we will lose many of our advantages.

Reader: Will a loaf of bread cost more for us inhabitants of the Earth if remote observation of the state of grain crops is performed from satellites rather than the aircraft of agricultural aviation?

Cosmonaut: Monitoring of agricultural areas from space is virtually irreplaceable. Five minutes worth of photographs from a space complex takes the place of approximately year of work from a TU-134 SX aircraft. Here is true economy of labor resources and a decrease in costs.

To be honest, we are not always able to monitor as we should. Frequently cloud cover hampers our observations, but these are solvable problems. We should also not abandon aircraft observations. Here we need a comprehensive approach.

## THE ECONOMICS OF SPACE FLIGHT

Reader: What does one space photograph cost?

Cosmonaut: The cost of a photograph depends on its quality and how it is processed. We should note that the photographs taken from our space station are competitive. But, unfortunately, our agencies frequently get to the market too late with this product. However, the sale of photographs may bring considerable profit, and in foreign currency. Today, the mean cost of a commercial photograph is 300-400 dollars.

Reader: How do the cosmonauts assess the future of space tourism in the USSR?

Cosmonaut: Space tourism is essentially the same thing as commercial flights. But, in all seriousness, we see no prospects for the development of "pure" tourism in space in the near future. For the time being this is too serious an enterprise, requiring serious training.

Reader: What should be given priority: commercial activity in space with the goal of obtaining benefits today, or fundamental research which will advance our nation on the road of progress in the future?

The two are not incompatible. Even today, our own flight program combines commerce with scientific research, that is, it is a mixed program. On the one hand, we are performing scientific observations, and on the other, we are obtaining valuable new biological preparations.

Reader: I heard that birds are being raised in a space incubator. Is that the only purpose of the experiment?

Cosmonaut: Yes we really did have baby birds. This experiment was involved with the global objective of creating a closed life support system for humans. One aspect of the problem has already been solved successfully -- that of water supply. On board we have a piece of equipment that collects all the water around, for example, perspiration and transforms it into absolutely pure, sweet tasting water containing the minerals we need. Module "D" has a system that produces distilled water. By electrolysis we separate it into oxygen and hydrogen. For now, we are discarding the hydrogen overboard, but the pure oxygen is used in the habitation modules of the station.

The other aspect of this complex issue is provision of food to the cosmonauts. The most promising direction is the raising of quails. Here we get both eggs and meat. For the time being, however, we are making do with canned quail-burgers

Reader: Where is the food better —on Earth or in space?

Cosmonaut: What I wouldn't give to have an ordinary pickle right now! However, Earth, we have been told, has decided to give us a gift. Along with the technological module, radishes will be delivered to us. We have been given permission to eat two apiece.

Reader: What is the role of space research in identifying the consequences of the [ecological] disaster on the Aral Sea?

Cosmonaut: Right now we can see the Aral very clearly. We are computing the surface area of the lake and the area of the islands there. As for the consequences of the ecological disaster, they must be assessed by specialists. We are ready to help them. And for this reason we believe that all interested organizations must be more active in their utilization of the results of space research. Make proposals, and we, the cosmonauts, will try to implement them in practice. It is precisely ecological problems that can be solved most effectively from space.

## THE ECONOMICS OF SPACE FLIGHT

Reader: I am confident that leasing can make space flights profitable and will do much to simplify the position of the USSR in this area. If necessary I am ready to help compute the economic rationale for this proposal.

Reader: Have you thought about whether it is possible to lease a spacecraft?

Cosmonaut: And why not?. As far as we know leasing will be introduced in economic enterprises and organizations and will do much to stimulate production. It is possible that, with time, leasing will make an important contribution to enterprises in the area of space.

Readers' questions put by: N Tarasenko, Ground Control Center

## KEY WORD INDEX

Acceleration, +Gx 20  
Acceleration Tolerance 20, 129  
**Adaptation** 1- 2, 12, 28, 108, 116, 129  
Adrenergic System 12  
Age Effects 7, 17, 100  
Air Cleaning 58  
Amino Acids 129  
Amphibians 22, 24, 33  
Anticonvulsants 92  
Arabidopsis 9  
Assessment Technique 8  
Atherosclerosis 7  
Atmosphere 116  
Audiogenic Seizures 112  
Automated Diagnosis and Prognosis 34  
Autonomic Homeostasis 89  
**Aviation Medicine** 4, 17, 102, 104, 127, 129  
"Avtosan-83" 34  
Balance 113  
Beets 62  
Biochemistry 1  
Biological Effects 94, 114  
**Biological Rhythms** 6, 127, 129  
Biomechanics 127  
Bioregenerative 37, 62  
Biospherics 6, 37  
Blood Parameters 50  
**Body Fluids** 7-8, 27, 88, 116  
Bones 71, 76, 129  
**Botany** 9, 62, 65, 94, 127  
Brain 14  
    Brain Circulation 16  
    Brain Structures 86  
Cabbage 62  
Caffeine 16  
Calcitonin 27  
Calcium 12, 27  
Callus Tissue 9  
Caloric Response 67  
Cardiac Activity 83  
Cardiac Structures 12  
**Cardiovascular and Respiratory Systems** 7, 8, 12-20, 47, 51, 83, 116, 129  
Carrots 62  
CELSS 37, 62  
Centrifugation 115  
Cerebral Hemodynamics 7, 14  
Computer Systems 4  
Computer Tomography 76  
Contingency Situations 44  
Cosmonaut Monitoring System 89  
Cosmonaut Selection 44, 98, 100  
Cosmonaut Training 44, 54, 129  
Cosmonauts 27, 52, 54, 76, 89, 91, 95, 96, 98, 105, 108, 116

## KEY WORD INDEX

COSMOS 33  
    COSMOS-605 71  
    COSMOS-613 71  
    COSMOS-781 71  
    COSMOS-1667 22, 28  
    COSMOS-1887 22, 28, 79, 129  
    COSMOS-2044 22,56, 129  
Countermeasures 2, 4, 7, 20, 31  
Crew Composition 96  
Cytogenetic Mutations 36  
Cytology 9  
Cytotoxic 56  
Dedifferentiation 9  
Deficient Diets 94  
Delivery 115  
Delta-Sleep Peptide 83  
**Developmental Biology** 9, 22-24, 65, 115, 127, 129  
**Digestive System** 26, 129  
Dill 65  
Dogs 113  
Drugs 4  
Dysbacteriosis 26  
Ecological Specifications 37  
Electrical Parameters 111  
Electromagnetic Fields 110  
**Endocrinology** 2, 4, 12, 27-33, 86, 110, 116, 129  
Enzymology 83  
Epidural 88  
**Equipment and Instrumentation** 4, 34, 44, 52, 54, 88, 89, 98, 129  
Erythrocytes 1  
Essential Hypertension 17  
Evaluation 60  
Exercise 1, 20, 31  
Exobiology 127  
Expedition Members 94  
Extreme Factors 4  
Eye Movement Response 91  
Eyes 112  
Fast-Twitch Muscles 79  
Females 6, 112,114, 115  
Flight Crews 17, 102  
Flight Personnel 4, 104  
Flight Training 104  
Fluid Redistribution 8  
Fluid-Electrolyte Balance 27  
Foton 33  
Functional Characteristics 62  
Functional State 105  
 $\gamma$ -Irradiation 111, 113  
GABA 95  
Garden Cress 65  
Gastrin 27  
Gastrointestinal System 26, 129  
**Genetics** 24, 36, 65, 98

## KEY WORD INDEX

GHBA 95  
Glucocorticoids 86  
Ground Simulations 127  
Group Dynamics 127  
**Habitability and Environment Effects** 37-44, 116, 129  
Head-Down Tilt 1, 7, 16, 31, 47, 50  
Headward Fluid Shifts 7  
Health 4  
Heart Rhythm 51  
Heat 2  
**Hematology** 6, 36, 47-50, 110, 116, 129  
Hemodynamics 7, 14, 17, 47  
Higher Plants 62  
Higher Plants-Man-Mineralization System 62  
Histology 48  
Horizontal Clinostatting 9  
Hormonal Regulators 27  
Hormone Levels 28  
Human Ecology 37  
**Human Performance** 2, 4, 14, 44, 51-54, 94, 98, 100, 104, 105, 106, 127,  
Humans 1, 4, 6, 7, 8, 14, 17, 20, 27, 31, 34, 36, 37, 47, 50, 51, 52, 54, 76, 85, 89, 91,  
92, 93, 94, 95, 96, 98, 100, 102, 104, 105, 106, 108, 116, 129  
Hygienic Evaluation 58  
Hyperbaric Oxygenation 36  
Hypergravity 115  
Hyperoxia 1  
Hypersecretory Stomach 26  
Hypokinesia 14, 26, 31, 47, 48, 50, 100  
    Hypokinesia With Head-Down Tilt 20, 50, 76, 106, 129  
        Long Term 76  
        360 Day 20  
        370-Day 50, 106  
Hypoxia 129  
Immobilization 12, 83  
Immobilization Cages 48, 70  
Immunity 129  
**Immunology** 4, 50, 56, 116, 127, 129  
Individual Differences 93  
Industrial Hygiene 2  
Inhibitory Mediation 86  
Intracranial Pressure 88  
Ischemia 12  
Isolated Hearts 12  
"Kontrol" 34  
Lactation 115  
LBNP 129  
Lens 22  
Lettuce 65  
**Life Support Systems** 37, 58-65, 129  
Limbs 22  
Lipid Peroxidation 1, 129  
Low Metabolism 71  
Low Barometric Pressure 1  
Lunar Soil, 127

## KEY WORD INDEX

Lymphocytes 36  
Macrophages 48  
Males 1, 6, 8, 14, 20, 31, 47, 50, 51, 52, 54, 70, 86, 93, 94, 106  
Man-Machine Systems 54, 127  
Mars Mission 37, 96  
Maternal Behavior 115  
**Mathematical Modeling** 54, 60, 67, 129  
Medical Factors 98  
Mental Tasks 51, 52  
Mental Work 14  
**Metabolism** 1, 2, 4, 27, 70, 71, 116, 129  
Mexamine 114  
Microbiology 58, 116, 129  
Microclimate 2, 116  
Microwave Irradiation 114  
Mineral Loss 76  
Mineral Metabolism 2  
Mir 65, 108, 116, 129  
    Mir-2 116  
Moisture and Carbon Dioxide Absorbers 58  
Morphohistochemical Analysis 79  
Morphology 9, 28, 33  
Motion Sickness 93  
Motor Effects 116  
Muscles 129  
**Musculoskeletal System** 71-79, 113, 116, 129  
Mutations 65  
Myocardial Dystrophy 17  
Myocardial Sclerosis 17  
Neonates 115  
Neurocirculatory Asthenia 17  
Neuroses 102  
**Neurophysiology** 4, 16, 67, 83-93, 95, 98, 108, 110, 112, 113, 116, 129  
Neurotransmitters 4  
Non-Traditional Medicine 4  
Nootropic Drugs 95  
**Nutrition** 4, 94, 116  
Nystagmus 85  
Oocytes 24  
**Operational Medicine** 34, 89, 95-96, 98, 116, 129  
Operators 51  
Orthostatic Tolerance 129  
Otolith Asymmetry 85  
Oxygen Circulation 16  
Oxygen Homeostasis 129  
Parasympathetic Nervous System 83  
Patients 7, 17, 36, 85  
Peas 62  
Perception 127  
Performance Efficiency 51  
**Personnel Selection** 98-100  
Pharmacological Agents 51  
Pharmacological Countermeasures 92, 95, 129  
Pituitary-Thyroid System 31

## KEY WORD INDEX

Plant Development 65, 127  
Plant Gravity Response 127  
Plant Tissue Culture 9  
Plants 65  
"Plevan-87" 52  
Postural Tests 88  
Preadaptation 12  
Pregnant 115  
Pressurized Environments 58  
Preventive Medicine 34  
Prognostic Indicator 111  
Proliferation 56  
Prophylactic Countermeasures, 116  
Prophylaxis 4  
Protection 12  
Protective Effects 83  
Psychodiagnosis 105  
Psychological Performance 52  
Psychological Readiness 54  
**Psychology** 4, 52, 54, 83, 89, 93, 100, **102-108**, 115, 116, 127, 129  
Psychophysiological Parameters 93  
Psychophysiological State 106  
Psychosomatic Illnesses 102  
PTH 27  
Rabbits 16, 83, 88  
**Radiobiology** 44, 65, **110-116**, 129  
Radioprotectors 114  
Radish 65  
Rats 12, 28, 56, 79, 83, 86, 92, 111, 112, 114, 115  
Rats, Males 48  
Red Blood Counts 6  
Regeneration 22  
Regenerative 60  
Repeated Exposure 7  
Repeated Flights 100  
Reperfusion 12  
Reproductive System 115, 129  
Review Article 110  
Rheological Parameters 47  
Risk Factors 102  
"Ritm "34  
Rosette Formation 48  
Safety 44  
Salyut-6 91  
Salyut-7 9, 76, 91  
Salyut-20 71  
Seeds 65  
Semi-Full-Scale Simulation 54  
Semicircular Canal 67  
Serotonin 114  
Silica Gel 58  
Skeletal Muscles 79  
Skeleton 71  
Skin 111

## KEY WORD INDEX

Sleep Patterns 108  
Slow-Twitch 79  
Solar Activity 6  
**Space Biology and Medicine 116, 127-129**  
Space Flight 9, 22, 27, 33, 37, 44, 52, 54, 56, 65, 76, 79, 89, 91, 95, 102, 108, 116, 129  
Space Flight, COSMOS-1887, -939 24  
    Long-Term 27, 37, 52, 54, 65, 71,76  
    Short-Term 27, 28, 71  
Space Medicine 34  
Space Connditions, 67  
Space Motion Sickness 92  
Space Suits 127  
Speech Analysis 105  
Spine 76  
Splenocytes 56  
Stress 4, 12, 14, 83, 89  
Stress Protectors 4  
Subdural Recording 88  
Suceptibility 93  
Suppressor 56  
Survival 44, 94, 114  
Tail Suspension 56  
Test Scores 104  
Theoretical Article 37, 60  
Thermal Homeostasis 127  
Thermal Regulation 129  
Thiamin 70  
Thyroid 28  
Tilt Test 8  
Time 127  
Tortoises 71  
Tritons 22, 24, 33  
Twin Studies 98  
Typology 17  
Ultimobranchial Glands 33  
UV-Irradiation 112  
Vagus Nerve 83  
Vibration Effects 86  
Visual 127  
"Vita" 34  
Weightlessness Simulation 9  
Wheat 62  
Wild Plants 94  
Zeolite 58





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