

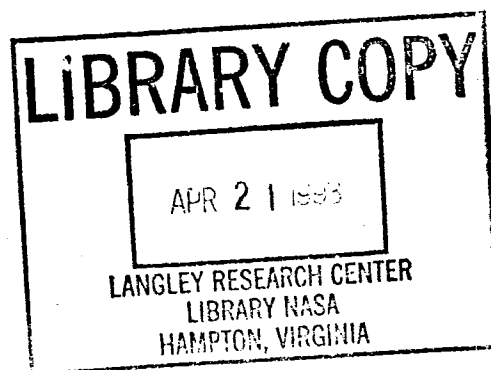
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# Digest of Russian Space Life Sciences

*Issue 33*

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**NASA**





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# Digest of Russian Space Life Sciences

*Issue 33*

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Information Program

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### Digest of Russian Space Life Sciences: Issue 33

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	Incorrect or inappropriate term	Suggested rendering

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Suite 800  
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## FROM THE EDITORS

This is Issue 33 of what used to be called the USSR Space Life Sciences Digest and will henceforth be known as the Digest of Russian Space Life Sciences. There has been an interval of approximately 1 year since the publication of the last Digest issue. We regret any inconvenience or frustration to our readers caused by this delay, which was occasioned by the need to devote all translation resources to work on "Space Biology and Medicine," a multivolume work under the joint aegis of NASA and the Russian Academy of Sciences, the first volume of which will be published soon. Although the recent upheaval and continued difficult situation in the former Soviet Union has slowed publication of scientific articles and books, we have accumulated a substantial back-log of material of high interest to our readers, and material continues to be received. We fully intend to continue production of the Digest, although publication schedules may be somewhat erratic in the near future due to continued demands of the book mentioned above. As before, we invite comments and suggestions from our readers.

Much of the material in this issue was taken from two books of conference abstracts, one from an international symposium on COSMOS biosatellite experiments and the other from a meeting of the biomedical group of the Intercosmos organization. We have no further information about the work described in these abstracts and to the best of our knowledge none is currently available in the United States.

We are grateful for the help of the following scientists, who acted as technical reviewers for this issue:

Mr. Ronald Dutcher  
Dr. Joseph Dervay  
Dr. Mary Anne Frey

Dr. Lauren Leveton  
Dr. Robert Rabin  
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Dr. John Uri  
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PAPERS:

P1533(33/91) Alpatov AM, Yevstratov YuA, Klimovitskiy VYa, Fuller, CA.  
*Instability of phases of circadian rhythms of body temperature in primates flown in space.*

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow  
University of California, Davis

In: Grigoryev AI (editor): COSMOS Biosatellites Abstracts of Papers Presented at an  
International Symposium.

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 10-11.

Biological Rhythms, Body Temperature, Desynchronization  
Monkeys, *Macaca mulatta*  
Space Flight, COSMOS-1514, -1667, -1887, -2044

**Abstract:** Introduction. Circadian rhythms are normally entrained (synchronized with) diurnal zeitgebers. Loss of entrainment (desynchronization of circadian rhythms) is likely to lead to depressed performance and health disorders. Circadian rhythms of body temperature, which reflect the state of the circadian system in mammals and are frequently used as a chronobiological indicator, were studied on COSMOS biosatellites to evaluate the risk of desynchronization in space flight.

**Methodology.** Circadian rhythms of body temperature in *Macaca mulatta* monkeys were studied during the flights of COSMOS-1514, -1667, -1887, and -2044. The monkeys were restrained in chairs limiting their mobility; light:darkness ratio was 16:8 and temperature was maintained at 23-26 °C. Body temperature was recorded automatically using telemetric transmitters implanted in the right axilla. Two monkeys were used for each flight experiment. Ground control conditions were run with the identical animals.

**Results:** In all monkeys, circadian rhythms of body temperature remained, to all appearances, entrained to the illumination schedule. Their periods, evaluated by the method of periodogram analysis, did not differ from 24 hours. However, the range of variation of the phases of circadian rhythms of body temperature was significantly broader in space than in the control condition.

Such an increase in the range of variation in phases was simulated by mathematical modeling of circadian rhythms of body temperature, using a Van der Pool oscillator with a stochastic component, by displacing the specific period of the rhythm to the boundary of the entrainment window.

**Conclusions.** The instability of phases found in circadian rhythms of body temperature in monkeys during space flight may be explained by displacement of the natural period of the circadian period in weightlessness, which, evidently, is a gravity-dependent parameter. If such an interpretation is correct, then in space flight the risk of desynchronization of circadian rhythms increases significantly. This circumstance should be considered in developing optimal work-rest schedules of cosmonauts, especially for long-term flights.

## BIOLOGICAL RHYTHMS

P1535(33/91) Balzer XU, Kiske-Bravo U, France G, Shlyk GG, Shirvinskaya MA.  
*Analysis of biological rhythms in the sleep EEG records of primates on COSMOS-2044.*

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow;  
Institute of Pathophysiology, FRG

In: Grigoryev AI (editor): *COSMOS Biosatellites Abstracts of Papers Presented at an International Symposium.*

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 16-17.

Biological Rhythms, Neurophysiology, EEG, Sleep, Adaptation  
Monkeys, *Macaca mulatta*  
Space Flight, COSMOS-2044

**Abstract:** Introduction. Since structural parameters of sleep are good indicators of the process of adaptation (or maladaptation) of an organism to new conditions, it was hypothesized that analyzing EEG records during sleep would be a feasible way to estimate the adaptation of monkeys to space flight.

**Methodology.** Periodicity of changes in mean values of amplitudes and periods of fluctuation of  $\alpha$ -,  $\theta$ - and  $\delta$ -waves were measured. Over a period of 2 hours records for successive 4-second periods for  $\delta$ -waves and 2-second periods for  $\alpha$ - and  $\theta$ -waves were analyzed in real time. In the analysis of amplitude characteristics of EEGs, 10 points were averaged for each interval. Autocorrelation functions were computed and the representative period of fluctuation of the smoothed EEG signal characterizing the position of the first autocorrelation function maximum was identified. Then, for each interval, starting at the point of the first autocorrelation function maximum, the representative period of fluctuation was identified for the initial EEG signal. Subsequent processing utilized a special "Biorhythm" program, which computed three functions: change in periodicity in time; frequency distribution of periods; and identification of stable and nonstable phases.

**Results.** During the flight, regardless of the range of frequencies, the primates manifested a reliable 130 second rhythm, comparable to one previously identified in galvanic skin response parameters in an experiment using hypokinesia with head-down tilt. At the beginning of the flight there were rather strong biological rhythms with a period of 44-88 seconds, which by the end of the flight increased to 150 seconds. When the ratios of stable and nonstable phases in the analysis of EEG biological rhythms were compared, the typological characteristics of the animals thus identified corresponded to their behavioral characteristics.

**Conclusions.** This method enabled measurement of periodicity in amplitude and frequency spectrum of EEGs during sleep. The process of adaptation of the animals to flight was marked by a decrease in the period of minute rhythms, followed by increase in the period of this rhythm to about 130 seconds in all the EEG waves studied.

P1546(33/910 Hecht K, Vachtel E, Yevgenov K, Shlyk GG, Shirvinskaya MA, Prokopshuk TYu, Truzhennikov AN.

*Study of dynamics of circaminute rhythms of sensory and motor functions of monkeys during performance of instrumental reflexes (COSMOS-2044).*

Authors' affiliation: Institute of Pathophysiology, FRG

Institute of Biomedical Problems, USSR Ministry of Health, Moscow

In: Grigoryev AI (editor): *COSMOS Biosatellites Abstracts of Papers Presented at an International Symposium.*

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 31-32.

Biological Rhythms, Circaminute Rhythms, Sensory, Motor Functions, Psychology,  
Instrumental Responses, Adaptation  
Monkeys, *Macaca mulatta*  
Space Flight, COSMOS-2044

**Abstract:** Introduction. In experiments performed on rats (COSMOS-1129) and monkeys (COSMOS-1514 and -1667) circaminute rhythms in sensory and motor functions were studied for the first time in animals during space flight. It has been established that the frequency variability of these biological rhythms is a sensitive criterion for evaluating reactivity.

**Methodology.** The current work involved a chronobiological analysis of temporal series composed of parameters of latencies (sensory rhythm) and times to perform motor reactions (motor rhythm) in performance of instrumental responses during the flight of two monkeys on COSMOS-2044 and in a control condition.

**Processing of the conditioned response parameters of the monkeys** used a specially developed program, "Minute Rhythms," combined with a menu, which made it possible to select methods and techniques for processing of data. The major methods of processing used included: linear interpolation of temporal series, filtration with a sliding mean, medial filter, rhythm analysis, regression analysis, etc.

**Results.** Beginning on day 1 of space flight, while dominant rhythms still tended to be multiples of one another, relative synchronization became more labile. In the monkey Zhakonya, days marked by greater stability alternated with those with greater lability of functional state. On day 3, synchronization of rhythms of sensory and motor functions began and by day 8 was fully established. A similar pattern was not observed in Zabiyyaka; in this monkey longer periods of 2-3 minutes were more prominent. These long-wave components occurred throughout the flight, as well as during the control experiment. Under control conditions, inter- and intraindividual differences were detected in the microrhythm structure of the functions studied at 1600 and 2100. Intraindividual differences, in all likelihood, are associated with the fact that measurements were made at different points in the circadian rhythm cycle. A dominant rhythm was found only within the motor function. At the same time there was relative synchronization of sensory and motor functions, more marked in Zhakonya.

**Conclusions.** The results showed that circaminute periods of sensory and motor functions of monkeys objectively reflect individual characteristics of animals and their potential for adaptation to experimental conditions.

PAPERS:

P1485(33/91)\* Grigoryev AI, Noskov VB, Atkov OYu, Afonin BV, Sukhanov YuV, Lebedev VI, Boyko TA.

*The status of fluid-electrolyte homeostasis during and after a 237-day space flight.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 15-18; 1991.

[6 references; 1 in English]

Body Fluids, Metabolism, Fluid-Electrolyte Metabolism, Homeostasis, Renal Function, Endocrinology, Hormonal Regulation, Adrenal Gland

Humans, Males, Cosmonauts

Space Flight, Long-Term, Salyut-7

**Abstract:** Fluid-electrolyte metabolism, renal function, and hormonal regulation were studied in two cosmonauts completing a 237-day flight on Salyut-7. During a 3-day period preflight and the first 5 days postflight, urine was collected and water consumption recorded. On day 30 preflight and days 1 and 8 postflight, blood was taken from the ulnar vein in the morning from supine fasting cosmonauts. On days 216-219 of flight, the cosmonauts' urine was collected for a 3-day period and their fluid and food consumption were scrupulously recorded. An aliquot of urine was sampled daily and frozen. Diuresis was measured on the basis of dilution of a lithium marker previously introduced into the urine container. Blood was taken from the vein of one cosmonaut on day 217 and from the other on day 218. In addition, the physician-cosmonaut, Dr. Atkov, took his own blood on day 219 of flight. After the blood was separated in a centrifuge, plasma samples were frozen and stored on board until the flight was completed. A special system, Plasma-01, developed by Soviet and Czechoslovak scientists, was used to process biological samples in flight. This system consisted of a centrifuge to separate the blood into plasma and blood cells, and also for preparing samples of material for freezing; a refrigerator-freezer for freezing samples and storing them at -20 °C, and an insulated container for returning the material to Earth in a frozen state. Preflight, on days 116 and 222 of flight, and day 2 postflight, a fluid-calcium loading test with calcium lactate was conducted to evaluate renal calciuretic function. In the morning, after blood was taken, fasting cosmonauts ingested 45 mequiv of calcium and water in the amount of 10 ml per 1 kg body weight. During the next 4 hours urine was collected. Before loading and 2 hours subsequent to it blood was taken from the finger for measurement of levels of calcium, magnesium, and phosphorus. For this purpose a semiautomatic analyzer was used in flight, consisting of a six-channel photometer with a centrifuge and microprocessor, and special flasks in which the reactions could occur in weightlessness. On the ground the samples of plasma and urine were analyzed for sodium and potassium using flame photometry; calcium and magnesium through atomic absorptiometry; phosphorus and creatinine through spectrophotometry; and chlorine titrimetrically. Concentrations of osmotically active substances were measured cryoscopically, and hormones were measured using radio-immune assay with commercial kits. In addition, the foods comprising the cosmonauts' rations during the 3 days of the in-flight experiment were analyzed for mineral components.

Preflight all the parameters reflecting fluid-electrolyte metabolism and hormonal status remained within the physiological norms. Diuresis on days 216-219 of flight did not deviate significantly from normal. However, for cosmonaut 1, renal excretion of sodium, chlorine, and magnesium was significantly diminished compared with baseline, while cosmonaut 2 displayed increased renal excretion of potassium and osmotically active substances. The excretion of creatinine in flight exceeded baseline in both cosmonauts. Differences between cosmonauts may be associated with differences in diet, although they had attempted to eat identical diets during the test. The percent of renal excretion of major electrolytes was calculated from data on the

diet consumed. This computation made it possible to estimate the contribution of the kidneys to support of fluid-electrolyte homeostasis in each cosmonaut, despite different levels of mineral consumption. Although there were individual differences, both cosmonauts displayed decreased renal excretion of sodium with respect to its level of consumption. In addition, cosmonaut 2 showed reduced relative diuresis.

These changes were accompanied by shifts in the system of hormonal regulation of homeostasis. For both cosmonauts renal excretion of aldosterone increased, while that of 11-deoxycorticosterone, a precursor in the aldosterone synthesis cycle, decreased, probably indicating increased mobilization for synthesis of the major mineralocorticoids. Plasma renin activity increased in both subjects. Excretion of free cortisol showed a tendency to decrease, while its level in plasma was elevated compared to baseline in both cosmonauts. These data suggest activation of both the glucocorticoid and mineralocorticoid functions of the adrenal glands. There was also a significant increase in synthesis of estrogens in all three crewmembers, for which the cause was unclear. ADH in plasma was depressed by 40% and 21% in two of the subjects, and unchanged in the third. In both subjects for whom urine was analyzed, renal excretion of ADH was increased. These data suggest that in long-term exposure to weightlessness increased production of hormones controlling fluid-electrolyte homeostasis is required to maintain the balance at an appropriate level. The increased need for these hormones could have been due to changes in ion homeostasis or decreased sensitivity of the kidneys to ADH. The latter has been demonstrated under conditions of long-term hypokinesia.

Levels of magnesium, phosphorus, and calcium in blood from the finger analyzed in flight did not differ from baseline in either subject. Two hours after calcium loading, there was an increase in blood calcium, while levels of the other minerals were unchanged, suggesting retention of the specificity of the reaction to this test.

On day 1 postflight, all three crewmembers displayed an increase in ionized blood fraction (by 20-28% over baseline); and a 9-15% decrease in concentration of potassium. Sodium levels were unchanged while osmolarity was depressed. These changes persisted on day 8 postflight, with the exception of calcium levels, which normalized. All three cosmonauts maintained a positive fluid balance on days 0 and 1 postflight, with relatively low excretion of osmotically active substances, especially sodium. During the subsequent 5 days, continuous monitoring revealed gradual normalization. Both cosmonauts lost weight on the flight, which can be attributed to hypohydration. Postflight blood levels of ADH and aldosterone increased compared to baseline in all three crewmembers. Renal excretion of these substances also increased. Renal excretion of glucocorticoids was relatively high, but despite increases in blood ACTH on day 8, level of hydrocortisone in blood decreased, possibly suggesting that the adrenal cortex was not secreting enough adaptive hormones during a period when physiological need for them was enhanced.

On day 2 of readaptation a calcium lactate loading test was conducted. Cosmonauts 1 and 2 displayed increased rate of renal excretion of calcium and increased total excretion of this ion during the 4-hour test. These changes were no more pronounced than after previous flights of 2-3 months. Level of parathyroid hormone in plasma increased by a factor of 2 in both cosmonauts postflight, while concentrations of calcitonin decreased markedly.

Thus, on days 216-219 of flight, despite individual differences in cosmonauts, there was a tendency for the body to retain fluid and sodium, due to restructuring of the system of hormonal control of fluid-electrolyte homeostasis. There were no signs of disruption of fluid-electrolyte homeostasis. Postflight, subjects displayed changes characteristic of altered fluid-electrolyte metabolism, suggesting hypohydration and restructuring of the excretory activity of the kidneys and hormonal regulation of fluid and mineral metabolism, serving to facilitate readaptation to conditions on Earth.

Table 1: Level of diuresis (in ml/day) and renal excretion of electrolytes (in mmole/day), osmotically active substances (OAS, in mosm/day) and creatinine (in mole/day) in cosmonauts pre- and inflight

Cosmonaut	Time	Parameter studied							
		diuresis	Na	K	Ca	Mg	Cl	OAS	creatinine
1	pre-flight	1400±90	220±10	69±14	4.9±0.8	4.2±0.7	230±9	900±70	12.4±0.1
	day 216	900	142	62	4.5	3.6	130	830	15.0
	day 217	1000	122	56	4.9	2.8	121	845	18.6
	day 218	800	136	46	4.0	2.5	117	916	16.8
2	pre-flight	900±80	140±7	42±4	3.8±0.7	3.9±0.6	140±6	700±40	12.4±0.1
	day 217	1300	154	72	4.0	4.5	134	1156	19.5
	day 218	1300	182	89	4.0	4.3	176	1150	25.7
	day 219	1100	128	56	2.3	2.3	133	713	11.5

Table 2: Renal excretion of hormones, fluids, and electrolytes (in % of intake) in cosmonauts pre- and inflight

Cosmonaut	Time	Parameter studied						
		aldosterone, µg/day	11-DOC, ng/day	hydrocortisone, µg/day	ADH, ng/day	Renal excretion, %		
						fluid	Na	K
1	pre-flight	7.3±0.4	355±90	530±40	92±3	50-60	80-90	80-90
	day 216	13.2	276	460	198	40	59	76
	day 217	30.1	307	530	268	30	39	70
	day 218	6.0	202	260	191	20	45	55
2	pre-flight	5.5±0.5	196±30	420±20	60±6	50-60	80-90	80-90
	day 217	16.0	205	430	296	70	57	77
	day 218	8.9	174	350	217	70	76	96
	day 219	2.2	116	210	139	60	49	70

Table 3: Concentrations of hormones in blood plasma of cosmonauts 1, 2, and 3 at various measurement periods

Parameter	Preflight			Day 217-219 of flight			Day 1 postflight			Day 8 postflight		
	1	2	3	1	2	3	1	2	3	1	2	3
Cosmonaut												
ADH, pg/ml	4.7	4.5	4.7	4.2	2.7	3.7	6.6	5.6	15.6	9.9	10.1	4.7
11-DOC, pg/ml	130	70	110	90	80	80	60	70	70	100	100	90
Aldosterone, ng/ml	195	140	150	160	185	165	275	260	200	200	275	120
11-dehydro- corticosterone, ng/ml	3.3	3.4	3.4	3.0	3.3	1.8	1.7	1.1	2.6	2.1	2.3	2.5
Hydrocortisone, ng/ml	32	98	18	166	141	27	108	170	6.0?	38	114	16
Testosterone, ng/ml	4.4	3.1	3.2	6.9	2.5	9.8	7.2	5.5	7.3	3.0	9.3	7.0
Total estrogens, pg/ml	33	60	69	482	551	276	35	45	--	150	285	190

P1549(33/91) Dotsenko MA, Larina IM, Rudneva RI, Sukhanov YuV, Truzhennikov AN.  
*The effect of space flight on fluid-electrolyte homeostasis of monkeys.*  
Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow  
In: Grigoryev AI (editor): *COSMOS Biosatellites Abstracts of Papers Presented at an International Symposium.*  
Leningrad 12-15 August 1991.  
Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.  
[227 pages]  
Pages: 36-37.

Body Fluids, Fluid-Electrolyte Homeostasis, Endocrinology, Calcitropic Hormones  
Monkeys, *Macaca mulatta*  
Space Flight, COSMOS

**Abstract:** Introduction. Exposure of humans or animals to weightlessness is accompanied by redistribution of the body fluids and changes in bone and muscle tissue, due to the decrease in functional loading on the musculoskeletal system accompanied by systemic restructuring of metabolic processes, including fluid-electrolyte metabolism.

Research studies were conducted on monkeys flown for 2 weeks on biosatellites with the goal of producing quantitative and qualitative information on the status of fluid-electrolyte homeostasis and associated systems of regulation.

**Methods.** Forty monkeys were studied preflight, and four immediately postflight in order to establish normal limits and compute normal values for all parameters of fluid-electrolyte metabolism and associated regulation systems.

Study of fluid-electrolyte homeostasis focused on body weight of the animals and fluid balance (as the difference between fluid intake and fluid excreted). Concentrations of sodium, potassium, calcium, magnesium, and phosphorus were measured by the method of atomic absorption spectrophotometry in samples of the pastelike food mixture, juice, aliquots of daily urine, feces, and blood serum. Radioimmune assay was used to measure the concentrations of aldosterone, parathyroid hormone, calcitonin, and the transport form of vitamin D.

**Results.** The state of the animals postflight was satisfactory. Body weight was virtually unchanged. Mean daily consumption of fluid in weightlessness was 300-350 ml. Fluid balance decreased, but remained positive.

There were increases in serum concentrations of calcium and potassium. Concentrations of sodium, phosphorus, and magnesium did not alter significantly. Level of secretion of aldosterone increased and those of calcitonin, parathyroid hormone, and the hydroxylated form of vitamin D decreased.

**Conclusions.** Decrease in fluid balance in the postflight period and its rapid recovery to baseline value suggest some dehydration. Comparison of the concentrations of calcium, parathyroid hormone, calcitonin, and the hydroxylated form of vitamin D suggests disruption of calcium homeostasis during this period. Changes in concentrations of electrolytes and calcitropic hormones in bone tissues are evidently secondary.



## PAPERS:

P1516(33/91) Chernova LS, Mashinskiy AL.

***Microbiological problem of cultivating higher plants under space flight conditions.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 65-66.

Botany, Higher Plants, Cultivation, Radish, Cabbage, Bok Choy

Microbiology, Microbial Cenoses of Plants

Space Flight, Long-Term, Mir, Svet

**Introduction.** One of the problems associated with cultivating higher plants on long-term orbital space stations is maintaining the stability of the microbial cenosis of the plants, which performs certain ecological functions that not only foster normal plant development, but also are important in producing a healthy spacecraft environment.

**Procedure.** Radish and bok choy plants were grown on Mir for a period of 54 days in the Svet greenhouse, developed by Bulgarian and Soviet specialists. The plants were grown on "Balkanin" granular salt-saturated natural zeolite manufactured in Bulgaria, combined with water-conducting hydroaccumulators made of polyvinyl foam and wicks of chlorine fabric. Two baseline and one synchronous condition were run, all in the Svet greenhouse so that the results of the flight and ground-based experiment could be compared. Microbiological samples of flight material were taken on-board the station, at the cosmonaut landing site, and under laboratory conditions. The total number of microorganisms was measured using the plate assay method. The nutrient medium was meat peptide agar for the heterotrophs, and cabbage agar for the autotrophic plants. Selective media were used for the study of special groups of microorganisms: actinomycetes were counted on starch ammonia agar, fungi on Czapek medium, and *E. coli* on Endo medium. The method of limiting dilutions was used to conduct a group analysis of the following functional groups of microorganisms: ammonia-fixing bacteria were isolated on peptone water, denitrifiers on Hiley medium, and cellulolytic bacteria on Vinogradskiy medium. Identification of isolated pure cultures was based on their morphological, physiological, and biochemical properties. Data were processed statistically using traditional microbiological methods.

**Results.** Measurement of contamination of the plants showed that the level of microorganisms at the end of growth was higher in the bok choy than the radish, by four orders of magnitude. It is possible that this is associated with lower phytocidal activity of bok choy plants. The level of *E. coli* bacteria in the experimental conditions was also higher in bok choy plants, while members of this group were absent in the control plants. Among the physiological groups of microorganisms studied, those participating in transformation of nitrogen-containing substances and ammonia-fixing bacteria dominated in the cabbage plant, while in the radish those species predominated that had been found to predominate in previous studies. The number of mold fungi on the leaves of the plants in flight was approximately  $10^3$  cells per 1 g dry plant matter, and included mainly members of the *Aspergillus* and *Penicillium* families. However, on the moist surface of the wick, fungus growth was more intense and led to the formation of a mycelial film. When plants were grown in the closed Svetoblok-M unit, such phenomena were not observed. This fact suggests the need for further improvement of certain components of the greenhouse structure and cultivation conditions.

**Conclusions.** Microbiological cenoses of radish and bok choy plants have some degree of stability when grown in the Svet greenhouse under conditions of space flight, i.e., physiological groups of microorganisms do not undergo fluctuations capable of disrupting the equilibrium of the microecosystem.

P1518(33/91) Antonyan AA, Mashinskiy AL, Sychev VN, Ivanova IE, Derendyayeva TA.  
*The state of the pigment system of photoautotrophic organisms under conditions of microgravity.*

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*

Moscow: 1991.

Pages 69-70.

Botany, Pigment Systems, Photosynthesis

Photoautotrophic Organisms, Microbiology, *Chlorella*, *Azolla*, Wheat, Radish, Kale

Space Flight, Life Support Systems, Bioregenerative Systems

**Introduction.** Development and production of man-rated bioregenerative life support systems requires consideration of a wide range of issues associated with the effects of weightlessness on the growth, development, and metabolism of the species of photoautotrophic organisms to be grown in a closed system. The most general parameter—common to all photoautotrophs—is the pigment system, the activity of which is highly significant in realizing the major function of plant organisms—photosynthesis.

This paper describes a multiyear comparative study of the effects of weightlessness on the state of pigments of various photoautotrophic organisms.

**Procedure.** The experiments used the unicellular algae *Chlorella* of the line LARG-1, the water fern *Azolla*, Eritrospermum-841 wheat, red radish with a white tip, and Khibinskaya kale. The ground controls were run in two variants: synchronous and laboratory. Amounts and composition of pigments were measured after preliminary extraction and chromatography on a SF-18 spectrophotometer.

**Results.** Comparative analysis of data showed that when various photoautotrophic organisms are grown in weightlessness, changes occur in the photosynthetic apparatus, especially decreases in the amounts of the major groups of pigment — chlorophylls and carotenoids—per unit dry and fresh weight. The greatest decreases were noted in *Azolla* and *Chlorella* and constituted 50 and 45% of the total, respectively. For wheat the decrease was smaller, about 30% compared with ground controls. These changes were found in organisms in which the rate of growth in weightlessness was close to that of the ground control. Only in experiments with vegetables (radish and cabbage) was the level of pigments per unit dry biomass the same as in ground control conditions. These latter results were evidently due to a significant lag in the growth and development of the plants in flight, accompanied by changes in a number of their characteristics, especially, the level of dry substance in the biomass, which was twice as high as that of the controls.

One characteristic change that occurred in the pigment composition of most of the species studied was a decrease in the ratio of chlorophyll to carotenoids, and comparative increases in the ratios of chlorophyll a to b and also of xanthophylls to carotene due to destruction of substantial amounts of the second members of each pair. Analogous data (obtained by these and other authors) on various species of algae and plants in extreme conditions on Earth suggest the nonspecific nature of the effects of weightlessness on these parameters. In separate experiments (postflight) it was established that these changes are reversible and have virtually no effect on photosynthetic functions, morphophysiological state, or other characteristics of these species during long-term cultivation.

**Conclusions.** On the whole, the effects of weightlessness on the pigment system of various photoautotrophic organisms are nonspecific in nature. The results suggest that changes in the

pigment composition are one of numerous protective-adaptive reactions that maintain the integrity and functional activity of the photosynthetic apparatus in weightlessness; however, these findings should be confirmed by further research.

P1519(33/91) Mashinskiy AL, Naydina VP, Derendyayeva TA, Ivanova IYe, Nechitaylo GS.  
*The lipid composition of wheat seedlings grown in weightlessness.*  
 Affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Energiya NPO  
 In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*  
 Moscow: 1991.  
 Pages 71-72.

Botany, Lipid Composition, Nutrition  
 Wheat  
 Space Flight, Mir

**Introduction.** Various changes occur in the structural and functional organization of growth and the biochemical properties of higher plants when vegetative growth takes place under exposure to microgravity. Changes have been found in rate of biochemical reactions, primarily associated with disruption of lipid metabolism. Detailed study of this process would make it possible to better understand the mechanisms underlying the effects of space flight factors. For this purpose wheat plants of the Skala variety were grown on Mir in November-December, 1990.

**Procedure.** The substrate for growing the plants was a tissue form of the Bion B-2 ionite substrate, with a volume of 239 cm<sup>3</sup>. The duration of cultivation in weightlessness was 18 days. Daily illumination was 18 hours, with 6 hours of darkness. Thirty plants were grown in an area 47.8 cm<sup>2</sup>, with illumination of 30 W/m<sup>2</sup> in the range of photosynthetically active radiation. During growth the amount of water provided was 165 ml. A laboratory control condition was run synchronously with the flight condition. The plants were weighed and fixed in liquid nitrogen on the ground 30 minutes after completion of the flight. Fatty acid composition of lipids (in %) was analyzed using gas chromatography, and the total level of fatty acids (in mg/g fresh biomass) was measured in control and flight wheat plants.

**Results.** The fatty acid composition of lipids of flight plants differed from that of control plants by virtue of decreased levels of linolenic acid (by almost 25%) and increased levels of palmitic, oleic, and linoleic acids (by 7, 15, and 5%, respectively). In addition, flight samples displayed some decrease in total levels of fatty acids (3.2 mg/g in the control and 2.9 mg/g in the experimental conditions). These results evidently attest to a slowing of processes of desaturation of saturated fatty acids in wheat seedlings grown in weightlessness. Decreased levels of polyunsaturated linolenic acids in the lipids of young plants under conditions of further growth could cause anomalous deviations in development, as well as decreased food value of the wheat.

**Conclusions.** The data obtained on the fatty acid composition of lipids in wheat seedlings suggest that space flight factors probably decrease the activity of enzymes participating in the process of desaturation, which is manifested as a decrease in growth processes. For this reason further study of the mechanisms underlying effects of space flight factors on higher plants is essential.

## PAPERS:

P1491 (33/91)\*Meyerson FZ, Kuznetsov VI, Saltykova VA.  
*The role of cholinergic regulation and stabilization of the structure of the myocardium in adaptive protection of the heart.*  
 Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
 25(2): 36-43; 1991.  
 [40 references; 26 in English]

Cardiovascular and Respiratory Systems, Myocardium, Adaptive Protection, Cellular Mechanisms, Neurophysiology. Cholinergic System, Vagus Nerves  
 Rats, Males, Isolated Hearts  
 Adaptation, Stress, Immobilization; Ischemia, Reperfusion

Abstract: The goal of this work was to compare the roles of activation of the central stress-limiting cholinergic system and cellular mechanisms underlying the "phenomenon of adaptive stabilization of structures" (PASS) in development of increased cardiac resistance to harmful factors. PASS is a term used to refer to adaptive protection of the heart on a cellular level, as manifest in the isolated hearts of adapted animals, which provides them with resistance to the harmful effects of reperfusion, toxic concentration of catecholamines, and  $Ca^{2+}$  and thermal shock. In addition, elements of the sarcoplasmic reticulum, mitochondria, and nuclei from the myocardia of adapted animals are highly resistant to autolysis.

Subjects of the experiments were 250 male Wistar rats. This research had three stages. During the first, experiments were performed on animals adapted to continuous stress (immobilization in cages) for 1, 5, 15, and 30 days. The experimenters measured the magnitude of the tonic effect of the vagus nerves on the heart, its threshold of fibrillation, and arrhythmia observed when the left coronary artery was occluded and then reperfused. This design provided information about the degree to which cardiac resistance to ischemic and reperfusion arrhythmia depends on adaptive increase in the tonic effect of the vagus nerves on the heart. During the second stage of the research, studies were conducted on rat hearts that were isolated 1, 5, and 15 days after beginning of the animals' continuous exposure to stress. Resistance of these hearts to toxic concentration of catecholamines, to the reperfusion paradox, and to known toxic concentrations of  $Ca^{2+}$  was studied. These studies made it possible to evaluate the dynamics of the heart's development of resistance to harmful factors, i.e., the dynamics of the "PASS." In the third stage, experiments were performed both on animals and on isolated hearts. In the animal experiments, exposure to continuous stress was terminated after 5 days — during the period when adaptive increase in the tonic effect of the vagus nerves is maximal — and then the dynamics of this phenomenon's disappearance were studied. In the studies of isolated hearts, these organs were taken 5, 10, 15, and 25 days after termination of a 15-day stress period. Resistance of the heart to the harmful effects of reperfusion was studied. It was possible to follow the disappearance of the adaptive activation of the cholinergic system and of the PASS, which had been fully developed during adaptation.

The stress stimulus used — immobilization in cages — stopped the growth of the experimental animals so that after 15 days their weight was 26% below that of control animals. After termination of stress, their weight recovered to normal levels within 15 days. The tonic effect of the vagus nerves on the heart was estimated from the difference in heart rate before and after administration of atropine sulfate in an intraperitoneal dose of 1 mg/kg. Fibrillation threshold was measured in the rats after a thoracotomy was performed under urethane anesthesia with artificial respiration. A coaxial needle electrode was introduced into the myocardium at the apex of the left ventricle. Starting at the point of the R peak on the ECG, the heart was stimulated with premature singular rectangular electrical impulses 10 ms in duration. The

beginning of the relative refractory period, i.e. the point where a single response occurred to the stimulation, was found while scanning the S-T interval with 3-threshold impulses. The magnitude of the threshold for stimulation of the ventricle was measured as the minimum current strength in milliamperes at which fibrillation occurred. Experiments with transitory ischemia and reperfusion were conducted under urethane anaesthesia with open chest and artificial respiration. A ligature was introduced below the left coronary artery, occluding it; after 10 minutes the ligature was released and the response of the heart to reperfusion and reoxygenation was evaluated for a 5-minute period.

In the isolated heart experiments, the heart was extracted from anesthetized rats and placed in a perfused system using Langendorff's method. A standard Krebs-Henseleit solution aerated with a 95% O<sub>2</sub>, 5% CO<sub>2</sub> mixture was used. Perfusion pressure was 9.5 kPa. Mechanical activity of the heart was measured using an isotonic sensor which recorded apical-basal contraction of the heart. ECG and mechanical activity were recorded using a special polygraph module. Disruption of cardiac rhythm was estimated on the basis of number of extrasystoles in the ECG for each animal and number of instances of fibrillation. Contracture was inferred from absolute changes in apico-basal length of the heart measured at the end of a stabilization period. Reperfusion damage was inflicted by restoring coronary flow after a 20-minute period of total ischemia. Physiological parameters were recorded after 1, 5, and 20 minutes of ischemia, and 2, 5, 10, and 20 minutes of reperfusion. Reperfusion damage to the sarcolemma was estimated on the basis of secretion of creatine kinase into the perfusate of the isolated heart. Creatine kinase activity was measured in the perfusate at minutes 2, 5, and 20 of reperfusion using spectrophotometry and was expressed in I.U./min per 1 g myocardial tissue. To produce adrenotoxic cardiac damage, epinephrine in a concentration of 10<sup>-5</sup> M was introduced into the perfusing solution for 15 minutes. Physiological parameters were measured in minutes 5 and 15 of exposure. Since both adrenergic and reperfusion damage to the heart are primarily due to excess Ca in cardiomyocytes, an experiment was performed on the effect of the contracture and arrhythmogenic effects of toxic concentrations of Ca on the stability of isolated hearts of animals adapted to stress. High concentrations of Ca were created by replacing the perfusing solution with a solution containing 10 mM Ca for 4 minutes.

Animals adapted to stress for 5 days showed marked bradycardia, while those adapted for 1 and 15 days showed only a tendency in that direction. Similarly only after 5 days of adaptation was there a marked increase over baseline in the negative chronotropic influence of the vagal nerves. Fibrillation threshold decreased after 1 day of stress exposure and recovered after 5 days of stress. On day 15, despite the decrease of the tonic effect of the vagal nerves to control levels, fibrillation threshold did not differ from baseline, suggesting that the effect of adaptation on eliminating initial disruption of the electrical stability of the heart, depends not only on the vagal nerves, but on other factors as well. Results on resistance to arrhythmia of the hearts of rats during transient ischemia and reperfusion show that stress associated with 1 day of exposure to immobilization significantly decreased resistance to acute forms of ischemic arrhythmia, which are primarily due to increased adrenergic effects on the heart. After 5 days of stress-adaptation, when there was maximal increase in the tonic effect of the vagal nerves, the total duration of these arrhythmias was depressed by a factor of 7 compared to control. On day 15 of adaptation, when the tonic effects of the vagal nerves had returned to normal, resistance to arrhythmia induced by ischemia, while less than that on day 5, was still significant. Resistance to reperfusion-induced arrhythmia, which is mainly attributable to local mechanisms, was greatest on day 15.

The authors conclude that the cholinergic system developing through adaptation to stress is a powerful anti-arrhythmic factor, although this effect is relatively short-lived and is no longer functioning on day 15 of adaptation. However, some other mechanism limiting ischemic and particularly reperfusion arrhythmias is apparently in operation at this time. One possibility

is that these protective mechanisms develop at the level of the heart itself. This is the reason isolated hearts were studied. Total ischemia decreased heart rate by a factor of 4 and amplitude of contraction and rate of contraction and relaxation by a factor of 8. Contracture failed to develop during ischemia and number of extrasystoles and other arrhythmias during ischemia was insignificant. Neither 1 nor 5 days of adaptation to immobilization stress had any significant effects on ischemic depression of contractility parameters. However, 15 days of adaptation significantly limited ischemic disruptions of contractility. In minute 20 of reperfusion, changes in contractile function were different from those occurring in ischemia, but the protective effect of adaptation was even more significant. In the control condition, by minute 20 of reperfusion, amplitude and rate of contraction and relaxation were depressed by approximately 40%. This was primarily due to presence of contracture in an amount equal to 26% of initial amplitude of contraction. The mean number of extrasystoles per heart was 113 and fibrillation occurred in two hearts. After 1 day of adaptation, no changes in these effects were noted. After 5 days of adaptation, depression of contractile function in reperfusion was diminished — number of extrasystoles was decreased by a factor of 3 and magnitude of contracture by a factor of 5 compared to hearts of non-adapted animals. Fibrillation did not occur. After 15 days of stress adaptation, reperfusion effects were essentially absent. In addition after 15 days of stress adaptation, release of creatine kinase into the perfusate of isolated hearts during reperfusion was decreased by a factor of 2 compared to non-adapted animals. These results are interpreted as suggesting that after 15 days of stress adaptation, the PASS played a major role in the anti-arrhythmic effect of adaptation in the total absence of the cholinergic system.

Since the increased adrenergic effect and excess influx of  $Ca^{2+}$  into cardiomyocytes play a major role in ischemia and reperfusion-induced damage to the heart, it was hypothesized that the PASS effect would manifest itself in increased resistance to catecholamines and  $Ca^{2+}$ . This hypothesis was confirmed with respect to epinephrine; the protective effect of 15 days of stress adaptation was significant for all parameters studied. Data for  $Ca^{2+}$  were analogous to those for epinephrine.

The last stage of the research investigated how long adaptive protection lasts after termination of adaptation to stress. Results showed that after termination of relatively short-term (5-day) adaptation, the increase in the tonic effect of the vagal nerves decreases to baseline within 12 hours. Effects of 5-day adaptation in decreasing duration of severe arrhythmia in ischemia and reperfusion also diminish within 12 hours. After 15 days of adaptation, protective effects against ischemia persist for 5 days, while against perfusion damage they persist at least 15 days.

The authors conclude that because of the synergy between rapidly developing but short-lasting central and slower to develop but longer-lasting cellular mechanisms, adaptive protection of the heart to the effects of stress factors can be both rapid and stable.

Table 1: Dynamics of the tonic chronotropic effect of the vagal nerves and threshold of fibrillation of hearts of rats in the process of adaptation to continuous exposure to stress

Table 2: Effects of adaptation to continuous exposure to stress on resistance of hearts of adapted rats to arrhythmia in transient ischemia and reperfusion

Table 3: Effects of adaptation to continuous exposure to stress on resistance of hearts of adapted animals to total ischemia and reperfusion

Table 4: Effects of adaptation to continuous exposure to stress on resistance of hearts of adapted animals to cardiotoxic concentrations of epinephrine



## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

Table 5: Effects of adaptation to continuous exposure to stress on resistance of hearts of adapted animals to cardiotoxic concentrations of  $\text{Ca}^{2+}$

Table 6: Disappearance of the cardioprotective effect in animals adapted to continuous stress for 5 days

Table 7: Disappearance of the cardioprotective effect in animals adapted to continuous stress for 5 days (disappearance of increased resistance to ischemic and reperfusion arrhythmia in experiments on animals)

Table 8: Dynamics of disappearance of the cardioprotective effect in animals adapted to continuous stress for 15 days (disappearance of adaptation resistance to ischemic and reperfusion damage)

Figure: Effects of adaptation to continuous exposure to stress on activity of creatine phosphokinase in perfusate of isolated hearts of rats during reperfusion after 20 minutes of total ischemia

**PAPERS:**

P1513(33/91) Meleshko GI, Guryeva TS, Dadasheva OA, Solovyov AYA, Balandin AN, Bodya K, Sabo V.

*Study of the embryonic development of quail in weightlessness.*

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Institute of Animal Biochemistry and Genetics, Slovak Academy of Sciences

In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*

Moscow: 1991.

Pages 61-62.

Developmental Biology, Embryonic Development, Adaptation

Quails, Eggs, Chicks

Space Flight, Mir, Life Support Systems, Bioregenerative Life Support Systems

**Introduction:** Investigations of embryogenesis of birds in space were made possible by the development, in collaboration with Czechoslovak scientists, of the Inkubator-2 facility, which was installed on board space station Mir. In March 1990, the Inkubator-2 experiment was begun on Mir to study the effects of space flight on the embryonic development of Japanese quail.

**Procedure.** Quail eggs from a single population of birds were delivered to Mir in a special container. The period of time from the moment the eggs were collected on Earth to the onset of incubation was 11-13 days. A total of 43 eggs were placed in the incubator. Incubation conditions were maintained within stipulated limits (temperature +37 °C; humidity 65-75%). A synchronous ground-based control condition was run at the same time as the flight condition. At stipulated times in the process of incubation (days 3, 7, 10 and 14 ) two eggs were removed from the incubator and fixed in an alcohol-glycerine mixture.

**Results.** Hatching began in the flight condition on day 17 of incubation (first chick) and by day 21, 8 fully developed chicks had hatched. The total rate of successful incubation (8 chicks from 35 eggs, including unfertilized eggs) was 23%, compared to 54.3% in the synchronous control condition and 63% in the laboratory control. The chicks that hatched showed all external signs of normal development, reacted to visual and auditory stimuli, and manifested activity and vocalization. However, due to the inability of the chicks to adapt to conditions of weightlessness, the experiment was terminated. The total duration of the chicks' lives in weightlessness was 2-4 days. Analysis of the flight material showed that the stage of development of the quail embryos corresponded to the age of the embryo in the norm. However, the frequency of morphological anomalies in the flight embryos is noteworthy. Of 13 embryos returned to Earth, 5 showed deviations from normal development of the eyes, brain, and beak. Developmental anomalies took the form of microphthalmia, anophthalmia, deformities of the beak, and anencephaly. This may be associated with the indirect effect of weightlessness through influence on gravity-dependent arrangement of the macrostructures of the egg (white, yolk, embryo, air space) and also changes in the environment.

**Conclusion.** The Inkubator-2 flight experiment demonstrated the possibility of obtaining normal, viable offspring in weightlessness when quail eggs laid on Earth are incubated in space.

P1539(33/91) Belousov LV, Luchinskaya NN, Ostroumova TV.

*Reactions of triton oocytes to space flight conditions.*

Authors' affiliation: Moscow State University

In: Grigoryev AI (editor): *COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.*

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 21.

Developmental Biology, Oocytes, Reproductive System, Golgi Apparatus

Amphibians, Tritons

Space Flight, COSMOS, Foton

**Abstract:** An important task in space biology is investigation of the effects of space flight factors on the reproductive system and the early development of fetuses, since the initial organization of the fetus occurs during oogenesis at the time of the establishment of the polar organization of the egg. It is well known that exposure to microgravity, especially prolonged exposure, and readaptation to conditions on the ground are accompanied by significant changes in hormonal and fluid-electrolyte balance. It is not impossible that such disturbances of homeostasis could affect the sensitive stages in processes responsible for the growth of the oocyte and establishment of egg polarity.

The effects of flight factors on oogenesis of the Spanish triton were studied in three flight experiments flown on COSMOS and Foton satellites in 1987-1990. The ovaries of experimental and control animals were fixed immediately, 2 weeks, and 2 months postflight. The ovaries fixed immediately after landing showed no signs of damage or oocyte resorption. Two weeks postflight, stimulation of oocyte growth was observed in flight tritons: the size of the oocytes was greater than in the control, and the number of marginal nucleoli in the nuclei was elevated. Ultrastructural analysis showed that during the stage of previtellogenesis there were significant differences in the structure of the Golgi apparatus of oocytes of flight and control tritons; the trans-most cisternae were diminished in size in the oocytes of flight animals, i.e. transport processes were inhibited in the oocyte. Oocytes fixed 2 months [Russian says 2 weeks, evidently a misprint] postflight again displayed normal structure of the Golgi apparatus.

This study demonstrates the sensitivity to space flight of the processes responsible for growth and maturation of oocytes, including transport of substances by means of the Golgi apparatus.

**PAPERS:**

P1537(33/91) Baranska W, Skopinski P, Kujawa M, Prodan NG.

*Morphometric study of the adrenal glands of rats flown for 7 and 13 days on biosatellites COSMOS-1667 and -1887.*

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow; Laboratory of Electron Microscopy, Institute of Biological Structures, Medical Academy, Warsaw, Poland.

In: Grigoryev AI (editor): *COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.*

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 6-7.

Endocrinology, Adrenal Gland, Morphology, Stress Response

Rats

Space Flight, COSMOS-1667, -1887

**Abstract:** Introduction. The issue of whether weightlessness leads to development of a stress response in mammals is still open. A comparative morphometric study was performed of the adrenal glands of rats exposed to weightlessness for 7 and 13 days, as well as of the adrenal glands of vivarium and synchronous control groups. Histomorphometric analysis was performed on cells of the glomerular, fascicular, and reticular zones of the cortical substance and cells of the medullary substance of the adrenal glands. The reliability of the difference between the experimental and control groups was evaluated using Duncan's test.

**Results.** It was established that exposure to weightlessness is accompanied by an increase in the volume of cell nuclei in the glomerular and fascicular zones of the cortical substance of the adrenal glands, with an association between increase in the volume of cell nuclei in the glomerular zone and duration of space flight. The volume of cell nuclei of the fascicular zone was somewhat greater in rats flown on COSMOS-1667 than on COSMOS-1887. In the reticular zone of the cortical substance in the adrenal glands there were no reliable differences between the volumes of cell nuclei of the flight and control groups. In the medullary substance of the adrenal glands, the volume of cell nuclei progressively decreased with increasing exposure of the rats to weightlessness.

P1549(33/91) Dmitriyeva NP, Plakhuta-Plakutina GI, Amirkhanyan YeA.  
***Ultrastructural changes in calcium-regulating systems in rats with injured legs in weightlessness.***

Authors' affiliation: Institute of Developmental Biology, USSR Academy of Sciences, Institute of Biomedical Problems, USSR Ministry of Health, Moscow

In: Grigoryev AI (editor): **COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.**

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 35-36.

Endocrinology, Thyroid, Parathyroid, Calcium Regulation, Metabolism

Rats

Space Flight, COSMOS-2044, Musculoskeletal System, Leg Injury

**Abstract:** Introduction. Disruption of calcium metabolism and bone demineralization in weightlessness requires further study of the underlying mechanisms. This motivated the current study of the functional status of the thyroid and parathyroid glands in rats with injured legs exposed to space on COSMOS-2044.

**Methodology.** Electron microscopy was used to study C-cells (parafollicular cells) of the thyroid glands and parathyrocytes in five rats exposed for 14 days to weightlessness and sacrificed 4.5-7 hours after landing, and in the same number of rats in vivarium and synchronous control groups.

**Results.** Among populations of thyroid C-cells, one can identify: 1 - cells with well developed granular endoplasmic reticula and small number of secretory granules, which actively synthesize and secrete the hormone; 2 - cells in the stage of rest with numerous stored granules; 3 - cells of an intermediate type, synthesizing a moderate amount of hormone. In rats of the flight group, cells with stored secretion composed 62% of the total (in the control 20%), while cells secreting hormone actively or to a moderate extent composed 38% (in the control 80%), attesting to inhibition of secretion and release of hormone in rats of the flight group.

Among the parathyroid samples, three major groups of cells can be identified: 1 - active cells with a well developed granular endoplasmic reticulum; 2 - moderately active cells; 3 - relatively inactive cells with isolated short structures of the granular endoplasmic reticulum. In rats of the flight group, active and moderately active parathyrocytes comprised 88% of the total (in the control 25%), and relatively inactive cells 12% (in the control 75%).

**Conclusions.** Decrease in functional activity of C-cells of the thyroid gland and increase in activity of the chief cells of the parathyroid glands attest to a substantial disruption of regulation of calcium metabolism in weightlessness and may contribute to bone demineralization and inhibition of mineralization of newly forming bone calluses.

## PAPERS:

P1488(33/91)\* Potapov AN, Strogonova LB, Damiryay AU.

*Major trends in the development of experimental equipment for physiological research on the ground and in space.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 26-31; 1989.

[35 references; 17 in English]

Equipment and Instrumentation, Physiological Research, Zora, Pleven-87, Son-3, Balaton, Fiziotest-6, Korteks-2, Ekhograf-2, BIOS-Primat, Topol-D

Humans, Cosmonauts, Review Article

Space Flight, Space Medicine

**Abstract:** This paper reviews technology used in physiological research in space and ground-based space medical research that has been made possible in the last decade by the development of electronics and computer technology and improved procedures for processing information and conducting physiological investigations. These innovations will in the future enable studies currently performed in terrestrial physiological laboratories to be conducted under space flight conditions. Among the latest developments used in physiological research are ultrasound, computer tomography, and MRI-tomography. Polygraphs capable of recording physiological parameters on multiple channels and integrating them are noted as being especially useful in space medicine. The use of the modular principle is considered conducive to improvement of the integrative processing of physiological information. Computer capacities for on-line or real time analysis of complex sets of physiological data are also important.

Instruments used on spacecraft must not only be reliable and have high performance parameters, but also must conform to special space flight requirements with respect to limits on size and weight, material consumed, energy usage, thermal conditions, tolerance of vibration, etc. Physiological instruments used in space must be noninvasive. The leading tendency in support of scientific research in space flight is the use of sets of instruments which serve as a flexible system, including devices for gathering, storing, representing, and processing (including transmission to Earth) biomedical information. Such a system may consist of several equipment racks. In the USSR the equipment used for gathering physiological data in space flight is subdivided into that for performing medical monitoring and that for scientific studies.

The on-board apparatus used allowed complete automation of research on the second manned Soviet-Bulgarian flight, which utilized a system of scientific apparatus for performing an entire biomedical research program, consisting of the Zora unit and the self-contained Son-3 and Pleven-87 units. This system enabled research on mechanisms of motor coordination, excitability of muscle membranes, evaluation of vestibular and eye movement interaction, evaluation of sensorimotor reactions, and study of the phase structure of sleep. The self-contained devices could be used independently or included in the system. The Son (sleep)-3 apparatus recorded EEG, ECG, EOG, and EMG sleep. Pleven-87 is an independent microprocessor system. When it was necessary to store a large amount of information, the Pleven-87 could be connected to the memory of the on-board computer to enable transmission of data to Earth.

Within the framework of Intercosmos, Hungarian-Soviet cooperation led to the development of the Balaton instrument, which records GSR, heart rate, reaction time, and error rate and is used in psychophysiological research. This device is based on a microprocessor with four measurement programs and a control program. Experimental data can be input in a dialogue mode. Results of the experiment are presented in a numerical table. Fiziotest-4, a result of Soviet-Polish collaboration, controls an automated system for studying adaptation of humans to

## EQUIPMENT AND INSTRUMENTATION

physical exercise. Aside from the control unit, the system includes a bicycle ergometer, a microcomputer, a printer, and a plotter. Polish scientists also developed the microprocessor-based Fiziotest-6, for measuring and recording psychophysiological parameters, including spirometric data. Soviet and Cuban scientists developed yet another psychophysiological system, the Korteks-2. This system consists of a microprocessor module for stimulation and recording and a microprocessor-based module for data processing. It records EEG, EOG, and ECG and evaluates motor responses.

The second Soviet-French flight used the Ekhograf-2 device for the study of peripheral and central circulation. This device consists of an ultrasound echograph, a videotape recorder, and a microprocessor for controlling the instruments and processing information. The "pulsing Doppler" mode permits measurement of rate of blood flow in large vessels deep within the body. The design of the device has advantages for obtaining two-dimensional representations of the heart and vessels and makes it possible to increase the reproducibility of measurements of parameters of intracardiac hemodynamics.

An example of an automated system used on a Soviet biosatellite was the automated BIOS-primat capsule system for maintenance of primates and conduct of research in the area of neurophysiology and the cardiovascular system. The Topol-D apparatus for magnetic recording of physiological data was used as a supplement to BIOS-primat. This device has high recording density and uses frequency modulation, enabling many hours of continuous recording of physiological information on 11 channels. It was used on COSMOS-936, -1129, and -1514.

P1496(33/91)\* Mikhaylichenko PP, Pokhorenko MYu, Tikhonchuk VS, Ushakov IB.  
*An experimental unit for evaluating the physical endurance of animals.*  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
25(2): 56-57; 1991.  
[7 references; 1 in English]

Equipment and Instrumentation, Swimming Pool  
Small Laboratory Animals  
Endurance

**Abstract:** The authors designed and built a five-lane swimming pool in which five animals can swim simultaneously, with automated recording of swimming time in each of the lanes. The device consists of a swimming pool with five individual lanes, a photographic recording block, consisting of two photographic cassettes at the "start" and "finish," and an electronic unit for controlling the device and processing information. The "finish" compartment has a "rescue" platform that serves as a motivator to induce the animals to swim. A generalized experimental design would involve training the animals to swim the length of the pool a standard number of times, and to climb onto the platform at the end of the given distance. The recording system is triggered when the animals pass over an arbitrarily designated start and finish line; this starts the clock. This device was tested successfully in an experiment involving the effect of  $\gamma$ -radiation on endurance.

Figure 1: Overall view of the swimming unit

Figure 2: Control and recording module, photographic recording module

Figure 3. Flow chart of the swimming unit

Figure 4: Effect of  $\gamma$ -irradiation on physical work capacity of rats in the swimming unit



**PAPERS:**

P1541(33/91) Boca A, Groza P.

*Histochemical studies of the digestive system of rats after flight on COSMOS-2044.*

Authors' affiliation: D. Danielopolu Institute of Normal and Pathological Physiology, Bucharest, Rumania

In: Grigoryev AI (editor): *COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.*

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 23-24.

Gastrointestinal System, Digestive System, Histochemical Analysis, Metabolism  
Rats  
Space Flight, COSMOS-2044, Tail Suspension

**Introduction.** This work represents a continuation of research performed earlier on COSMOS series biosatellites. It presents the results of histochemical studies of the digestive system of rats after 14 days of space flight.

**Methodology.** Four groups of animals were studied: flight, synchronous control, vivarium control, and rats suspended by the tail in head-down position. Histochemical studies were performed on fragments of the submandibular and sublingual glands, stomach, pancreas, and intestine.

**Results.** Histochemical studies did not reveal significant differences between the flight and control groups in activity of acid phosphatase, alkaline phosphatase, magnesium-dependent ATPase, lactate dehydrogenase, NAD- and NADP-diaphorase [sic. original does not state where]. An analogous pattern was observed in the stomach. Leucine aminopeptidase and glucose-6-phosphate [sic., phosphatase?] were studied in the intestine. Although activity of these enzymes increased after flight compared to the vivarium control, these results are complicated by the fact that the synchronous control showed marked individual differences, and in the tail suspension group, increases were even more significant.

Postflight there was an increase in acid phosphatase in B-cells of the pancreas; however, an even greater increase was seen in the synchronous group, and the greatest increase in the tail-suspended group.

All the organs studied displayed a decrease in reactions to neutral and acid glycoproteins in the flight and tail-suspension groups. The greatest reactivity with neutral glycoproteins was noted in the sublingual gland, stomach, and small intestine. The large intestine showed a higher level of acid glycoproteins. Eosinophilic cells accumulated in the submucosa of the stomach in all the experimental groups.

**Conclusion.** As in previous studies, the digestive system showed a moderate decrease in level of acid and neutral glycoproteins postflight, while concentrations of leucine aminopeptidase and glucose-6-phosphate increased. These changes are peripheral signs not only of stress, but also of certain transitional changes in metabolism.

P1547(33/91) Groza P, Boca A.

***Changes in the digestive system of rats after space flight and restricted physical activity.***

Authors' affiliation: D. Danielopolu Institute of Normal and Pathological Physiology, Bucharest, Rumania

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 33-34.

Gastrointestinal System, Digestive System, Histochemical Analysis, Endocrinology,  
Adrenocortical Hormones

Rats, Adrenalectomy

Space Flight, COSMOS-2044, Restricted Physical Activity

**Abstract:** Introduction. This work presents results of histochemical studies of the digestive systems of rats after space flights varying in duration and restricted motor activity, and also restricted activity in adrenalectomized rats.

**Methodology.** Experimenters measured neutral glycoproteins, sialo- and sulfomucin in the salivary glands, mucous lining of the stomach, and small and large intestines and leucine aminopeptidase and acid phosphatase in the small intestine.

**Results.** After flight and exposure to restricted physical activity, neutral glycoproteins decreased in all the organs studied, and these changes were a function of the duration of exposure to the extreme factor. The intensity of histochemical staining for leucine aminopeptidase and acid phosphatase in the small intestine increased with duration of flight and of restricted activity. In adrenalectomized rats, changes were in the same direction, despite significant decreases in concentrations of serum corticosterone. When duration of restricted activity increased to 60 days, histochemical reactions in the organs studied normalized. The same pattern of changes was identified in the adrenalectomized rats.

**Conclusions.** Changes induced by space flight and restricted motor activity (decreased glycoprotein in the sublingual glands, mucous lining of the stomach, and intestines and increased leucine aminopeptidase and acid phosphatase in the small intestine) are in the same directions, justifying the use of models of restricted motor activity for simulating effects of space flight factors. Longer exposure to restricted motor activity leads to normalization of the histochemical pattern.

Plasma levels of corticosterone alter in parallel with histochemical reactions and do not depend on adrenocortical hormones. Mechanisms underlying changes in glycoproteins and enzymes of the digestive system are still unknown.

## PAPERS:

P1507 (33/91) Smirnova AV, Grigoryeva LS, Voronkov Yul, Polyakov VV.

*Genetic aspects of the study of the effects of space flight factors.*

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health;

In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*

Moscow: 1991.

Pages 25-26.

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow

Genetics, Mutagenesis, Information Transmission,

Theoretical Article

Space Flight

**Abstract:** With the increasing duration of orbital flights and potential for future flights to other planets, research on the effects of gravity on the mechanisms underlying adaptive regulation of physiological functions and processes at various hierarchical levels takes on increasing importance. One of the important trends in research is the study of genetic mechanisms of regulation under space flight conditions. Even in the near future these studies will have practical significance, making it possible to obtain information on the nature and mechanisms of the effects of flight factors on genetic processes. Potentially adverse factors include ionizing radiation and weightlessness. In particular, altered gravity may affect the process of mutagenesis and transmission of inherited information and, in a number of cases, modify the effect of radiation. At the present time there would seem to be a good rationale for expanding genetic research in a number of interrelated genetic areas: studies in population-biology with multiple generations of insects in weightlessness; studies in the areas of cytogenetics; biochemical genetics; neurogenetics; and other areas overlapping with genetics. One of the major goals here is associated with identifying correlates of individual (or typological) differences in the physiological sensitivity of humans to the effects of adverse environmental factors at the level of genetic processes of regulation.

P1497(33/91)\* Delone NL, Seleznev YuV, Yegolina NA, Voronkov Yul, Solonichenko VG, Antipov VV.

***Study of heterochromatin of metaphase chromosomes using C-banding stain in cultures of cosmonaut lymphocytes.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 58; 1991.

[8 references; 4 in English]

Genetics, Heterochromatin, Metaphase Chromosomes  
Humans, Cosmonauts, Hematology, Lymphocytes  
Space Flight, Mir

**Abstract:** Scientists studied venous blood of one member of a Mir crew before and after a 326-day flight (Cosmonaut 1). In addition, the blood of the other cosmonaut (Cosmonaut 2) on this crew was studied preflight. Cytogenetic preparations were obtained using a standard method of cultivating lymphocytes followed by staining for heterochromatin. C-bands of the heterochromatin surrounding the centromere of chromosomes 1, 9, 16 and Y-chromosomes were measured on photographic negatives of metaphase chromosomes using a device for examination of microfilms.

In each case five metaphases were selected using a standard method. These chromosome segments, known as areas of constitutive heterochromatin, are revealed using C-banding stain, the specificity of which is evidently associated with compact structures from highly-repetitive satellite DNA and corresponding proteins. Study of the size of C-bands in mono- and dizygotic twins has shown that they may be considered characteristic parameters of an individual chromosome complement. However, in normal populations the size of C-bands varies widely and no association has yet been found between change in size and any physiological characteristics. There are, however, some data suggesting that heterochromatin participates in responses to extreme factors. Although for all chromosomes studied, the data showed decreased size of C-bands in a cosmonaut postflight compared to his own preflight levels and levels in normal subjects, it should be noted that measurement conditions were not strictly comparable, and after landing the cosmonaut's lymphocytes showed diminished proliferation, a confounding factor.

Table: Mean absolute sizes of C-bands of chromosomes 1, 9, 16, and Y-chromosomes (in  $\mu\text{m}$ )

Subject	Chromosomes				
	1	9	16	Y	S
I Cosmonaut I preflight	1.42 $\pm$ 0.15	1.25 $\pm$ 0.20	0.67 $\pm$ 0.15	0.98 $\pm$ 0.21	1.07 $\pm$ 0.08
II Cosmonaut II preflight	1.25 $\pm$ 0.16	1.11 $\pm$ 0.24	0.76 $\pm$ 0.18	1.16 $\pm$ 0.19	1.08 $\pm$ 0.09
III Study 1 (N=124)	1.27 $\pm$ 0.23	1.10 $\pm$ 0.20	0.72 $\pm$ 0.14	1.05 $\pm$ 0.13	0.96 $\pm$ 0.08
IV Study 2 (N=100)	1.26 $\pm$ 0.23	1.13 $\pm$ 0.20	0.85 $\pm$ 0.14	1.13 $\pm$ 0.21	1.03 $\pm$ 0.09
V Cosmonaut I postflight	1.01 $\pm$ 0.25	0.92 $\pm$ 0.24	0.37 $\pm$ 0.30	0.38 $\pm$ 0.21	0.67 $\pm$ 0.12
VI Volunteer *	1.40 $\pm$ 0.14	1.15 $\pm$ 0.08	0.83 $\pm$ 0.17	1.03 $\pm$ 0.11	1.12 $\pm$ 0.0

\* Fixation and preparation of material was comparable to procedures used for Cosmonaut 1 postflight.

Differences between conditions I and V and V and VI are reported to be statistically significant (samples of 5 chromosomes)

P1501(33/91)\* Delone NL, Voronkov Yul, Solonichenko BG, Antipov VV.  
***Genetic aspects of human adaptation to long-term space flight.***  
 Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
 25(2): 10-15; 1991.  
 [50 references; 9 in English]

Genetics, Adaptation, Personnel Selection  
 Humans, Cosmonauts, Theoretical Article  
 Space Flight, Long-Term

**Abstract:** The authors divide the goals of support of long-term space flights from the standpoint of human genetics into the following areas:

1. Genetic counseling of cosmonauts, including during the initial stages of medical selection.
2. Genetic monitoring of cosmonaut state and development of recommendations during space flights.
3. Genetic predictions of human evolution in space. Genetic analysis of increases in variability and capacities for selection for inhabitants of self-contained space colonies. Consideration of the issue of the development of "new races of space men."

Early research in space genetics, mainly directed at searching for chromosome restructurings, is described as fragmentary and inadequate from the standpoint of applicability to human subjects. The authors consider that the major goal of space genetics should be to study genetic mechanisms of adaptation. Experience with space biology and medicine suggests that the major problem is individual differences of responses of humans or human physiological systems to space flight factors and subsequent readaptation. They stress the importance of the concept of "reaction norm," which can be related to the theory of differences in "constitution." From a practical point of view, they propose for human space genetics an individual differences-constitution-based approach employing the concept of "adaptive phenotype," referring to a stable set of genetic and phenotypic characteristics of human organisms. A similar approach (called syndromal) is used in clinical genetics to identify subgroups of patients suffering from certain diseases for particular types of tailor-made treatments.

The authors propose the following methods for use in studies in human space genetics:

1. Clinical-geneological method. Construction of a genealogy for the cosmonaut proband, study of his closest relatives, to identify any inherited pathology so as to exclude susceptibility to space flight or readaptation factors.
2. Cytogenetic methods. Study of metaphase and prometaphase chromosomes using differential stains and the methods of molecular biology. Of particular importance is the study of heterochromatic regions of the chromosomes, since these evidently support genotypic adaptation to altered ambient conditions.
3. Molecular genetic methods. Use of advanced methods from molecular biology to study individual human genes and particular segments of DNA. Such methods include hybridization of nucleic acids on cytogenetic preparations; analysis using specific DNA-probes; and analysis of polymorphism of the length of restriction fragments of DNA (genetic fingerprinting).
4. The method of genetic markers, including biochemical, electrophoretic, immunological, and serological methods of identifying individual serum proteins and erythrocyte and leukocyte

enzymes. These methods are considered to have potential for presymptomatic diagnosis and can also be used to track the appearance of new mutations at a population level.

5. Screening methods for diagnosing individuals carrying heterozygous genes.

6. Methods of phenotypic analysis, including anthropometry, photoanthropometry and study of dermatoglyphics for identifying an individual's phenotype.

Many of these methods will be directed at identifying healthy individuals carrying genes that do not have a deleterious effect under normal circumstances, but may have negative effects under extreme conditions of space flight.

P1548(33/91) Delone NL, Antipov VV, Voronkov Yul.

***The effect of weightlessness on gene expression.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 34-35.

Genetics, Gene Expression, Chromatin, rDNA, Adaptation  
Plants; Oocytes, Fish, Amphibians; Lymphocytes; Human, Monkey  
Space Flight, COSMOS, Mir

**Abstract:** Introduction. Density of chromatin in the nucleus may change as a function of various external factors. The ability of blocks of genes to enter a state in which transcription can occur depends on the state of the chromatin. A great deal of data suggest that weightlessness affects the euchromatin-heterochromatin ratios.

**Methods.** Experiments were performed on a broad range of biological subjects—plant cells, oocytes of fish and amphibians, and lymphocytes of monkeys and humans. Cytogenetic methods were the primary ones used, including staining of C-bands, electron microscopy, etc.

**Results.** Results of 32 experiments conducted on COSMOS biosatellites and other flight vehicles were analyzed. Data indicated a decrease in zones of heterochromatin in chromosomes of lymphocytes in peripheral blood of cosmonauts completing long-term flights. Space flight caused the number of chromosome associations in lymphocytes of peripheral blood of monkeys to increase, as well as the number of amplifications of ribosomal genes in the oocytes of amphibians (the number of supplementary nucleoli increased). Measurement of ribosomal RNA in oocytes of tritons showed an increase in 28s and 5.8s and the appearance of significant numbers of 45s fractions. In a series of experiments on amphibians, this increase was threefold.

**Conclusions.** Flight conditions, including weightlessness, may significantly intensify expression of genes of rDNA, which may be considered an indicator of adaptation. Decrease in heterochromatin in flight attests to the participation of the genetic apparatus in the process of the organism's adaptation to weightlessness at the chromatin level. This reaction, evidently, is a general biological phenomenon, and is common to many species.



## PAPERS:

P1506(33/91) Ivanova SM, Yarlykova YuV, Labetskaya OI, Brantova SS, Spitsyna NYe.  
*Characteristics of erythrocyte metabolism and membrane state in humans after long-term space flights.*

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*

Moscow: 1991.

Pages 11-12.

Hematology, Metabolism, Erythrocyte Metabolism, Erythrocyte Membranes  
 Humans, Cosmonauts  
 Space Flight, Long-Term

**Introduction:** At present there is no unambiguous explanation for the mechanism underlying decrease in red blood cell mass in response to exposure to space flight factors. Although the major reason for this phenomenon is decrease in rate of erythropoiesis, this does not exclude other mechanisms that could lead, on the one hand, to hemolysis of a portion of the erythrocytes (as attested to by the threefold increase in rate of hemolysis in rats flown on COSMOS-782 and -936) and, on the other hand, to premature elimination of erythrocytes with altered forms from the blood stream (results of studies on Skylab).

**Method.** The parameters under investigation were studied spectrophotometrically and fluorometrically, while the lipid and phospholipid spectra of the membrane were determined using thin layer chromatography.

**Results.** Shifts in erythrocyte metabolism identified after long-term space flights were mainly manifest in changes in glycolysis, decrease in levels of ATP and reduced glutathione, and a simultaneous increase in activity of the enzymes (glucose-6-phosphate dehydrogenase and enzymes of the antioxidant system) responsible for maintenance of the structural integrity of cells. This suggests that there was no primary destruction of intracellular metabolism and reflects the development of compensatory reactions serving to prevent destructive processes on the membrane level. Evidence for this is provided by the shifts in lipid and phospholipid composition of the membrane and in activity of transport ATPase, which altered membrane state affecting its resistance to acid hemolysis and in some cases (after 326- and 360-day flights) decreased erythrocyte deformability.

**Conclusions.** Long-term effects of space flight factors lead to changes in biochemical parameters indicative of metabolism and the state of erythrocyte membranes, which, evidently, are adaptive in nature and result from changes in such key aspects of the blood as electrolyte composition, lipid spectrum, and hormonal status.

P1493(33/91)\* Dlusskaya IG, Gaydamakin NA, Kiselev RK.

***Reactions of some components of the red blood system to periodic exposure to submaximal acceleration.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 47-50; 1991.

[6 references; 1 in English]

Hematology, Red Blood System

Rats, Male

Acceleration, Submaximal, Periodic Exposure

**Abstract:** Experiments were performed on 35 outbred male rats exposed to repeated +Gz acceleration of 14-g, with rate of increase of 2-g/sec and 10 plateaus lasting 30 seconds each. The animals were restrained on the centrifuge platform in narrow cages. Four conditions were run: I) single exposure to acceleration; II) two exposures within a week; III) two exposures per week for a period of 4 weeks; and IV) daily exposure for a period of 5 days. Control rats were maintained under vivarium conditions. Peripheral blood was taken from an incision at the tip of the tail. Reticulocytes and erythrocytes were measured in blood 0.5-1.5 hours after the last exposure to acceleration in conditions I, III, and IV and in addition 1 day after exposure in condition III. A modified method using acid erythrograms was used to assess the functional status of the erythrocyte pool. Unlike the classical method, the modified method enabled measurement of two new kinetic parameters: maximal rate of erythrocyte hemolysis measured in E/min and duration of maximal rate of hemolysis measured in seconds. The authors used an index of functional activity of erythrocytes defined as the product of the two preceding variables divided by 100. Rate of change of optical density was measured automatically, ensuring high reproducibility. The working solution consisted of a 2.5 ml suspension of erythrocytes in physiological saline and 0.25 ml 0.006 M HCL. Changes in optical density were recorded every 10 seconds. Each measurement was made twice. Temperature was maintained at 24 °C. In the first three conditions, the spleen and livers of subjects were subjected to morphological analysis. Rats were sacrificed 1 day after acceleration exposure. This period was selected to exclude acute response to acceleration so as to get a clearer picture of the consequences of tissue restructuring. Material was fixed in Carnoy's fixative and stained with hematoxylin and eosin, and methyl green/pyronin. Activity of lactate dehydrogenase (LDH), succinate dehydrogenase (SDH), and glutamate (G), as well as levels of glycogen and ribonucleoproteins were measured in fresh frozen liver tissue sections.

The acute effect, decrease in erythrocyte resistance, was subject to individual variation and short-lived. During the period from 0.5-1.5 hours after a single and second exposure, erythrocyte resistance was somewhat depressed compared to control, with increased individual variability. After five exposures or a 1-month period of two exposures per week, duration of maximal hemolysis rate was significantly above control, causing the index of functional activity of erythrocytes to be elevated. Improvement of the functional state of the erythrocyte pool after repeated exposure to acceleration was short-lived and disappeared after 1 day. This effect may be considered a result of compensatory activation of erythropoiesis in response to short-lived decrease in cell resistance. Daily exposure to acceleration for 5 days (group IV) induced a significant decrease in number of erythrocytes and a 70% increase in reticulocytes. Reticulocytosis was also characteristic of animals in condition III, both immediately and after 1 day. In this group number of erythrocytes was elevated during the first 1.5 hours after the eighth exposure to acceleration, but depressed after 1 day. These data suggest that +Gz acceleration has a negative effect on resistance and levels of erythrocytes in rats, in the absence of stable compensatory activation of erythropoiesis in response to repeated exposure.

Morphological analyses revealed bleeding in the lungs to be associated with acceleration exposure. In the spleen after one or two exposures there was moderate depletion of lymphocyte

follicles. There were some signs of pyknosis in sites of extramedullary hemopoiesis. In the stroma of the pulp there were increased levels of free and phagocytosed iron-containing pigment. After two exposures there was an increase in the number of reticular cells with pyroninophilic cytoplasm, which formed large areas along the trabeculae and under the capsule. There were more pyknotic cells in areas of extramedullary hemopoiesis, and a small amount of nuclear detritus. After eight exposures, numerous small sites of erythropoiesis appeared in the pulp. These sites contained many cells with pyknotic nuclei, as well as so-called microcytes, and nuclear detritus. There were only insignificant iron-containing pigments in the reticular cells. Changes in the spleen, in the form of massive accumulation of hemosiderin in reticular stroma cells, were noted after one and two exposures, evidently due to increased hemolysis of erythrocytes in the blood vessels and spleen. The decrease in siderin after eight exposures may be explained by increased erythropoiesis in the pulp and thus greater utilization of iron.

In the liver, after a single exposure there was congestive hyperemia and separation of hepatic plates. These changes were more severe after two and especially eight exposures. In the latter condition, there was also a significant difference in the size of the nuclei of hepatocytes, including small hyperchromatic nuclei and large light nuclei. After one and two exposures, there was some increase in activity of SDH and GDH, and significant increase in LDH activity, along with moderate decrease in glycogen levels. After eight exposures, activity of SDH and GDH and glycogen levels were depressed, while LDH activity remained elevated. The authors conclude that after one and two exposures, circulatory hypoxia results in changes in the liver that should be considered adaptive, associated with increased energy formation and protein synthesis. This is also indicated indirectly by increase in activity of SDH and GDH and levels of ribonucleoproteins. After eight exposures hypoxia of the liver lasted for 4 weeks. In this condition, evidently compensatory adaptive responses were insufficient and levels of SDH and GDH activity decreased, while LDH remained high and cells with hyperchromatic nuclei appeared.

The authors conclude that the results indicate the presence of interacting destructive and regenerative processes. During the first week after beginning of exposure, destructive processes dominated, including decreased resistance and increased hemolysis of erythrocytes, decrease in their number, accumulation of hemosiderin in the spleen, development of sites of bleeding, and hypoxic processes in the liver. Regenerative processes occurring after the first and second exposure to acceleration include reticulocytosis and increased synthesis of ribonucleoproteins in hepatocytes. After the first week, regenerative processes led to continuing reticulocytosis, increased erythropoiesis in the spleen, appearance of large hepatocytes and increased functional activity. However, evidently the harmful effects of repeated exposure resulted in the increases in erythrocytes and their functional activity being relatively short-lived. These results attest to the unstable equilibrium between destructive and regenerative processes in the red blood system under conditions of regular exposure to acceleration.

Table 1: Functional state of erythrocytes, changes in level of erythrocytes and reticulocytes in blood of rats at various periods after exposure to acceleration

Table 2: Nature and quantity of bleeding in rats after exposure to acceleration

Condition	Number of rats	Number of rats with bleeding	
		isolated, small	numerous, large
I - 1 exposure	6	3	- -
II - 2 exposures	6	6	- -
III - 8 exposures	6	- -	6
Control	6	2	- -

Figure 1: Changes in rate of acid hemolysis in a rat at various times after one exposure to acceleration

Figure 2: Spleen of rat exposed twice

Figure 3: Spleen of rat exposed to acceleration eight times over a 1 month period

P1498(33/91)\* Noskov VB, Kravchenko VV, Batenchuk-Tusko TV.

*Dynamics of hematocrit values in humans on space flights varying in duration.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 59; 1991.

[13 references; 8 in English]

Hematology, Hematocrit

Humans, Cosmonauts

Space Flight, Long-Term, Mir

Abstract: Dynamics of hematocrit values were studied in 16 cosmonauts completing long-term flights (from 120 to 366 days) on Mir. In each subject, hematocrit values were measured from 1 to 6 times during the flight, for a total of 40 observations. The method of centrifugation on a microcentrifuge, extensively used in clinical practice, was employed. A special device was used to take blood from the finger in flight. For each measurement, two heparinized capillaries with capacity of 9  $\mu$ l were filled with blood simultaneously. The centrifuge operated for 3 minutes 20 seconds at a rate of 11,500 rpm. The results were read from a linear scale on the base of the centrifuge along each capillary and were generally identical in each capillary.

Hematocrit values measured ranged from 37 to 50%. The percentage change of each hematocrit value measured in space from the corresponding baseline value was computed for each individual. During the first 8-20 days in space, there were equal numbers of increases and decreases in hematocrit value. This pattern is attributed to differences in rate and severity of individual reactions during the early period of adaptation to weightlessness. Fluid redistribution to the head in space should lead to increased concentration of blood and increased hematocrit, due to decrease in circulating blood volume. Subsequently, there is evidently restructuring of blood distribution in the body, which may be subject to individual differences.

At a later period of space flight, hematocrit decreased in virtually all cosmonauts. During the entire period from day 30 to 320 of flight, hematocrits were depressed by 4-13% compared to baseline, but did not vary as a function of flight duration. These data are consistent with those indicating decreased erythropoiesis, hemoglobin mass, and quantity of erythrocytes in peripheral blood in cosmonauts. Furthermore, these results may be taken to suggest stabilization of fluid-electrolyte homeostasis during long-term exposure to space.

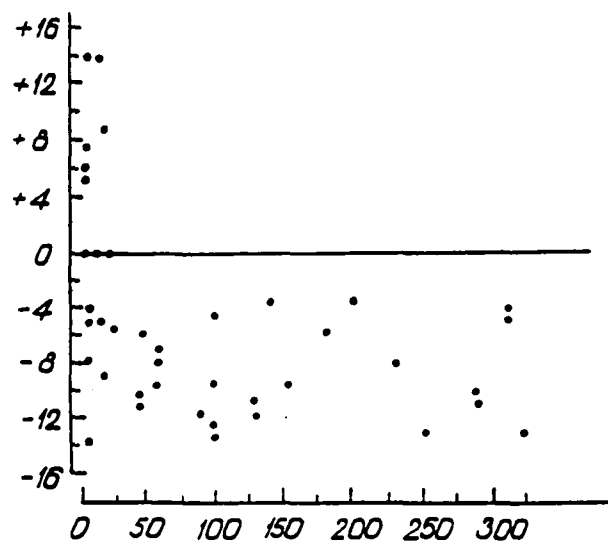


Figure: Dynamics of hematocrit value (in %) in cosmonauts during flights varying in duration  
Abscissa - days of flight; ordinate - percent change of hematocrit compared to preflight

PAPERS:

P1508(33/91) Ioseliani KK, Zhukova OP.

*Study of mental performance of cosmonauts on a long-term flight on Mir.*

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*

Moscow: 1991.

Pages 29-31.

Human Performance, Mental Performance

Humans, Cosmonauts

Space Flight, Long-Term, Mir

Introduction. Reliable long-term functioning of manned research complexes requires a high level of performance in crewmembers, who constitute the most important component of the "crew-spacecraft-living environment" system. For this reason one of the most important problems to be solved by space psychophysiology is the timely evaluation and prediction of the mental performance capacity of cosmonauts, especially on long-term flights, which are especially stressful.

Methodology. Research was conducted on the Pleven-87 apparatus developed by Soviet and Bulgarian specialists. A microprocessor system was used to present tasks and process and record results. The experiment (Prognoz) required the cosmonaut to perform a series of tasks—continuous arithmetic at a set rate, complex sensorimotor reactions with psychological feedback, conditioned motor responses to a combination of signals, and reactions to a moving object—pre-, in- (days 51 and 52), and postflight.

Evaluation of mental performance capacity used a 9-point scale, in which a score of 7.1-9 was equated with high, 4.1-7.0 with average, and 1.0-4.0 with low levels of mental performance capacity.

Results. Throughout the entire period of the study, including the pre- and postflight periods, one cosmonaut showed steady improvement in the majority of recorded parameters with a high level of initial performance. When he performed arithmetic operations during the study, it was clear that the set rate allowed him significant extra time. When the other cosmonaut performed counting and logical operations at a set pace in combination with sensorimotor reactions, he displayed inappropriate use of his own psychophysiological reserves given the complex experimental conditions. The composite indicator of his mental performance capacity in flight was 6.8-7.0, corresponding to an average level. In both cosmonauts, the score for accuracy of performance, especially for the arithmetic tasks was higher than the speed score. Thus both cosmonauts were more focused on accuracy than speed of performance, suggesting emotional and motivational stability and ability to concentrate.

Conclusions. One cosmonaut displayed a high level and the other an average level of mental performance and both manifested emotional stability.

These techniques could be used for an in-depth study of the mechanisms of adaptation to space flight conditions and development of recommendations to optimize cosmonaut performance.

P1510(33/91) Salnitskiy VP, Shevchenko LG, Dudkin AB, Nikonov AV, Ryabov EV.  
*Study of performance capacity of cosmonauts during the initial period of exposure to weightlessness.*

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: *Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.*

Moscow: 1991.

Pages 33-34.

Human Performance, Flight Simulator, Docking, Psychology, Stress, Adaptation  
Humans, Cosmonauts  
Space Flight, Salyut, Mir, Initial Period

**Introduction.** This work was devoted to study of the dynamics of work task performance and psychophysiological status of cosmonauts during the initial period of exposure to weightlessness.

**Method.** Experimental investigations were conducted on board Salyut and Mir stations using the method of simulation of manual control of berthing, fly-around, and docking of a spacecraft with a rendezvous target. The method can be described as follows. The cosmonaut, sitting at his work station in the spacecraft, is presented with a television picture of the rendezvous target, which is transmitted along the telemetric communications channels from a ground-based training/research simulator, which contains a simulation of the manual control system. Based on the information he is given and in accordance with a stipulated performance algorithm, the cosmonaut manipulates the control levers to transmit commands along the telemetric lines to the simulator. This design allows an optimal combination of the cosmonaut's actual working conditions with safety, economy, and replicability of the research.

Five cosmonauts were tested with each performing from four to five tasks. The research was conducted on day 3 or 4 of exposure to weightlessness. During the course of the experiment, parameters of performance level, electrophysiological parameters, and the spectral characteristics of the cosmonauts' speech were recorded.

**Results.** Analysis of experimental data showed that during the first manual control session, due to increased psychological stress, there was a dramatic decrease in the quality of performance (up to complete breakdown of performance), heart rate increased (by 15-35%) and speech increased in pitch (by 25% to 45%). As cosmonauts participated in more control sessions, they adapted psychologically to the task — quality and accuracy of work increased, while signs of psychological stress decreased.

**Conclusion.** Performance of three or four training exercises using an on-board or ground-spacecraft training simulator before a cosmonaut performs manual spacecraft control operations should significantly increase the quality of his work.

## PAPERS:

P1502(33/91)Popova IA, Vetrova YeG, Zaytseva LB, Zabolotskaya IV, Kurkina LM, Larina ON, Markin AA, Fedotova NYu.

***Metabolism in cosmonauts: Conclusions of biochemical analyses of blood in crewmembers of seven prime crews of Mir.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 5-6.

Metabolism

Humans, Cosmonauts

Space Flight, Long-Term, Mir, Prime Crews 1-7, Salyut-6, -7

**Methods.** A total of 16 cosmonauts, who had completed flights of 125, 131, 151, 160, 166, 175, 179, 241, 326, and 366 days, were studied. Experimental conditions and the analytic methods used were identical for all crews and have been described in previous publications.

**Results.** On the first day following long-term flights, 15 cosmonauts displayed hyperglycemia, 10 increased concentrations of lactate, 7 elevated pyruvate, and 8 depressed pyruvate. Half the subjects displayed signs of lipolysis activation and lipomobilization characteristic of the acute stage of stress, with substantial increases in free fatty acid and triglyceride blood levels. The opposite type of lipid metabolism, with significant decrease in levels of fatty substrates in blood, was displayed by the other half of the subjects and it is hypothesized that this is precisely the type of lipid metabolism occurring in weightlessness. A particular pattern of altered enzyme levels was observed after long-term flight: on day 1 postflight, there was diminished activity of malate dehydrogenase in 14 cosmonauts, diminished activity of lactate dehydrogenase in 10, and a significant increase in activity of creatine kinase in 12 due to increase in the muscle isoenzyme of the myocardial isoform (in 7 subjects), increase in activity of alanine and asparagine transaminase in 8 and 9 cosmonauts, respectively, and increased levels of alkaline phosphatase in 9 cosmonauts, attributable to activation of the hepatic or bone isoenzyme. In a number of instances biochemical blood parameters exceeded the bounds of the physiological norms; however, by day 7 these parameters had virtually normalized.

Results of measurement of parameters of nitrogen metabolism and dynamics of serum proteins were not in the same direction in all cosmonauts and were subject to individual differences. A characteristic decrease in level of uric acid in blood was noted in the majority of subjects. In no case did this parameter normalize by day 7 postflight.

**Conclusions.** Results of biochemical investigation of blood in cosmonauts completing long-term flights on Mir were consistent with existing ideas about the effects of space flight factors on human metabolism, demonstrating, however, some degree of individual differences and lack of correlation with flight duration.



P1494 (33/91)\* Popova IA, Vetrova YeG, Rustamyan LA, Nosova YeA.

***Metabolites of carbohydrate and lipid metabolism and serum enzymes in humans in response to a graded exercise test during long-term hypokinesia with head-down tilt.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 50-54; 1991.

[12 references; 2 in English]

Metabolism, Carbohydrate, Lipid, Enzymology

Humans, Males

Hypokinesia with Head-Down Tilt, 370-Day, Prophylactic Countermeasures, Exercise, Drugs

**Abstract:** This study used nine healthy males, ages 27-42, who underwent hypokinesia with head-down tilt (-5°) lasting 370 days. Four subjects (group A) used prophylactic measures, including exercise and drugs to correct metabolism, throughout the whole period. The remaining five (group B) began the prophylactic program after 120 days of treatment. Blood was taken from the ulnar vein during a graded exercise test in subjects in a supine position in a baseline period and on days 128 and 248 of hypokinesia. In each case five blood samples were taken: before exercise; after standard loading of 130 W; after 10 minutes of rest; after variable exercise loading determined by heart rate of  $150 \pm 5$  per minute for a period of 3 minutes; and after 30 minutes of rest. Enzymospectrophotometry with commercial kits was used to measure activity of lactate dehydrogenase (LDH),  $\alpha$ -oxybutyrate dehydrogenase (H-isoform of LDH), muscle isoforms of creatine kinase (CK), malate dehydrogenase (MDH), levels of triglycerides, nonesterified fatty acids (NEFA), lactate, pyruvate, and glucose.

Before hypokinesia, at rest, there were no differences between groups A and B in any parameter. Changes in response to standard (130 W) exercise (increase in pyruvate and MDH activity; tendency for NEFA to increase and glucose to decrease) were in the same direction in both groups but differed in magnitude. On day 128 of hypokinesia, standard exercise induced changes in group A that differed only slightly from those before bedrest. The most significant was a higher level of glucose in blood after exercise. In group B responses of these parameters to exercise were significantly different from those occurring at baseline, including decreased levels of glucose and NEFA immediately after exercise, and a clear tendency for triglycerides to decrease. Increase in MDH activity after exercise was significantly greater than before hypokinesia. Parameters manifesting significant intergroup differences after exercise included level of glucose, triglycerides, and lactate and activity of LDH, type-H LDH, and CK. The effects in group B suggest use of carbohydrate and not fatty substrates at rest, and decrease in levels of the major energy substrates in blood during exercise, with inadequate replenishment. When the exercise test was repeated on day 248, response to 130 W exercise in group B included normalized levels of NEFA in blood, decreased (compared to baseline) levels of pyruvate, and continued elevated MDH activity. LDH activity dropped in both groups A and B. The only intergroup differences remaining significant in response to standard exercise at this time were LDH and H-type LDH activity, suggesting countermeasures were effective for both groups.

When exercise level was determined by heart rate, before hypokinesia there was evidence of increased supplies of carbohydrate substrates (glucose) and their intensive use not only through oxidation, but through glycolysis, so that this level of exercise can be considered aerobic or mixed aerobic-anaerobic. On day 128, group A's response to this exercise level compared to its response before hypokinesia involved greater increases in triglycerides and activity of LDH, and greater decrease in NEFA in blood and did not differ greatly from that on the same day to standard exercise. When group B was tested at this level of exercise on day 128 of hypokinesia, in contrast to their response to standard exercise, concentrations of triglycerides increased, accompanied by insignificant changes in glucose and NEFA. Activity of serum enzymes was either unaltered or decreased. Levels of lactate and pyruvate increased less than in

response to 130 W exercise. These results may be due partially to the fact that the amount of exercise performed to this criterion was diminished by 13% for this group on day 128. On day 248, performance of exercise to heart rate of 150 beats/minute led to the same changes for group A as occurred on day 128. The only difference was that the increase in pyruvate and LDH activity was less extreme than on day 128, suggesting a return to an aerobic pattern. For group B the beneficial effects of prophylactic measures on day 248 for this level of exercise were less extreme compared to day 128 than for group A, but were manifest in an increased level of NEFA, which had been unaltered on day 128.

These results are interpreted as suggesting that deconditioning during prolonged hypokinesia substantially alters the nature of energy support of exercise. A characteristic metabolic manifestation of decreased physical performance capacity is an imbalance in the support of exercise from the major energy substrates, inappropriate utilization of substrates, inadequate, although elevated, activity of enzymes, and accumulation of incompletely oxidized metabolic products in blood. The use of prophylactic measures proved to be effective in preventing the effects of hypokinesia on dynamic parameters of energy metabolism in response to exercise.

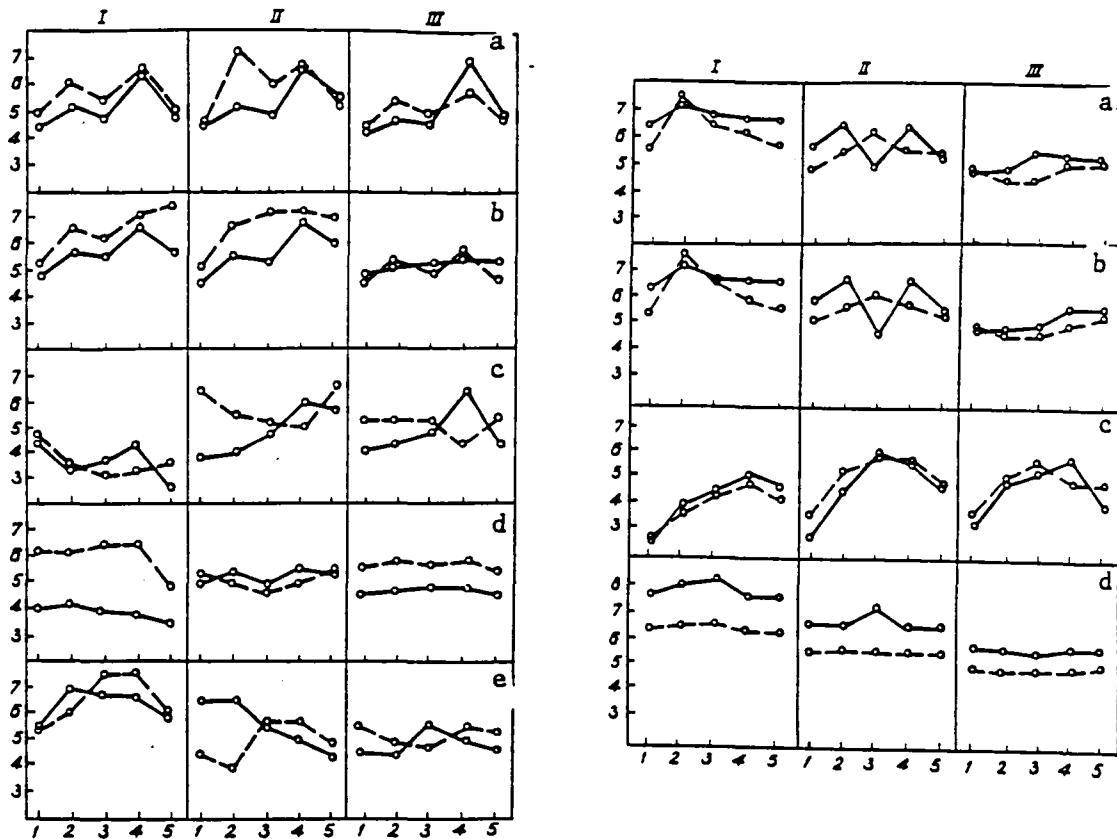


Figure 1. Activity of serum enzymes in response to stepwise increasing exercise  
 Abscissa: 1 - before exercise; 2 - after exercise 1; 3 - after 10 mins rest; 4 - after exercise 2; 5 - after 30 mins rest. Solid line - group A; dashed line - group B, I - before hypokinesia with head-down tilt; II - day 128; III - day 248; a - LDH, b - Type H LDH; c - MDH, d - CK

Figure 2: Concentrations of blood substrates in response to stepwise increases in physical exercise a - lactate, b - pyruvate, c - glucose, d - triglycerides, e - NEFA. Remaining designations as in Figure 1.

P1550(33/91) Dotsenko MA, Rudneva RI, Kurkina LM, Truzhennikov AN, Kario VR.  
*Metabolic parameters in monkeys flown on COSMOS Biosatellites.*  
Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow;  
Berlin-Buch Clinic, FRG  
In: Grigoryev AI (editor): *COSMOS Biosatellites: Abstracts of Papers Presented at an  
International Symposium.*  
Leningrad 12-15 August 1991.  
Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.  
[227 pages]  
Pages: 37-39.

Metabolism, Biochemical Parameters of Blood  
Monkeys, *Macaca mulatta*  
Space Flight, COSMOS, Nutrition

**Abstract:** Introduction. Adaptation of humans or animals to extreme conditions of space flight is accompanied by changes in metabolic reactions, including protein homeostasis, which may result in depletion of protein reserves. Recovery of normal functions of bone and muscle tissue under these conditions, when quantitative and qualitative intake of nutrients is adequate, is possible if anabolic processes are of high enough intensity.

The goal of the present work was to study certain quantitative parameters of metabolic homeostasis of monkeys flown for 2 weeks on biosatellites.

**Methods.** Animals flown on COSMOS biosatellites were fed biologically adequate pastelike rations balanced with respect to minerals, proteins, fats, and carbohydrates, prepared from natural products and subjected to thermal processing. The chemical composition of each sample of food was constant, with 70% water content. In the daily ration the ratio of proteins, fats, and carbohydrates was 1:0.85:4.9, and pH was 4.0. The animals drank a mixture of juices. The daily average consumption of pastelike food was 350-500 g.

Metabolic studies involved measurement of the following parameters: body weight, amount of food and juice consumed, and quantity of urine and feces. Concentrations of alanine aminotransferase, aspartate aminotransferase, lactate dehydrogenase, creatine kinase, glutamate dehydrogenase, amylase, alkaline phosphatase, choline esterase, and also of glucose and metabolites of protein metabolism (total protein, albumins, urea, creatinine) were measured in blood plasma taken from the ulnar vein.

**Results.** Body weight of the animals flown on biosatellites did not change significantly. Study of biochemical parameters of blood indicative of anabolic and catabolic metabolism in monkeys revealed elevated levels of liver enzymes—alanine aminotransferase, aspartate aminotransferase, and glutamate dehydrogenase. In all animals, creatine kinase activity was elevated. There was a decrease in level of albumin, while level of total protein was within normal limits.

**Conclusions.** Increase in the activity of a series of enzymes, and also some changes in parameters of carbohydrate and, to a lesser extent, protein metabolism evidently resulted from functional changes in organs and tissues of the monkeys in response to the transition from weightlessness to the Earth's gravity.

## PAPERS:

P1514(33/91) Maksimova IV, Smirnova MN, Sychev VN, Levinskikh MA, Prokhorov VG.  
***Effects of flight conditions on Mir on the composition of microflora in an "algae-bacteria-fish" ecosystem.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Department of Microbiology, Moscow State University

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 59-60.

Life Support Systems, Algae, Bacteria, Fish, Ecosystem

Microbiology, Microflora

Space Flight, COSMOS-1887, Akvarium, Mir

**Introduction.** A previous experiment investigating the effect of flight conditions on COSMOS-1887 on the composition of microflora on an "algae-bacteria-fish" ecosystem (Akvarium experiment) revealed a series of differences in the quantitative and qualitative composition of bacterial components, compared to ground control conditions. However, it remained unclear whether these changes were due to the effects of microgravity, or whether conditions associated with the unscheduled landing, which led to a 12-hour period during which the aquarium temperature dropped to 5 °C, were the significant factors. Because of the need to clarify the effects of microgravity on microflora of this ecosystem, the previous experiment was replicated on Mir.

**Procedure.** The ecosystem consisted of a pure culture of the alga *Chlorella vulgaris* Beijer line LARG-1 and the oviparous fish *Poecilius reticulata* Pet. The design of the aquarium was the same as employed previously, but the effective volume did not exceed 0.5 L. The previous illumination schedule of 16:8 hours was followed and temperature was maintained at 24 °C. The experiment lasted 12 days. Two control aquaria were maintained on Earth with the same conditions. Samples were removed from the flight and control aquaria at the same times. The total amounts of bacteria were measured microscopically after filtering aliquots through membrane filters and staining with erythrozyne; the number of viable forms was counted after dilution and seeding in meat peptone agar with addition of 1° B wort, starch ammonia agar and Hutchinson medium.

**Results.** After completion of the flight, the composition of microflora and the number of bacteria of various physiological and systematic groups in the experimental and control conditions were markedly different. The total level of bacteria in the flight condition was elevated by 187% with respect to the control. On average the amount of amylolytic bacteria was elevated by 370% on starch ammonia agar; cellulolytic bacteria were elevated by 94%. However the number of colonies growing on the meat peptone agar exceeded the amount in the ground control by only an insignificant amount.

After the flight, the variety of bacteria in the flight variant decreased by half, and the quantitative ratios among the dominant species altered: 79% of all of the bacteria belonged to two *Pseudomonas* lines (62 and 17%), while in the initial sample and the control samples at the end of the experiment this parameter did not exceed 30% (21 and 9%). The number of representatives of the *Flavobacterium* family was depressed by a factor of three.

**Conclusions.** After exposure of an algae-bacteria-fish ecosystem to space on Mir, there was a sharp increase (compared to a ground control) in the amount of bacteria growing on starch ammonia agar and Hutchinson medium, and only insignificant changes in the amount of bacteria

growing on meat peptone agar with wort. There was also a decrease in the heterogeneity of bacteria species and a change in the quantitative ratios among the dominant species. The results generally confirmed the data from the COSMOS-1887 experiment. It is hypothesized that these changes in the composition of microflora may be associated with the effect of microgravity on other components of the ecosystem and especially its phototrophic element—algae.

P1517(33/91) Sychev VN, Doukha J.

***Study of the capacity to store algae inoculum on the Mir station.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Institute of Microbiology, Czechoslovak Academy of Sciences

In: Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.

Moscow: 1991.

Pages 67-68.

Microbiology, Inoculum Storage, Algae, Life Support System

*Chlorella*

Space Flight, Mir, Chlorella-A System

Introduction. When experiments were conducted on the Mir station using the Chlorella-A equipment system, it was proposed that the inoculum be delivered to the system ahead of time and stored for as long as 3 months. A study was therefore undertaken of the growth and development of one-celled algae in the Chlorella-A system after long-term storage of inoculum under conditions similar to those on Mir.

Procedure. The experiments used *Chlorella vulgaris* LARG-1 algae. The culture was first grown in a luminostat with 17 klx illumination up to a density of 50 million cells/ml, after which the state of the algae population was analyzed. The relative numbers of dead cells and cells with diminished viability, moderate-sized cells, and age distribution of the population were determined. A mineral nutrient medium was then added to the algae suspensions to a density of 0.5 and 0.2 million cells/ml and the resulting matter was placed in syringes of the Chlorella-A unit. The inoculum was stored in darkness at a temperature between 18 and 23 °C for 1, 1.5, and 3 months. After storage the inoculum was analyzed and inoculated into containers of the Chlorella-A unit. The algae were cultured in accordance with the flight experiment schedule.

Results. Analysis showed that after 1.5 months of storage there was a decrease of 20-25% compared to the baseline in the number of cells in the population. The relative numbers of dead cells increased from 1 to 10%, while numbers of cells with diminished viability increased from 4 to 20-30%, depending on the density at which the material was stored. Changes occurred in the age distribution of the cells in association with decreased numbers of cells with autospores and increases in the number of autospores themselves, leading to a decrease in the average cell size after storage, from 4.0-4.2  $\mu\text{m}$  to 3.5-3.8  $\mu\text{m}$ . On the whole, analysis of the algae population after storage revealed changes in the major parameters compared to the baseline; however, parameter changes did not threaten the viability of the population.

Study of the growth and development of algae grown in the Chlorella-A system showed that storage of the inoculum did not affect the growth curve of the population. Thus, rate of growth in the linear growth phase was 45-48 million cells/ml per day, the same as in the control. No changes were noted in duration of the lag phase, which was 2 days for all conditions. The absence of any changes in the growth parameters between experimental and control conditions suggests that all changes in the cultures after storage occurred only at the population level and did not affect biological organization at the organismic level.

Conclusions. After long-term (up to 3 months) storage, algae culture inocula do not lose their activity. When cultured after storage in the Chlorella-A system they grow and develop normally. The results of this research suggest that an experimental design using the Chlorella-A system on board Mir involving delivery of inoculum to the station ahead of time is acceptable.

P1544(33/91) Gavrilova OV, Gabova AV, Goryachinova LN, Filatova YeV.

*Chlamydomonas* on board COSMOS-2044.

In: Grigoryev AI (editor): *COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.*

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 30-31.

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Microbiology, Cell Morphology, Population Dynamics

*Chlamydomonas*

Space Flight, COSMOS-2044

**Abstract:** Introduction. Experiments performed under space flight conditions with eukaryotic one-celled organisms, produced data relevant to changes in the morphophysiological states of the cells, including increase in size of cells (*Paramecium*, *Tetrahymena*, *Chlorella*) and increased rate of growth of a culture and later transition to the stationary growth phase (Infusoria). *Chlorella* also displayed changes in structure of the plasmalemma.

The main goal of the present experiment was morphological analysis of the state of a culture of *Chlamydomonas* exposed to space flight conditions.

**Methods.** The experiments used lines of *Chlamydomonas reinhardtii* CALU No. 495+. Material was cultivated on the surface of an 0.8% agarized L<sub>2</sub> medium and examined with light and electron microscopes. Statistical processing used an IBAS image analyzer.

**Results.** In the experimental (flight) condition more cells retained flagella compared with controls and there were fewer deformed cells. The cell viability was the same. The size of the cells was greater in the experimental condition at all stages of the life cycle of *Chlamydomonas*. The data suggest that after a 2-week flight, there were more cells in the stage of active growth.

Ultrastructural analysis showed that in flight cultures, there were no changes in structure, shape, or distribution in intracellular organelles, nor was there any change in the ratio of the size of organelles and cytoplasm. Cells exposed to microgravity showed greater variability in the size of organelles.

**Conclusion.** These results indicate that the effects of microgravity are observed on the cellular as well as the population levels. These data on *Chlamydomonas* are corroborated by results of experiments performed on *Infusoria* and *Chlorella* and suggest that when exposed to microgravity, all one-celled organisms undergo similar changes at the cellular, as well as the population level.

## PAPERS:

P1492 (33/91)\*Oganov VS, Skuratova SA, Murashko LM.

*Contractile properties of skeletal muscles of rats after flight on COSMOS-1887.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
25(2): 44-47; 1991.

[15 references; 7 in English]

Musculoskeletal System, Skeletal Muscles, Contractile Properties, Fast-Twitch, Slow-Twitch Rats

Space Flight, COSMOS-1887, Tail Suspension

Abstract: Experimenters studied preparations from 22 animals divided into four groups: space flight (13 days in duration) — 4 animals; synchronous ground control — 5 animals; vivarium control — 7 animals; baseline control (animals sacrificed 5 days before beginning of the flight) — 5 animals. Data from the last two groups did not differ and the baseline control is not discussed. Since, for technical reasons, animals of the flight group were only studied 2 days after flight, in a fifth condition animals were subjected to 13 days of tail suspension and then studied either immediately (n=7) or after 2 days of readaptation. After animals were sacrificed by decapitation, preparations of muscles of the forelimbs (*brachialis*, medial head of the *triceps brachii*) and hindlimbs (*extensor digitorum longus*, soleus, and lateral and medial heads of the gastrocnemius muscles) were studied. An undescribed method was used to study contractile properties of glycerinated muscles. From each muscle, 25-35 bundles containing 5-10 fibers were isolated. In addition to weights of intact muscles, parameters measured included peak amplitude of isometric contraction ( $P_{max}$  in g/mm<sup>2</sup>), peak force of isometric contraction ( $P_{max}$  in N/mm<sup>2</sup>), impulse of force (area under the curve from t=0 to time of peak tension, considered as a measure of performance), maximal rate of contraction on the linear portion of the mechanogram, and maximal rate of half-relaxation in preparations of muscle fibers in a solution of ATP+Ca<sup>2+</sup>.

Weighing of muscles showed that, compared to the control group, in the flight group the greatest weight loss occurred in the fast-twitch locomotor *extensor digitorum longus*, *m. brachialis* and fast-twitch postural lateral head of the gastrocnemius muscles. There was moderate loss in the medial head of the gastrocnemius, and virtually no loss in the medial head of the *triceps brachii* and slow-twitch postural soleus muscles. The relative weight (divided by body weight) of the *extensor digitorum longus* and *brachialis* muscles remained the same, that of the lateral head of the gastrocnemius decreased, and that of the remaining muscles increased slightly but significantly. These results differ from results when muscles are weighed immediately after longer flights (up to 3 weeks). In such cases the ascending order of weight loss has been found to be: *m. brachialis*, *extensor digitorum longus*, medial head of the *triceps brachii*, and soleus muscle. In the tail suspension group, immediately after treatment greatest weight loss occurred in the soleus and both heads of the gastrocnemius. After 2 days of readaptation, there was a reliable increase in the absolute mass of the soleus (although it remained below control level) and some tendency for the other muscles to decrease in weight. The relative weight of the soleus increased after 2 days on the ground, and that of the other muscles remained the same. The authors conclude that muscle weight results for rats flown on COSMOS-1887 reflect reactions of skeletal musculature to increased gravitational loading on Earth after 13 days of weightlessness. In particular, the lack of change in absolute weight and increase in relative weight of the soleus may be attributed to the high density of its capillary network due to increased blood supply and fluid retention in the tissues, which typically occurs in the soleus during the early postflight period.



Changes in contractile properties of the muscles postflight also reflect the effects of the 2-day readaptation period. Increased tissue hydration may be the reason that, despite unaltered absolute weight of the soleus, flight animals displayed a 24% decrease in capacity of soleus muscle fibers to generate force and a 29% decrease in impulse force. However, it should be noted that decreases in the strength properties of the soleus were less severe than after short-term (1 week) and longer flights. Unlike the postural soleus muscle, the force of contraction in the fast-twitch locomotor muscles—the *extensor digitorum longus* and *brachialis* muscles—increased by 27% and 36%, and impulse of force by 39% and 78%, respectively. Analogous tendencies, suggesting hyperfunction of these muscles in flight, were observed earlier, but only after longer flights (3 weeks) and the results obtained here may be associated with the 2-day adaptation period. This is confirmed by the fact that there was significant recovery of force of contraction of the soleus during the first 2 days of readaptation after tail suspension, and the force of the *extensor digitorum longus* increased somewhat. Thus the decrease in contractile force of the soleus and increase in that of *extensor digitorum longus* fibers may be attributable to the increased loading on the hind limbs after return to Earth. Lack of significant decrease in force of contraction of muscle fibers is evidently due to activation of protein synthesis and increase in their sensitivity to endoplasmic  $\text{Ca}^{2+}$ .

The maximal rate of development of muscle fiber contractions in animals of the flight group was significantly depressed in the slow-twitch soleus and fast-twitch *extensor digitorum longus* (by 34% and 24%, respectively); rate of contraction of fibers in the fast twitch postural medial head of the *triceps brachii* and lateral and, to a lesser extent, medial heads of the gastrocnemius increased. Rate of half-relaxation was depressed in all muscles, but significantly so only in the soleus. Unlike the case with previous flights, after the flight of COSMOS-2044 changes in rate of contraction of postural muscles were heterogeneous, which the authors associate with differences in restructuring of the isomyosin composition and decrease in mobility of  $\text{Ca}^{2+}$  in the sarcoplasmic reticulum in their fibers. This is likely to have been influenced by the 48-hour period of readaptation to Earth's gravity. This was confirmed by results in the tail-suspension group, where there were statistically significant increases in speed of contraction (by 35%) and half-relaxation (by 43%) in the soleus muscle immediately postflight, but 2 days later these parameters had returned to normal. The authors conclude that even a 2-day readaptation period after a 13-day space flight significantly modifies the changes induced by weightlessness in physiological properties of skeletal muscles.

MUSCULOSKELETAL SYSTEM

Table 1: Muscle weight in rats flown on COSMOS-1887 (flight 13 days, readaptation 2 days)  
1a Absolute weight, mg

Muscle	Flight group	Synchronous	Vivarium
Soleus	149.6±8.1	150.8±5.1	151.2±3.4
% synchronous	-0.8	- -	
% vivarium	-1.0	-0.2	
<i>Extensor digitorum longus</i>	141.5±3.7	159.7±3.5	161.5±2.8
% synchronous	-11.2**	- -	
% vivarium	-12.4**	-1.3	
Lateral head of gastrocnemius	870.9±28.0	1011.5±20.9	1009.6±21.7
% synchronous	-13.9**	- -	
% vivarium	-13.7**	- -	
Medial head of gastrocnemius	705.3±26.4	745.2±15.0	748.9±15.9
% synchronous	-5.4	- -	
% vivarium	-5.8	-3.4	
Medial head of <i>triceps brachii</i>	178.3±4.9	221.8±6.7	180.6±5.9
% synchronous	-19.6**	- -	
% vivarium	-1.2	+22.9**	
<i>M. brachialis</i>	186.3±5.6	203.2±4.9	198.5.1
% synchronous	-8.3*	- -	
% vivarium	-6.3	+2.2	

1b Relative weight (% of body weight)

Muscle	Flight group	Synchronous	Vivarium
Soleus	0.048±0.002	0.043±0.001	0.044±0.001
% synchronous	+11.4*	- -	
% vivarium	+8.3*	-2.7	
<i>Extensor digitorum longus</i>	0.045±0.001	0.043±0.001	0.047±0.001
% synchronous	-1.8	- -	
% vivarium	-6.1*	- -	
Lateral head of gastrocnemius	0.274±0.008	0.288±0.006	0.298±0.005
% synchronous	-4.6	- -	
% vivarium	-7.8**	-3.4	
Medial head of gastrocnemius	0.221±0.005	0.212±0.003	0.216±0.004
% synchronous	+2.5	- -	
% vivarium	-5.4	-2.0	
Medial head of <i>triceps brachii</i>	0.056±0.002	0.063±0.002	0.049±0.003
% synchronous	-10.9*	- -	
% vivarium	+14.2*	+28.2**	
<i>M. brachialis</i>	0.058±0.001	0.058±0.001	0.057±0.001
% synchronous	+1.3	- -	
% vivarium	+3.4	-1.5	

Note. Here and in Table 2 \* = p <0.05, \*\* p < 0.01

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Table 2: Muscle weight in rats exposed to hypodynamia (suspension 13 days, readaptation 2 days)

2a Absolute weight, mg

Muscle	Suspension day 13	Readaptation day 2	Vivarium
Soleus	106.1±5.1	118.6±3.8	158.8±4.1
%readapt. 2	-10.5*	- -	
% suspens. 13	- -	+11.8*	
%vivarium	-33.2*	-25.4**	
<i>Extensor digitorum longus</i>	180.0±4.4	171.5±2.7	190.3±3.7
% readapt. 2	+5.0	- -	
% suspens. 13	- -	-4.7	
% vivarium	-5.4	-9.9	
Lateral head of gastrocnemius	937.3±21.2	912.9±15.1	1067.5±25.9
% readapt 2.	+2.7	- -	
% suspens. 13	- -	-3.0	
% vivarium	-12.2**	-14.5**	
Medial head of gastrocnemius	832.9±9.3	805.7±17.9	960.0±23.6
% readapt. 2	+3.4	- -	
% suspens. 13	- -	-3.3	
% vivarium	-13.2**	-16.1**	

2b Relative weight (% of body weight)

Muscle	Suspension day 13	Readaptation day 2	Vivarium
Soleus	0.029±0.002	0.033±0.001	0.040±0.002
%readapt. 2	-12.1*	- -	
% suspens. 13	- -	+15.4*	
%vivarium	-28.5**	-17.5**	
<i>Extensor digitorum longus</i>	0.049±0.002	0.048±0.001	0.0048±0.002
% readapt. 2	+2.1	- -	
% suspens. 13	- -	-1.5	
% vivarium	+1.5	0	
Lateral head of gastrocnemius	0.259±0.008	0.255±0.005	0.269±0.008
% readapt 2.	+1.6	- -	
% suspens. 13	- -	-1.5	
% vivarium	-3.8	-5.4	
Medial head of gastrocnemius	0.225±0.007	0.225±0.005	0.242±0.002
% readapt. 2	0	- -	
% suspens. 13	- -	+0.06	
% vivarium	-7.2*	-7.1**	

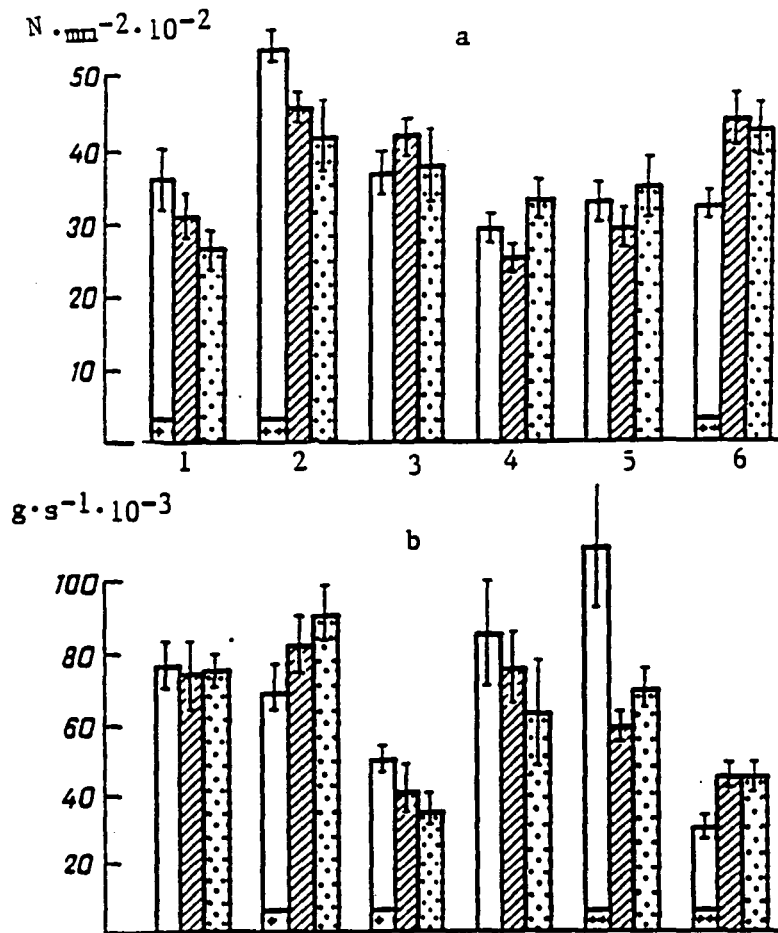


Figure 1. Changes in peak force of isometric tension (normalized per unit area of muscle) (a) and rate of contraction (b) in muscle fibers of various muscles after flight on COSMOS-1887.

Here and in Figure 2: 1 - *M. brachialis*; 2 - *Extensor digitorum longus*; 3 - Medial head of the *triceps brachii*; 4 - Medial head of the *gastrocnemius*; 5 - Lateral head of the *gastrocnemius*; 6 - *Soleus*

Here and in Figures 2 and 3: White bars - flight, hatched bars - synchronous control, dotted bars - vivarium control. \* differences between flight and vivarium group statistically significant; \*\* differences between flight and both vivarium and synchronous statistically significant ( $p < 0.05$ ).

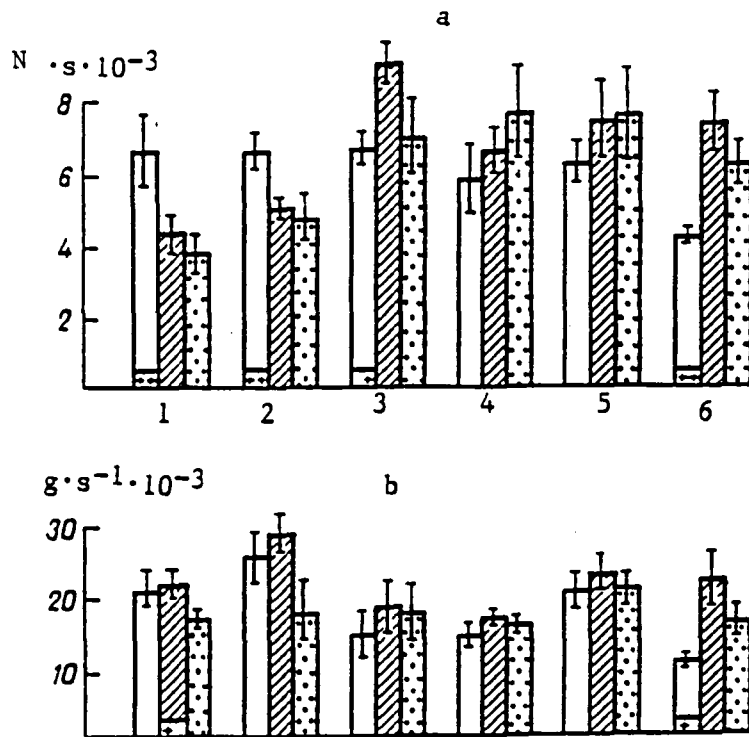


Figure 2. Changes in impulse of force (a) and rate of half-relaxation (b) of muscle fibers in various muscles of rats after flight on COSMOS-1887,

Legend: As in Figure 1.

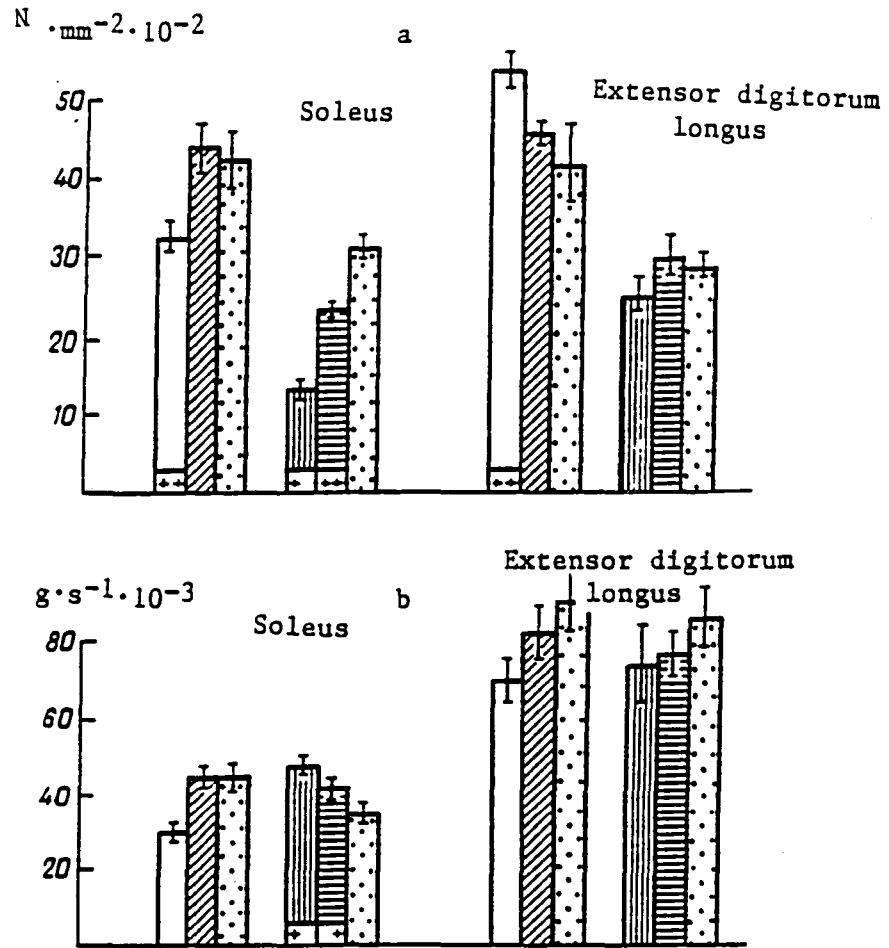


Figure 3: Changes in peak force of isometric tension (normalized per unit area of muscle)(a) and speed of contraction (b) in muscle fibers of the soleus and *extensor digitorum longus* after flight on CCSMOS-1887 and tail suspension

White bars - flight group; diagonally hatched - synchronous control; dotted - vivarium control; vertically hatched - tail suspension; horizontally hatched - recovery after tail suspension.

## MUSCULOSKELETAL SYSTEM

P1500(33/91)\* Samoylov NG.

***Effectiveness of laser puncture in maintenance of the structure of skeletal muscles during long-term hypokinesia.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 61-63; 1991.

[14 references; 8 in English]

Musculoskeletal System, Skeletal Muscles, Structure

Rats, Males

Hypokinesia, Long-Term, Laser Puncture

**Abstract:** Experiments were performed on male Wistar rats aged 1, 4, 6, and 24 months (N=280). Hypokinesia was produced by placing the experimental animals in immobilization cages, where they remained for all but 45 minutes per day. Rats were fed standard rations. There were three groups: group 1 was a vivarium control; group 2 animals were subjected to hypokinesia; group 3 animals were subjected to hypokinesia and underwent laser acupuncture. Duration of hypokinesia was 10, 50, 100, and 150 days. Throughout this period rats were weighed every day and after sacrifice their muscles were weighed. A low energy helium-neon laser with wavelength of 638.2 nm and power of 25 mW/cm<sup>2</sup>, operating in a continuous mode was used. Biologically active acupuncture points (corresponding to the fourth point of the meridian of the large intestine, and the 36th point of the meridian of the stomach in human acupuncture) were irradiated. Duration of laser puncture was 15 seconds per point. Irradiation sessions continued daily throughout the experiment. After sacrifice of the rats, the soleus, as a muscle containing red fibers, and the *extensor digitorum communis*, as a muscle consisting of white fibers, were isolated. Muscle tissue was fixed, sections were prepared for electron microscopy, and stereological analysis was performed. Test grids were used for counting ultrastructures. Organelles were counted on standard photographs 13 X 18 cm. Analysis of variance was used to assess statistical significance.

Hypokinesia alone led to marked loss of weight and muscle mass. This effect depended on age of the animals and was most extreme in the youngest animals, the majority of which died during the first 10 days of treatment, losing 58.4% of their body weights. For all ages, loss of muscle mass was more extreme in the soleus than in the extensor muscle. Laser puncture increased body weight and had the most effect on muscle weight in 1-month-old animals and the least effect in 24-month-old animals. Stereometric analysis of muscle samples showed that hypokinesia alone decreased volume of mitochondria and myofibrils compared to controls, with the most extreme effect occurring after 50 days of treatment. Laser irradiation of acupuncture points of animals exposed to hypokinesia significantly increased amounts of myofibrils and mitochondria. This was true for mitochondria to a greater extent in the red soleus than in the white *extensor digitorum communis*. Laser puncture had the greatest effect on the muscles of the youngest rats.

Table 1: Age kinetics of body weight of rats exposed to hypokinesia and laser puncture varying in duration

Table 2: Age kinetics of stereological parameters in the soleus muscle of rats exposed to hypokinesia and laser-puncture varying in duration

Table 3: Age kinetics of stereological parameters in the *extensor digitorum communis* muscle of rats exposed to hypokinesia and laser-puncture varying in duration

P1534(33/91)Bakulin AV, Oganov VS, Földes I.

***Functional adaptation of bone to changes in mechanical loading.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow; Institute of Anatomy, Medical University, Hungary

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 14-15.

Musculoskeletal System, Bone, Osteoporosis, Mechanical Properties, Mineralization, Leg Bones, Adaptation

Rats

Space Flight, COSMOS-1514, -1667, -1887, -2044, Tail Suspension, Hypergravity

**Abstract:** Introduction. The goal of the present work was to identify the role of the mechanical factor in the genesis of gravity-dependent osteoporosis by examining the values and dynamics of parameters of the structure, mineralization, and mechanical properties of bone tissue.

**Methods.** Experiments on COSMOS-1514, -1667, -1887, and -2044 and in ground-based simulation experiments studied changes in the leg bones of rats. The mechanical properties of whole bone, the mineral components of the spongiosa of the epiphysis, metaphysis, and cortical bone of the diaphysis, and histomorphometric parameters of spongiosa of the metaphysis and diaphysis were investigated.

On the ground, unloading of the rear legs (hypodynamia) was modeled using tail suspension. Duration of the experiments ranged from 7 to 150 days with subsequent readaptation to weight loading. Centrifugation was employed to create hypergravity of +2-g (21 days).

**Results.** Research on the mechanical properties of bone tissue enabled identification of characteristic changes occurring in response to unloading. These included: decrease in ultimate strain; changes in modulus of elasticity (a tendency to increase during the first 5-7 days of weightlessness or hypodynamia and then to decrease); and decreases in limit of proportionality and ultimate strength. These effects were only partially correlated with development of osteoporosis (decrease in mineral saturation) and reflected qualitative changes in bone material. Changes were minimal in the cortical bone of the diaphysis, although the strength of the entire femur in bend tests was substantially diminished due to displacement of the fracture area into the distal metaphysis, where the development of osteoporosis was the most severe.

During readaptation after hypodynamia and hypergravity, changes in the modulus of elasticity and ultimate strain of spongy bone tissue were opposite to those occurring in hypodynamia. At the same time, in some cases there was a significant decrease in strength due to intensified osteoporosis.

**Conclusions.** The results obtained provided biomechanical insight into the mechanism underlying depression of bone remodeling and development of osteoporosis in bone tissue in hypodynamia and weightlessness and suggested the following hypothesis. Changes in the amount of mineralization and deformability of bone under conditions of unloading are due to the absence of functional mechanical fatigue damage and the associated subsequent resorption and replacement of highly mineralized microstructures, processes which occur in bone adapted to the Earth's gravity. In weightlessness, on the one hand, there is accumulation of highly mineralized components and, on the other, decrease in the natural flow of minerals from skeletal depots to tissue fluid and blood plasma, potentially leading to changes in the functioning



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of the associated regulatory systems. Development of osteoporosis occurs inhomogeneously in various areas of the skeleton, and a significant portion of highly mineralized structures is retained, causing the observed decrease in strength and increase in brittleness of bones.

P1536 (33/91) Baranska W, Marciniak M, Baran W.

***Morphometric investigation of the ultrastructure of satellite cells in the soleus muscles of rats exposed to weightlessness on COSMOS-936.***

Authors' affiliation: Laboratory of Electron Microscopy, Institute of Biostructure, Medical Academy, Warsaw, Poland

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 17-18.

Musculoskeletal System, Soleus Muscle, Satellite Cells

Rats

Space Flight, COSMOS-936

**Abstract:** Introduction. Experiments with rats on COSMOS biosatellites have established that exposure to weightlessness leads to development of an atrophic-dystrophic process in the muscles (especially the soleus). Satellite cells, which play an important role in the development and regeneration of muscles, have not yet been studied. The goal of this study was to perform quantitative morphometry of the ultrastructure of satellite cells in the soleus muscles of rats exposed to weightlessness.

**Methodology.** The research material was the soleus muscles of five rats that had flown for 18.5 days on board COSMOS-936 and of a vivarium control. The morphometric analysis used the electron diffraction pattern of the soleus muscle obtained with a JEM 100C electron microscope at magnifications of 17,500 and 29,000 X. Morphometric analysis of satellite cells used Weibl's method, involving a grid with a constant number of points, and also a digitizer and IBM/PC/XT type computer. The data were processed statistically.

**Results.** The satellite cells of rats exposed to weightlessness displayed a decrease in cross sectional area and a concurrent increase in the ratio of cell surface area to volume. The most marked changes were noted in the nuclei of satellite cells, the cross sectional areas of which decreased, while the ratio of the nucleus surface to volume increased. The nuclei of satellite cells of flight group rats had a high content of heterochromatin.

## MUSCULOSKELETAL SYSTEM

P1540(33/91) Besova NV, Savelyev SV, Gulimova VI.

***Calcitonin-secreting cells and the skeleton of caudate amphibians after space flight.***

Authors' affiliation: Research Institute on Human Morphology, USSR Academy of Medicine

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 22-23.

Musculoskeletal System, Skeleton, Metabolism, Calcium, Endocrinology, Ultimobranchial Gland,  
Calcitonin, Limb and Eye Regeneration, Developmental Biology

Amphibians, Tritons

Space Flight, COSMOS, Foton

**Abstract:** Understanding the mechanisms underlying the regulation of calcium metabolism in weightlessness requires comprehensive study of all the associated systems of the body.

Amphibians are the most convenient subject for such studies, since they tolerate weightlessness well, and have both a cartilagenous and a bony skeleton, while the cells secreting calcitonin form a separate organ—the ultimobranchial gland. The use of tritons as experimental subjects has made it possible to study certain aspects of the problem of calcium homeostasis in weightlessness. The major goals were to study the effect of weightlessness on the secretory activity of calcitonin-secreting cells, to assess the state of the skeleton, and to analyze the morphogenetic activity of the pharyngeal epithelium.

A series of 12 to 14-day experiments were conducted on COSMOS and Foton biosatellites. The experiments used caudate amphibians—tritons. The state of the calcitonin-secreting cells, the skeleton, and the pharyngeal epithelium were studied both in intact animals and in tritons with their eyes and front legs removed. The same organs were studied in parallel in animals in the synchronous, transport and laboratory control groups. The sublingual system, front leg girdle and the tissue between the peritoneal and pericardial cavities were isolated. The tissue was fixed in Bouin's fixative and embedded in paraffin. Serial sections 10  $\mu\text{m}$  thick were affixed to glass and stained using Mallory's method with Congo red and Alcian blue. Calcitonin was identified with immunohistochemical methods using antibodies and synthetic calcitonin.

Results of the study showed that, during 12- to 14-day flights, calcitonin-secreting cells undergo hypertrophy accompanied by retention of the colloid contents in the cavities of enlarged folliculi of the ultimobranchial gland. In a number of cases folliculi calcified. The changes observed led to significant death of secretory cells by the end of the flight and decrease in the amount of calcitonin secreted. The same animals displayed resorption of the supporting and visceral skeletons. Both the cartilage and the bone elements were subject to this process. The pharyngeal epithelium was enlarged and cells of the proliferative layer infiltrated the underlying connective tissue. In the experiment combining destruction of the eyes and limbs, these effects of weightlessness were enhanced. Regrowth of the organs and systems studied was observed 1.5-2 months postflight.

## MUSCULOSKELETAL SYSTEM

P1542(33/91) Burkovskaya TYe, Nazarov VM, Frontasyeva MV, Gundorina SF.

***Elemental composition of bone tissue in rats flown on COSMOS-2044.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow; Joint Institute of Nuclear Research, Dubna.

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 25-26.

Musculoskeletal System, Bone Tissue, Tibia, Bone Callus, Elemental Composition, Metabolism, Mineral Metabolism

Rats

Space Flight, COSMOS-2044, Experimental Fracture, Tail Suspension

Introduction. The problem of altered bone mineral metabolism in response to weightlessness requires detailed study of the elemental composition of this tissue.

Methodology. The method of neutron-activation analysis was used to measure the levels of 15 elements and trace elements in the diaphysis, metaphysis, and epiphysis of the tibia and bone callus of rats with experimentally induced fractures of the fibula produced 2 days before the start of a 14-day space flight or tail suspension. In addition, the fibula was studied in intact rats otherwise treated analogously. Bones of vivarium and synchronous groups served as controls.

Results and Conclusions. It was found that concentrations of elements in different sections of the same bone and in different bones differed widely from each other, while they were relatively stable in different samples of bone in the same location. The ratios among concentrations of elements in various samples were generally unchanged in the flight and synchronous groups. Exposure to weightlessness led to decreased levels of Ba, and increased levels of Br and Co in all samples and to redistribution of Ca, P, Mg, Zn, and I among different bones. Concentrations of the remaining elements showed relative constancy in some fragments, but in others either decreased (Na, K, Zn) or increased (Cl, Rb). In bone calluses there was a decrease in concentrations of Br, Rb, and Sb. The greatest decrease in all elements and some trace elements occurred in the tibial metaphysis. In tail-suspended rats, changes in elemental composition were less extreme, and were somewhat different in pattern from that shown by rats in the flight group.

## PAPERS:

P1495 (33/91)\*Kalniya IE, Bluma RK, Ushakov AS, Sominskiy VN  
*Changes in levels of serotonin and histamine in human blood in response to a 370-day period of hypokinesia with head-down tilt.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 54-55; 1991.

[8 references; none in English]

Neurophysiology, Serotonin, Histamine

Humans, Males

Hypokinesia With Head-Down Tilt, 370-Days, Prophylactic Countermeasures, Exercise, Drugs

**Abstract:** This study was performed on nine healthy men, ages 27-42, who underwent hypokinesia with head-down tilt (-5°) lasting 370 days. Four subjects (group A) used a set of prophylactic measures, including exercise and drugs to correct metabolism, throughout the entire period. The remaining five subjects (group B) began the prophylactic program only after 120 days of treatment. Material studied was blood taken from the ulnar vein of resting, fasting subjects in the morning during the baseline period, on days 50, 110, 170, 230, 290, and 350 of treatment and also on days 30 and 60 of post-treatment recovery. Levels of serotonin and histamine were measured in blood samples by spectrofluorometry.

During the baseline period, levels of serum serotonin and histamine were within the physiological norms for both groups. Subsequently, at all times during hypokinesia, there were significant decreases in mean blood levels of serotonin and histamine in both groups compared to baseline, with the exception of histamine for both groups on days 50, 170, and 290. Changes in histamine and —starting on day 170 — serotonin were cyclical in nature, with increases in one occurring at the same time as decreases in the other. On days 30 and 60 of recovery, mean levels of these biogenic amines were elevated compared to levels on day 350 of treatment, but these parameters remained depressed compared to baseline. The authors argue that the observed decreases in levels of the amines studied, along with fluctuations in their ratios, suggest that the body is not able to compensate for the changes in the activity of the serotonin- and histaminergic systems. Although the prophylactic measures did not prevent these changes, they did have some ameliorative effects. The most pronounced intergroup differences were identified on day 50 of treatment. At this point serotonin was depressed in both groups but more so in group B; histamine was elevated in group A and depressed in group B. On day 170, 50 days after group B began the prophylactic program, histamine blood levels were elevated. At the end of hypokinesia and during recovery, serotonin was higher in group A than in group B, possibly reflecting higher effectiveness of prophylactic measures in group A.

Table: Blood levels of serotonin and histamine in subjects

P1505(33/91) Kornilova LN, Bodo G, Benczee G, Goncharenko AM, Grigorova V, Manev A, Elkan K.

***On the genesis of anomalous eye movement responses in weightlessness.***

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Central Hospital of the Hungarian Army, Institute of Physiology, Bulgarian Academy of Sciences, Institute of Space Research, Bulgarian Academy of Sciences

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 9-10.

Neurophysiology, Eye Movement Responses, Vestibular System, Adaptation  
Humans, Cosmonauts  
Space Flight

**Introduction.** This study investigated the characteristics, nature, and etiology of sensory disorders in weightlessness and also studied processes of sensory adaptation to these conditions. Studies were performed in field conditions within the "Optokines" (USSR, Hungary) and "Labirint" (USSR, Bulgaria) programs during manned space flights. One experiment looked at the level and nature of spontaneous eye movements.

**Method.** Inflight investigations were conducted on days 3 and 5 (11 subjects), 9, 22, and 30 (4 subjects), and 116 and 164 (2 subjects). Eye movements were recorded using electrooculography with the "Oking-Aelit" apparatus and the "Zora" computer system. Spontaneous activity was recorded with eyes focussed straight ahead and in peripheral position open and closed.

**Results.** During the initial period of adaptation to weightlessness (day 3), at rest with eyes closed, all subjects manifested enhanced saccadic and drifting eye movements and 6 out of 11 showed spontaneous vertical nystagmus. Amplitude of peripherally directed saccadic movements increased in both horizontal and vertical directions. Correcting saccades or end-position nystagmus also occurred. Velocity of focussing eye movements decreased. On day 5, spontaneous eye movements had decreased sharply, and spontaneous nystagmus disappeared.

During late stages of flight (days 116, 164), spontaneous eye movement activity was stable in one subject, while in the other destabilization of the eyes and vertical nystagmus were again recorded. Postflight changes in severity and nature of spontaneous eye movements were similar to flight data.

**Conclusions.** During adaptation to weightlessness there is an intensification of the functional activity of the vestibular and associated oculomotor systems. The nature of spontaneous eye movements suggests participation of both central and peripheral components of the vestibular system.

P1532(33/91) Ayzikov GS, Shipov AA.

***Balance functions and vestibulomotor responses in rats after flight on COSMOS biosatellites.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 6-7.

Neurophysiology, Postural Reactions, Balance, Vestibulomotor Function

Rats

Space Flight, COSMOS-782, -936, -1129, Artificial Gravity

Abstract: Conclusions are drawn from postural reactions, balance functions and vestibulomotor responses in rats after flights on COSMOS-782, 936, and -1129.

It was established that exposure to weightlessness impairs postural and motor reactions in rats, including balance functions. No changes were found in nystagmus parameters (latent period, duration, number of beats, frequency). There was a significant increase in latent period of the lift? reaction measured on the basis of mechanical components of muscle responses and relative retention of the righting reflex, both in the presence and absence of visual control.

In animals flown in space in artificial gravity of 1-g, postural reflexes and balance functions were close to those in control animals. Animals so treated showed a marked tendency to increased nystagmic latent period and also decreased duration, number of beats and frequency compared to parameters in animals in the ground control condition. The latent period of the lift? reaction was unaltered, and the righting reflex was absent when visual control was precluded.

Based on the results obtained, it was concluded that long-term weightlessness has no effect on the receptor structures and centers of the vestibular system, or that these effects are so short-lived that by day 2 postflight they cannot be detected. Exposure to artificial gravity diminishes the sensitivity and reactivity of the semicircular canals and leads to increases in the role of the visual system in implementation of functions of balance and orientation in space.

P1538(33/91) Belichenko PV.

***Morphology of giant multipolar neurons of the brain stem reticular formation in rats flown on COSMOS biosatellites.***

Authors' affiliation: Brain Institute, USSR Academy of Medicine, Moscow

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 19-20.

Neurophysiology, Brain Stem, Reticular Formation, Giant Multipolar Neurons, Rostral Nucleus, Vestibular and Trigeminal Systems

Rats, Males

Space Flight, COSMOS-1667, -1887, -2044

**Abstract:** Introduction. Giant multipolar neurons (GMN) are integrative trigger cells, whose dendritic branches integrate afferent impulses from various sensory systems, including the vestibular and trigeminal systems participating in the mechanisms disrupting and correcting various functions in weightlessness. The authors studied the morphology of GMN of giant cell nuclei of the reticular formation in the medulla oblongata of rats after 7-day (COSMOS-1667) and 14-day (COSMOS-2044) space flights and of the rostral nucleus of the pontine reticular formation after a 14-day flight (COSMOS-1887).

**Methods.** Brain samples from male Wistar rats in flight, synchronous control, and vivarium control groups were studied. The frontal block of the brain at the level of the radicle of the V nerve was stained using Golgi's method to study the GMN of the rostral nucleus of the pontine reticular formation or at the level of the VII nerve for study of the GMN of the giant cellular nucleus of the medullary reticular formation. The neurons were traced using the tracing device of a microscope. Forty-two neurons were studied in the COSMOS-1667 experiment (15 neurons from the flight group, 14 from the synchronous group, and 9 from the vivarium group); 37 in the COSMOS-1887 experiment (14 from the flight group, 14 from the synchronous group, and 9 from the vivarium group); and 62 in the COSMOS-2044 experiment (21 from the flight group, 20 from the synchronous group, and 21 from the vivarium group). The geometry and orientation of the dendrites of the GMN of the reticular formation were analyzed using the ASM system (Leitz?, FRG) and a PDP-11 computer using 35 parameters.

**Results.** After the 7-day flight on COSMOS-1667, there were no significant changes in geometric parameters of the giant multipolar neurons. However, there was less orientation of dendrites in the direction of the vestibular nuclei and more in the direction of the midline of the brain in flight rats than in the synchronous and vivarium controls. After 14 days of flight on COSMOS-1887 the branching of dendrites increased in all cells in the GMN, as did the total number of foci of maximal branching, and orientation of the dendrites toward the trigeminal nuclei as compared to the vivarium group. Compared to the vivarium group, rats completing a 14-day flight on COSMOS-2044 showed decreases in the area of the neuronal body, the total length of dendrites, number of foci with maximal branching in dendrite territory, orientation of dendrites to the pyramidal tract, and increases in length of dendrites in sectors oriented to the vestibular nuclei and the midline.

**Conclusions.** 1) Study of one class of neurons of the brain of rats after 7- and 14-day flights on COSMOS-1667, -1887, and -2044 made it possible to track changes in the morphology of GMN in the reticular formation, and to hypothesize that the vestibular and trigeminal sensory systems participate in the development of CNS compensatory processes in weightlessness.



2) Long-term exposure of rats to weightlessness affects both the morphology of the neuronal body and its dendrites. 3) Decrease in orientation of dendrites toward the vestibular nuclei after 7 days of flight may be associated with the initial (acute) period of adaptation to weightlessness; however, increase in orientation of dendrites toward the vestibular and trigeminal nuclei after a 14-day flight is evidently associated with the establishment of new connections during continued exposure to weightlessness.

## PAPER:

P1499(33/91)\*Noskovic P, Shmaida V, Rachek L, Ahlers I, Shalagovic D. (Czechoslovakia). *The effect of hypokinesia on food consumption and leg muscle atrophy in rats: The effect of insulin.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 60-61; 1991.

[22 references; 20 in English]

Nutrition, Food Consumption, Musculoskeletal System, Leg Muscle Atrophy  
Rats  
Hypokinesia, Endocrinology, Insulin

**Abstract:** This paper describes an attempt to prevent the initial decrease in food consumption, decrease in body weight, and muscle atrophy observed in Wistar rats undergoing tail suspension by injecting them with insulin, which increases appetite and stimulates weight gain. Before the experiment, rats were habituated to laboratory conditions and placed in individual cells. Throughout the experiment rats received standard feed and water *ad libitum*. They were maintained on a cycle with 12 hours of illumination per day. Duration of the experiment was 15 days. There were three groups, each containing eight rats. The first group consisted of suspended rats injected daily with 5 MED/kg of insulin. The second group consisted of suspended rats injected with saline. The third group formed the vivarium control. Food consumption and body weight of each rat were measured daily. After completion of the experiment the rats were sacrificed and their soleus and gastrocnemius muscles isolated and weighed. Concentration of glycogen was measured in samples of the soleus and quadriceps of the femur.

Relative to the control, both groups of suspended rats displayed significantly diminished food consumption 24 hours after beginning of the experiment. After 48 hours, food consumption normalized and was approximately equal for all three groups throughout the remainder of the experiment. Thus, insulin at the dose used had no effect on the amount of food consumed. (Higher doses of insulin have been found to lead to death in a substantial number of animals). Amount of food consumed correlated with body weight. Initial weight loss in suspended animals persisted throughout the experiment, although it was not progressive. The weight of soleus and gastrocnemius muscles was decreased compared to controls in both suspended groups. Injection of insulin did have a positive effect on concentration of glycogen in the soleus and femoral quadriceps muscles. The lack of effect of insulin on food consumption and weight gain may have been due to the low doses used or else to increased tissue resistance in suspended rats.

Figure 1: Dynamics of food consumption in rats over a 15-day period

Figure 2: Dynamics of body weight in rats over a 15-day period

Figure 3: Relative mass (in mg per 100 g body weight) of soleus and gastrocnemius muscles

Figure 4: Concentrations of glycogen in soleus and femoral quadriceps muscles

**PAPERS:**

P1486(33/91)\* Stupin YuV, Bogomolov VV, Vasilyeva TD.  
***The sanatorium stage of medical rehabilitation of cosmonauts after long-term space flights.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 18-21; 1991.

[20 references; 2 in English]

Operational Medicine, Medical Rehabilitation, Sanatorium  
 Humans, Cosmonauts  
 Space Flight, Long-Term

**Abstract:** The rehabilitation of cosmonauts after long-term space flights involves a number of stages. The first and most critical stage occurs at the rehabilitation base of the cosmodrome or at the Gagarin Cosmonaut Training Center. During this period, emphasis is on curtailment of adverse readaptation symptoms; enhancement of the functioning of the cardiovascular and musculoskeletal systems; recovery of orthostatic tolerance, balance, and coordination; and elimination of postflight fatigue. The goal of the second stage of medical rehabilitation (30-40 days) is complete recovery of the capacities and health of the cosmonauts. This stage takes place at a sanatorium in the city of Kislovodsk. This paper presents data about the sanatorium stage for 18 cosmonauts completing space flights lasting from 75 days to 1 year. Procedures used were developed on the basis of results of special simulation studies using healthy volunteers, as well as of treatment of patients suffering from various disorders. Programs are tailored for individual cosmonauts on the basis of results of the first stage of rehabilitation and individual preferences for certain types of athletic activities.

The sanatorium stage lasts 30-40 days. The first 2 days at the sanatorium are devoted to acclimatization, with the daily schedule being free. Subsequently rehabilitation centers around exercise therapy, physical training, jogging on a special outdoor course (Terrainkur), swimming, hydrotherapy and thermal procedures, various types of massage, and mineral baths (in Narzan water). Important to the rehabilitative process is the daily schedule, alternation of exercise and rest periods, diet, and psychological measures. Members of cosmonauts' families are present at the sanatorium, reportedly with a positive effect on psychological recovery.

Medical monitoring performed on the cosmonauts in the study included observation (periodic examination by specialists), ECGs at the beginning and end of their stay at the sanatorium, clinical analysis of blood and urine, and recording of blood pressure and pulse during mineral and mud baths and exercise. When cosmonauts traversed the standard outdoor walking/running course (3 km long with altitude differential of 151 m), tele-electrocardiography was performed to enable appropriate control of level of exercise through altering walking rate and route. Throughout the cosmonauts' stay at the sanatorium, various muscle groups were tested for endurance and speed/strength properties, and plantography (measurement of platypodia by taking an impression of the sole of the foot) was conducted.

When they arrived at the sanatorium the cosmonauts displayed moderate weakness, taking the form of increased tendency for fatigue, feeling of sleep deficit, and diminished exercise tolerance. Neurological examination and investigation of internal organs generally failed to reveal abnormalities. However, in a few cases cosmonauts showed slight unsteadiness in the Romberg position with eyes closed. ECGs recorded at rest revealed continued decrease in T wave amplitude compared to preflight and decreased QRS amplitude in some cosmonauts compared to preflight. During the early period at the sanatorium blood pressure and pulse were labile during mild exercise and postural stimulation (tilt and stand tests). Blood parameters were within normal limits but levels of erythrocytes and hemoglobin were depressed compared to

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preflight. Urine was generally unaltered. There was loss of normal curvature in muscle contours of the back, buttocks, and thighs and there were changes in bearing (stooping, diminished abdominal tonus). Compared to preflight, exercise tests revealed incomplete recovery. Plantography indicated flattening of the arches of the foot compared to preflight. Cosmonaut status during this period was evaluated as indicative of satisfactory adaptation to environmental conditions, with moderate decrease in functional reserves and stress on regulatory systems during moderate physical exercise.

Starting on day 3, various rehabilitative measures were employed, mainly exercise therapy and physical training on a moderate training and then a full schedule. Specially developed sets of exercises were incorporated in morning calisthenics, daily workouts on the athletic field, and regular sessions in the swimming pool. All these exercises were designed to improve statokinetic and coordination functions, and increase speed, strength, physical endurance and performance. Two- and three-peaked loading curves was used for exercise, with heart rate allowed to reach 126-132 during the first week, and 160 subsequently. The Terrainkur (specially laid out hilly walking course) played a key role in rehabilitation. During the first days of their stay the cosmonauts walked up to 5 km with altitude differential no greater than 200 m and rate of 60-80 steps/min. Heart rates was allowed to reach 140 bts/min., and respiration rate 26-34 breath/min., with systolic BP increasing up to 20-40 mm Hg, and recovery requiring up to 12-15 minutes, suggesting deconditioning. Subsequently at the end of their first week, with duration and difficulty of their walking route increased gradually (up to 6-9 km with altitude differential of 450-500 m and variable walking rate) fluctuation of hemodynamic parameters was lower, and recovery required only 7-8 minutes. By the end of the sanatorium phase the route traversed reached 14-16 km, with some portions even run; pulse and respiration rate responses were appropriate for this level of activity.

In the first few days of active rehabilitation, the cosmonauts frequently experienced pain in the muscles of their legs and back and puffiness of the ankle joint. These symptoms were alleviated by massage and therapeutic exercise in the pool, in addition to hydrotherapeutic and thermal procedures. Massage, with emphasis on the back and leg muscles, was conducted before the most strenuous exercise session for the day. After exercise, regional therapeutic rehabilitative massage was performed. The set of rehabilitation measures included 14-16 baths in Narzan mineral water. These were assessed positively by the cosmonauts and their cardiovascular response was appropriate. Twice a week, cosmonauts took saunas combined with hydrotherapeutic procedures (various types of showers, underwater massage), which had an extremely positive effect on general well-being and neuropsychological status.

The second half of the sanatorium period involved extensive use of athletic games (soccer, volleyball, tennis, excursions, and in the winter sledding and skiing). At the end of this period the cosmonauts' state reached or approached baseline. Cardiovascular parameters normalized, traces of debility disappeared. Erythrocyte, hemoglobin, and leukocyte counts increased and there was marked increase in static and dynamic endurance.

P1487\*(33/91)\* Bayevskiy RM.

***Medical problems associated with automated monitoring of the health of cosmonauts.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

25(2): 21-26; 1991.

[19 references; 6 in English]

Operational Medicine, Health Monitoring

Humans, Cosmonauts

Space Flight, Equipment and Instrumentation, Automated System

Abstract: This review paper divides the discussion of automation of inflight medical monitoring into three parts: issues of collection of diagnostic information on long-term flights, generation of processing algorithms, and actual development of on-board computing devices. With regard to the development of an automated system for dynamic operational medical monitoring in flight, the author describes a system with two types of output to the ground. After initial automated processing and analysis of data, data is transmitted to the work station of the physician on duty at the ground control center so that he can respond to it in real time. In addition, subsequent to automated processing, data enter a local data base and then a central data base. The information from these bases is used by medical experts during the intervals between communication sessions for more in-depth and comprehensive analysis of crew health. In general, AI expert systems are considered highly promising for use in space medicine.

Development of algorithms for analysis and evaluation of medical information is a central problem for creating the type of automated systems under discussion here. Algorithms used in automated systems for monitoring crewmember health may be divided into three groups: 1) algorithms for automated processing of raw data to produce a numerical series of parameters indicative of various types of physiological processes; 2) algorithms for automated analysis of medical/physiological parameters to identify symptoms associated with adverse effects of space flight factors or development of pathology; 3) algorithms for automated evaluation of data in the interests of diagnosis. Initial processing of data may be completely automated, as is the case for ECGs, or a specialist may first identify certain points on the curve, which after identification are processed automatically. Automated analysis of changes in medical and physiological parameters utilize graphic, logical or mathematical methods. Selection of the most informative graphic presentations, especially of related parameters, is an important medical task. An example of logical representation is the analytic approach associated with establishing the normal range of a parameter's fluctuations and signalling when values exceed it. The most important type of mathematical method is statistical analysis of parameter values.

Automated evaluation of results of processing and analysis is the most difficult part of automating cosmonaut medical monitoring systems. Much experience with automated diagnosis has been attained in clinical practice, which is concerned with the symptomatic stage of pathology, while space medicine must focus on the presymptomatic stage. In addition, some deviations from the norm can be attributed to the various stages of the general adaptation syndrome that takes place in space.

The subgoals of the automated evaluation of medical monitoring information are to diagnose functional state and to predict probable changes. Algorithms for diagnosis are focussed on particular manifestations of maladaptation (e.g., decrease of orthostatic tolerance or development of motion sickness). These deviations occur against a background of nonspecific symptoms of the general adaptation system. In very general terms, functional physiological states can be divided into three areas: the norm, borderline states, and pathological conditions. In space medicine it is critical that borderline states, in which homeostasis is maintained but at

## OPERATIONAL MEDICINE

high physiological cost, be recognized. Diagnostic algorithms here may be based on comparison of data from mathematical analysis of cardiac rhythm and the results of provocative testing.

Algorithms for predicting functional states are based on three approaches: heuristic, physiological, and mathematical. In the heuristic method standard scales of functional state are provided to experts and they predict changes at a given point in time. The physiological approach considers stages in the adaptation process and is focussed on identification of trends in stress on regulatory systems and functional reserves. One example of a mathematical approach is the use of regressive models.

Systems for automated medical monitoring for flights can be divided into those with an invariant program and those with flexible programming. An example of the former is the LMTS-2 (Local medical technical system) system created for operational medical monitoring during the most critical stages of flight (orbital injection and descent and EVA). This system allows the duty physician to monitor in real time the dynamics of any 4 parameters of the 72 input every minute into the data base. At the same time he can watch a display on the color monitor and obtain a hard copy table. Deviation of parameters beyond a given range is signalled either by a blinking light or a sound. After each communications session, additional information that it has generated is entered into the data base. Evaluation of functional state based on comprehensive analysis of ECG parameters, cardiac rhythm, pneumography, and impedance plethysmography occurs both in real time and during work with the data base.

An example of the second type of system is the automated system designed to solve problems of medical support of long-term flights. This system consists of five independent, automated, medical/technical systems linked by a central data base. Each system is used to perform a certain task and software may be developed as algorithms are improved. Since there is no need for all the systems to operate simultaneously, the entire system may be implemented on two or three personal computers. One of the medical tasks that this system could solve is the creation of specialized data bases of medical/physiological information obtained during long term flights.

Figure 1: Structure of an automated system for dynamic automated operational medical monitoring of the health status of cosmonauts in flight

Figure 2: A way to depict diagnostic information obtained in flight

Figure 3: Types of structure of automated medical technical systems for monitoring the health of cosmonauts

## OPERATIONAL MEDICINE

P1502(33/91) Kotovskaya AR, Vil-Vilyams IF, Gavrilova LN, Lyamin VR, Yelizarov SYu.  
***Endurance of +G<sub>x</sub> acceleration by members of Mir-Soyuz international crews.***

Authors' affiliations: Institute of Biomedical Problems, USSR Ministry of Health, Gagarin  
Cosmonaut Training Center

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working  
Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Pages 6-7

Operational Medicine, Acceleration Endurance

Humans, Cosmonauts

Space Flights, Mir-Soyuz, Short Term, Visiting Crews, Karkas Suit, Multiple Flights

Introduction. An important goal of medical support of space flight in the Intercosmos program is maintenance of high acceleration endurance in cosmonauts during return to Earth. There is virtually no data in the literature concerning international crewmembers' endurance of +G<sub>x</sub> acceleration.

Method. Endurance of acceleration during descent from orbit to Earth was analyzed in eight cosmonauts who were members of the Soviet-Syrian, Soviet-Bulgarian, and Soviet Afghan crews and in the French cosmonaut. Durations of flights were 8, 10, 9, and 26 days, respectively. The Karkas anti-acceleration suit was used on the 26-day flight only.

Results. Endurance of +G<sub>x</sub> acceleration, up to 4-g in magnitude, was generally satisfactory in all cosmonauts during descent. However, compared with testing on the centrifuge using an analogous schedule, endurance was found to be diminished in all subjects. Descent acceleration was perceived as 1-2-g more severe than it actually was. In individual cases, symptoms limiting acceleration endurance, such as extrasystoles and multiple petechial hemorrhages in the skin of the back, occurred. Visual disturbances were absent, but sinus tachycardia and tachypnea did take place.

It is noteworthy that heart and respiration rate in crewmembers without previous flight experience increased during exposure to descent acceleration to  $116 \pm 12$  beats/min. and  $26 \pm 2$  respirations/min., and were respectively 32 and 30% ( $p < 0.05$ ) greater than in cosmonauts previously participating in flights ( $88 \pm 17$  beats/min. and  $20 \pm 2$  respirations/min). There were no significant differences as a function of flight duration or use of the anti-acceleration suit.

Conclusions. Endurance of +G<sub>x</sub> acceleration by members of international crews of the Mir-Soyuz complex after short-term (from 8 to 26 days) exposure to weightlessness was satisfactory, although physiological stress was observed. Changes in physiological parameters under exposure to acceleration during descent from orbit to Earth were associated mainly with individual differences among cosmonauts and their previous experience with space flights.

P1504(33/91) Kotovskaya AR, Vil-Vilyams IF.

***Endurance of +G<sub>x</sub> acceleration by members of prime crews 3-6 on Mir-Soyuz after exposure to weightlessness for from 5 to 12 months.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow; 1991.

Pages 8-9.

Operational Medicine, Acceleration Endurance

Humans, Cosmonauts

Space Flight, Long-Term, Mir, Karkas Suit, Prophylactic Countermeasures

**Introduction.** One goal of space medicine is to maintain a high level of tolerance and performance capacity under exposure to acceleration during descent from orbit after long-term exposure to weightlessness. However there is very little data in the literature on this subject.

**Method.** An analysis was conducted of endurance of acceleration by nine cosmonauts after exposure to weightlessness of 152 to 366-days duration, accompanied by use of an improved set of prophylactic measures and the Karkas anti-acceleration suit.

**Results.** Endurance of acceleration during return to Earth was satisfactory in all cases. No visual disturbance or disorder of cardiac rhythm occurred. However, the cosmonauts perceived the magnitude of the acceleration as greater than it actually was by 0.7-4.4-g. Impeded breathing and speech were observed. A sensation of sinking of the larynx was reported. Heart rate during exposure to descent acceleration reached 84-114 beats/ min. and respiration rate was 18-32 breaths/min. These parameters were 8-82% and 16-81%, respectively, greater than during ground tests on the centrifuge on an analogous schedule in the same individuals.

Magnitude of physiological shifts did not increase when flight duration increased from 5-6 to 12 months, possibly due to the use of sufficient prophylactic measures and anti-acceleration protection. Thus, under exposure to acceleration after 5-6 and 12-month flights, heart rate was 90-114 and 102-114 beats/min, respectively, and respiration rate was 18-24 and 20-26 breaths/min, respectively.

**Conclusions.** Endurance of +G<sub>x</sub> during the final stage of long-term flights, when prophylactic measures and an anti-acceleration suit were used, was satisfactory; however, this was achieved at the cost of marked stress on physiological systems. The data obtained attest to the need for further improvement of anti-acceleration protection for cosmonauts on long-term flights.



## PAPERS:

P1509(33/91) Ponomareva IP.

***Psychophysiological experiments on board Mir (within the Intercosmos program).***

Author's affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: **Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.**

Moscow: 1991.

Page 31-32.

Psychology, Psychophysiology, Human Performance, Neurophysiology, Sleep, EEG, Adaptation  
Humans, Cosmonauts  
Space Flight, Mir, Intercosmos

Abstract: Previous studies on space flights using methods and equipment developed by the nations participating in Intercosmos have made it possible to accumulate data on psychological status and performance capacity of cosmonauts, and to establish how these varied as a function of individual differences among cosmonauts and previous flight experience.

To enhance understanding of the psychophysiological aspects of working in space, various methodologies were developed for support of psychological research on board Mir.

1. For the first time in the practice of Soviet cosmonautics, polygraphic records were made of physiological parameters of sleep (experiment Son-K), using an instrument developed by the Institute for Study of the Brain of the Bulgarian Academy of Sciences. Study of sleep on short- and long-term flights in cosmonauts of Bulgaria, Afghanistan, and the USSR yielded information on the structure of sleep in weightlessness. Maintenance of normal sleep duration and typical EEG-structure of sleep during 8-day flights attested to the cosmonauts' high adaptive capacities, including retention of the restorative function of sleep. When the phase structure of sleep was analyzed on long-term flights (up to 241 days), all the characteristic stages were found to be present, but their relative proportions differed from the norm and hypnograms varied over the course of the flight. During the first 120 days, first and second stage sleep (superficial sleep) predominated, while at the end of the flight the relative duration of third and fourth stage sleep (deep sleep) increased. Here it is relevant to consider the special role of  $\delta$ -sleep in human adaptation to changing environmental conditions.

The information obtained on the EEG phase structure of sleep, in combination with subjective evaluation of its adequacy, served as additional diagnostic criteria, expanding ideas on the functional reserves of the body during adaptation of cosmonauts to space flight conditions.

2. Investigation of psychological performance capacity used the Pleven-87 psychophysiological complex, which makes it possible to evaluate and predict human mental performance capacity. Analysis of the results confirmed the appropriateness and utility of the methods selected, their sensitivity to the dynamics of specific psychological processes and components of performance capacity, and also their potential for future use in a medical monitoring system.

3. The joint (USSR, Cuba) experiment —Cortex-2—was designed for the study of background and evoked bioelectric activity of the brain under space flight conditions. Analysis of control data under conditions simulating space flight factors identified the most important Spearman correlations among various components of visual evoked potentials and other physiological and psychophysiological parameters.

Thus, introduction of electrophysiological methods(using an IBM PC type computer) into space flight research makes it possible to significantly expand the area of application of scientific knowledge (physiology of sleep, performance capacity, individual differences, etc.) to the solution of practical problems in manned space flight.

P1511(33/91) Kozerenko OP Ivanov AA, Sled AD, Mirzadzhhanov YuA, Ryabov EV.

***Psychological support of cosmonauts in flights on Mir and problems of psychological prophylaxis.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 47-48.

Psychology, Psychological Support, Prophylaxis  
 Humans, Cosmonauts  
 Space Flight, Mir, Equipment and Instrumentation

**Introduction.** Experience with psychological prophylaxis in support of manned flights on Salyut-6 and -7 confirmed the effectiveness of the use of a routine psychological support system for cosmonauts and served as the basis for the further development and improvement of this system to better support the increasing duration and complexity of Mir missions.

**Methods.** Maintenance of cosmonauts' professional and emotional state—the purpose of psychological support — was achieved through a system of informational support: provision of significant information on the communications channel, availability of on-board recreational facilities, organization of communications sessions with families and others, delivery of mail and newspapers, etc.

**Results.** A comparative analysis of information relevant to psychological support on the flights of the eight Mir prime crews showed that the utility and effectiveness of such support measures depend on an interrelated set of administrative, technical, economical and psychosocial factors .

Increasing technological capacities have made it possible to provide the following psychological support measures:

- communications satellites for "meetings" with families (beginning with the fifth prime crew /PC-5/) allowing extended (up to 60 minutes) and reliable reception of video images on board;
- tele- and radio bridges for "meetings" (PC-4) with parents and friends from various cities of the USSR;
- telephone conversations with families (PC-5-8);
- communication with amateur radio operators and availability of on-board computer technology for recreational purposes (PC-3, PC-8).

Changes in the social situation in the country and the high interest of cosmonauts in current events motivated the establishment of radio- and television meetings of the crews with a wide range of representatives of society: deputies, journalists, political commentators, writers, etc. utilizing "ground control center-spacecraft-ground control center" transmission lines (bypassing the television studio). This technology increased the potential of informal communication sessions to compensate for deficits in social contacts (for example, during the flight of PC-5, there were 70 such sessions with participation of 57 user stations on the ground).

Although availability of the latest hardware and sensitivity to social issues have enhanced the quality of psychological support to space station crews, there is still the possibility that certain

aspects of the psychological support system itself may break down (for example, the hardware may fail, or guidelines may not be followed), decreasing the effectiveness of psychological prophylaxis (as occurred with PC-3).

**Conclusions.** Further work on the problem of psychological prophylaxis, especially with regard to future extremely long-term (interplanetary) flights, must be directed at improving the system of on-board facilities, seeking additional sources of information support; developing psychological curricula for training medical personnel, and seeking ways to realize the individual creative potential of cosmonauts.

P1512(33/91) Shaposhnikov YeA, Malinkina YuA, Rudometkin NM, Gerasimovich AA.  
***On certain results of psychoneurological monitoring of the state of cosmonauts on space station Mir.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: **Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.**

Moscow: 1991.

Pages: 49-50.

Psychology, Neurophysiology, Psychoneurological Monitoring, Asthenization  
Humans, Cosmonauts  
Space Flight, Long-Term, Mir

**Introduction.** Neuropsychological monitoring during space flights utilizing remote research methods is an important component of the system for medical monitoring, diagnosis, and prophylaxis.

**Methodology.** This paper presents the results of study of the neuropsychological status of 15 cosmonauts on space station Mir on flights from 125 to 366 days in duration. A comprehensive evaluation of the neuropsychological status of crewmembers employed psychological, neurological, and psychiatric analysis of a wide range of parameters, including self-rated well-being, quality of sleep, emotional and autonomic reactivity, mental work capacity, sensitivity, motor function (including facial expression, and gestures), interpersonal interactions, level of motivation, etc. Sources of clinical diagnostic information were radio conversations, television sessions, and results of physiological and psychophysiological tests.

**Results.** The data suggest that specially selected and trained professionals, supported during flight by effective prophylactic measures, generally demonstrate a relatively high level of nervous system functioning and performance. Nevertheless, seven cosmonauts flying for more than 1-1.5 months, showed a tendency, varying in severity and duration, to manifestations of asthenization (asthenization is defined as an abnormal state marked by weakness, increased tendency to fatigue, irritability, and disorders of attention and memory) of the nervous system was noted. Signs of emotional excitability, mood swings, sleep disorders (mainly, difficulty falling asleep and superficial sleep), and signs of fatigue at the end of the working day were observed. There were scattered complaints of headache, and a sensation of heaviness in the head. Evidently these dysfunctions were due primarily to impeded intracranial blood flow and microcirculation associated with weightlessness, emotional stress, and changes in work/rest schedule (especially when repeated and difficult EVAs had to be performed during the night ).

**Conclusions.** For in-depth study of the asthenic changes found, and also for early diagnostic and therapeutic correction of probable psychosomatic disorders on long-term flights, it is necessary to use modern, highly efficient methods of diagnosis (echographic studies) in actual flights and simulation experiments. The information obtained will facilitate further improvement of measures to prevent disorders of the central and peripheral nervous systems on long-term orbital flights.

P1419(33/91)\* Bobrovnikiy IP, Ponomarenko VA.

***Occupational health from the standpoint of human ecology and some biochemical approaches to the problem of evaluating it in individuals working in high risk professions.***

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[26 references; 6 in English]

Psychology, Human Performance, Operational Medicine, Occupational Health, Human Ecology  
Humans, Flight Personnel, Patients, Neurosis  
Biochemical Parameters, Endocrinology, Exercise Response

**Abstract:** The authors define the concept of occupational health from the standpoint of human ecology as the health of an individual considered in the context of the specific conditions of his job performance. This concept invariably involves the health of the population and the entire set of social, climatographic and other conditions of the living environment. Occupational health is defined as the process of maintaining and developing the regulatory capacities of an individual, his physical, psychological and social well-being in order to support a high level of job performance and occupational and physiological longevity. Evaluation of occupational health must involve: 1) evaluation of health status of the individual and the immediate, cumulative and remote consequences of his job performance conditions; 2) analysis of the reliability of his job performance; 3) study of level of motivation, and mental and social comfort. Biochemical parameters can be used to evaluate functional status. With regard to occupational health they should be employed to evaluate the biological reserves that support effective occupational performance.

The two studies described represent examples of the use of biochemical methods to analyze the occupational health of flight personnel. The first study used as subjects 38 patients in various flight occupations during the hospital portion of their certification examination. Twenty had been diagnosed as having symptoms of asthenia or moderately severe neurotic reactions, in 75% of the cases combined with neurocirculatory asthenia of hypertensive or mixed type. Data from clinical psychological examinations indicated that they tended to have such personality traits as dissatisfaction with their status in life, pessimism, depression, oversensitivity, and anxiety. The remainder of the subjects were apparently healthy. In addition, 18 subjects (including 7 diagnosed as asthenic or neurotic) were given a bicycle ergometer test. In the second study 56 pilots of one-man aircraft were investigated. Biochemical analyses were performed, subjects responded to questionnaires evaluating well-being, activity, and mood, and sensorimotor reactions and oxygen consumption were measured during a standard bicycle ergometer test. Venous blood was taken in the morning from fasting subjects and in the first study also after the bicycle ergometer test. Traditional clinical laboratory analyses were made of blood plasma. Levels of cortisol, insulin, testosterone,  $\beta_2$ -microglobulins, cAMP, and cGMP were measured using radioimmune assay; erythrocytes through flame photometry; and levels of diene conjugates through spectrophotometry after extraction of lipids. Rate of renal excretion of epinephrine and norepinephrine was studied using spectrofluorometry 2 hours before and after physical exercise. Levels of immunoglobulin were measured. Data were tested for statistical significance using the t-test, Wilcoxon-Mann-Whitney test, and discriminant analysis.

In the first study the subjects diagnosed as neurotic showed a clear pattern of symptoms, including changes in hormonal regulation (higher level of catecholamine excretion in the morning; depression of corticosteroid and sex hormone secretion; activation of the insulin system); increase in level of cGMP and primary products of lipid peroxidation; decrease in activity of cytoplasmic enzymes in blood plasma; atherogenic disorders of lipid and purine metabolism; decreased renal filtration; and accumulation of IgG in plasma. Discriminant

analysis correctly identified healthy and neurotic individuals in 95% of the cases on the basis of an equation including levels of uric acid, total cholesterol, activity of glutamyl transpeptidase, and level of cAMP/cGMP in plasma and diuresis and rate of renal excretion of epinephrine in the morning. When the equation derived was applied to the subjects in the second study, eight subjects were identified as neurotic. One of these had previously been diagnosed as suffering from neurocirculatory asthenia and the other seven were without clinical symptoms, but with clear signs of diminished physical and mental work capacity and depressed self-evaluation on the questionnaire. When the subjects in the first study were given a bicycle ergometer stress test, those diagnosed as neurotic were unable to complete the test, leading to a significant difference in amount of work performed by healthy and neurotic subjects.. With respect to changes in biochemical parameters in response to exercise, subjects identified as neurotic differed from healthy ones by more extreme reactions of urinary  $\beta_2$ -microglobulin and cortisol, aspartate and alanine aminotransferase, lactate dehydrogenase, IgA and sodium in plasma. Levels of urinary epinephrine and norepinephrine, and plasma insulin, cortisol/insulin ratio, and uric acid failed to show the exercise response characteristics of healthy subjects. These differences are summarized as indicating diminished stress tolerance in the neurotic subjects.

Table 1: The most important characteristics of biochemical parameters in pilots with neurotic disturbances

Table 2: Some characteristics of parameters in pilots showing biochemical indications of neurotic states

Table 3: Dynamics of parameters after bicycle ergometer test

**PAPERS:**

P1519(33/91) Gorlov VG, Yeliseyev AV, Dedov VI.

***Combined biological effects of exposure to space flight factors: Facts and possible research directions.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health.

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

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Pages 73-74.

Radiobiology, Combined Effects

Humans, Cosmonauts, Theoretical Article

Space Flight, Ionizing Radiation, Space Flight Factors, Modifying Effects

Abstract: During space flight the human body is exposed to the effects of multiple factors (weightlessness, hypokinesia, electromagnetic fields, ionizing radiation, etc.), which may significantly modify the course of physiological functions and influence the efficacy of the prophylactic measures used. Understanding of the restructuring of the functioning of many physiological systems under the influence of the combined effects of multiple space flight factors is extremely important for space biology and medicine, since this will make it possible to determine the limits of the adaptive capacities of those systems, taking individual differences into account. Knowledge of the limits of adaptive restructuring in functional systems will allow us to determine the nature of the prophylactic and corrective measures that can be employed to increase the viability and performance capacity of the body as a whole.

Extensive experimental material has been obtained concerning the biological effects of combined exposure to multiple factors at various hierarchical levels in humans and animals. A number of laws of combined effects have been formulated. Of greatest interest from the standpoint of mechanisms of combined effects of physical factors is information about the modification of the effects of ionizing radiation by various agents, since during long-term space flight ionizing radiation will probably prove to be the most limiting factor. It has been shown that hypokinesia, acceleration, and rotation combined with radiation may induce both synergistic and antagonistic effects. Contradictory data have also been obtained in a series of works studying variability of radiation sensitivity when irradiation is combined with various types of stimulation (physical exercise, electric current, hypoxic hypoxia, etc.). The decreases and increases in radioresistance observed in these experiments were correlated with the development of certain stages of the adaptation process and depend on the initial state of the organism during irradiation. A similar approach should be used to consider the contradictory results of research on the combined effects of radiation and nonradiation space flight factors. When considering protection from the effects of multiple factors it is most important to bear in mind the quantitative and temporal properties of the effect of radiation itself. Having a cumulative effect, ionizing radiation alters the initial state of the organism, especially at the level of the most reactive and vulnerable components. The result of this may be additive, sensitizing, or synergistic effects of various physical environmental factors on the body. The authors propose several approaches that could make it possible to establish the laws governing the combined effects of various physical factors on the body.



P1520(33/91) Maznitsyna OA, Mitrikas VG.

***Testing of a mathematical model of radiation conditions on Mir using results of the Soviet-Bulgarian "Lyulin" experiment.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health.

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 75-76.

Radiobiology, Radiation Conditions, Radiation Safety

Mathematical Modeling, Dosimetry

Space Flight, Mir, Flight Trajectory, Geomagnetic Field, Lyulin Dosimeter

**Introduction.** One of the major tasks associated with support of space flights is maintaining radiation safety of crewmembers. A decisive role among the sources of cosmic ionizing radiation is played by the Earth's radiation belt. For this reason radiation conditions on the flight path are primarily determined by protons, concentrated in the zone of the South Atlantic Anomaly, where the radiation belt comes closest to the Earth.

**Procedure.** The flight trajectory of Mir in the geomagnetic B-, and L-coordinates was determined using USSR State Standard 25645.126: "The Geomagnetic field: A model of the field of intraterrestrial sources," . For each point on the trajectory, the dynamics of absorbed dose in a silicon detector were predicted from standard 25625.138 ("Natural radiation belts of the Earth. Spatial and energy characteristics of the proton flux.") and 25645.139, which concerns the characteristics of electrons, considering the stopping power of protons and electrons, and the generation of Bremsstrahlung  $\gamma$ -radiation, and the shielding effect of the body and equipment of the spacecraft.

**Results.** Levels and rates of absorbed doses during the flight of Mir through the South Atlantic Anomaly zone were compared with results obtained for June 10-14, 1988 in the Lyulin experiment, which was performed during the second Soviet-Bulgarian flight. Significant discrepancies were obtained from experimental data: calculated values of absorbed doses were 8-10 times greater than empirically measured doses, and there were temporal shifts of up to  $\pm 2$  minutes in dynamics of absorbed dose.

**Conclusions.** It is essential to improve models of fluxes of charged particles in the zone of the South Atlantic Anomaly of the Earth's radiation belts to take account of secular changes in the geomagnetic field.

P1521(33/91) Bengin VV, Makhmutov VA, Panova NA, Petrov VM, Shurshakov VA, Dachev TsP, Matviychuk YuN, Bankov NG, Semkova IV.

***Increase in dose rate of solar cosmic rays on space station Mir in September-October 1989 and March 1991.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Laboratory of Solar-Terrestrial Interactions, Bulgarian Academy of Sciences

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 76-77.

Radiobiology, Dose Rate

Dosimetry

Space Flight, Mir, Solar Cosmic Rays, Solar Proton Events, Lyulin Dosimeter-Radiometer

**Introduction.** Between 1989 and 1991, a Soviet-Bulgarian experiment was conducted on Mir using the Lyulin dosimeter-radiometer. This experiment provided the first measurements (with temporal resolution and dose sensitivity) of the dynamics of dose rate during a series of solar proton events, including the unique solar proton events in September-October 1989.

**Procedure.** The Lyulin dosimeter-radiometer is intended for measurement of dose, as well as flux, of penetrating particles and has a surface-barrier silicon detector (disk 300  $\mu\text{m}$  thick with an area of 2  $\text{cm}^2$ ). The threshold of discrimination for energy absorbed in the detector is 85 keV. The geometric factor of the instrument in an isotropic field of radiation during recording of flux from a hemisphere  $\approx 6 \text{ cm}^2\text{sr}$ , dose sensitivity  $\approx 10.5 \cdot 10^{-10} \text{ Gy/count}$ , accuracy of dose measurement  $\approx \pm 20\%$ , temporal resolution = 10-100 s. The measurements were performed in the large diameter work module of Mir. The station orbit had the following parameters: altitude 380-410 km, inclination 51.6°, period  $\approx 92$  minutes.

**Results.** For quiet conditions, the dose rate of absorbed cosmic radiation in the orbit of Mir was measured as  $D = (30 \pm 6) \cdot 10^{-5} \text{ Gy/day}$ . During the solar proton event, the penetration of fluxes of solar protons was observed on the station orbit. Temporal changes in dose rate during the solar proton event inside the station agreed with dynamics of fluxes of solar protons in near-Earth space obtained from the Geos-7 satellite. The additional dose to cosmonauts on the Mir orbit during the solar proton event was significantly below the acceptable dose for a single exposure. However, in interplanetary space, where there is no natural geomagnetic screening of spacecraft from fluxes of charged particles, solar proton events analogous to those taking place in September-October 1989 would present a serious radiation hazard.

**Conclusion.** In a Soviet Bulgarian experiment using the compound Lyulin dosimeter on board Mir, data were obtained on dynamics of radiation conditions during quiet and disturbed periods of solar activity. Such data are essential for ensuring the radiation safety of crews of manned spacecraft, including interplanetary spacecraft.

P1522(33/91) Fedorenko BS.

***Development of leukemia in rats irradiated with accelerated charged particles.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 80-81.

Hematology, Leukemia, Radiation Sickness, Remote Effects

Rats, Females

Radiobiology, Accelerated Charged Particles,  $\gamma$ -Radiation

**Introduction.** Study of the biological consequences of exposure to accelerated charged particles in laboratory animals is of great significance for evaluating the risk of development of late symptoms of radiation sickness and for setting standards for radiation exposure on space flights. This paper presents results of study of incidence of blood disease in rats irradiated with accelerated high energy charged particles

**Procedure.** The experiments used outbred sexually mature female rats and Wistar line rats. The animals were irradiated with protons with energy of 645 MeV and 9 GeV, helium ions of 4 GeV/nucleon, and gamma rays from  $^{60}\text{Co}$  in doses of 0.25-4.0 Gy. Dose rate was 7.5, 2.0, and 6.0 cGy/sec; and LET was 2.5, 2.3, 8.8, and 3.0 MeV/g/cm<sup>2</sup>. The animals were observed until their death. Frequency of leukemia, morphological symptoms of blood disease, and time of death were recorded.

**Results.** It has been established that in rats leukemia is primarily of the lymphoblast type. In some animals the disorders that developed resembled reticulosarcoma; however, in the majority of cases the cytological structure of the lymphoid organs was mixed. Diseases of the hemopoietic system manifested themselves as macroscopic changes in internal organs: enlarged spleen (26.5%), lymph nodes (23.3%), and thymus (25.3%), changes in the liver (13.2%), and cellular infiltration of pulmonary tissue (16.2%). Incidence of leukemia in nonirradiated outbred rats was  $10.1 \pm 3.0\%$ , while in nonirradiated Wistar line rats it was half this rate. In irradiated rats incidence of leukemia increased with dose. After  $\gamma$ -irradiation it increased from 10.5 to 19.4%, and after irradiation with protons with energy of 645 MeV from 9.7 to 26.9%, with helium ions from 9.1 to 30.0% and with protons of 9 GeV (Wistar rats) from 21.6 [sic.] to 25.6%. Exposure to radiation led to earlier development of leukemia. The majority of the irradiated rats developing leukemia died between days 500-700, while the nonirradiated rats that developed leukemia died between days 600-800 after the beginning of the experiment.

**Conclusions.** The relationship between incidence of leukemia in rats and dose of radiation is not linear. There is high incidence of leukemia at doses of 0.5 and 1.0 Gy, but incidence of blood disease does not increase and may even decrease with doses of protons with energy of 9 GeV and helium ions of 4 Gy. After animals were irradiated with protons of energy of 645 MeV and  $\gamma$ -rays there was a tendency for further increase in incidence of leukemia with increasing dose.

P1523(33/91) Kabachenko AN.

***Cataractogenesis in mice irradiated with carbon ions.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health.

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Moscow: 1991.

Pages 81-82.

Cataractogenesis

Mice

Radiobiology, Carbon Ions,  $\gamma$ -Radiation

**Introduction.** To develop a rationale for standards of radiation safety on space flights it is necessary to obtain data on the biological consequences of the different types of cosmic radiation on mammals. This paper presents the results of comparative study of the biological effectiveness of carbon ions ( $E=300$  MeV/nucleon,  $LET=12$  keV/ $\mu$ m) and  $\gamma$ -radiation from  $^{60}\text{Co}$  ( $LET=0.3$  keV/ $\mu$ m) with respect to incidence of cataracts in mice.

**Procedure.** The experiments were performed on mice of both sexes of the  $F_1$  line (CBA+C<sub>57</sub>B<sub>16</sub>). The animals were irradiated with carbon ions locally (on the head) or over the whole body in doses of 0.03, 0.05, 0.1, 0.2, and 0.5 Gy and with  $\gamma$ -radiation in doses of 0.5, 1.0, 2.0, 4.0, 5.0, and 6.0 Gy. Dose rate was 0.03 and 0.006 Gy/sec, respectively. A nonirradiated group served as the control. The mice were studied immediately before irradiation and then every 4 weeks, using an electro-ophthalmoscope without anesthesia. The pupils were dilated with a 1% solution of homatropine. Observations continued until the animals' deaths. Cataracts were scored according to a 4-point rating scale, according to a procedure for small laboratory animals. Statistical processing utilized the  $\chi^2$  statistic.

**Results.** It was found that in mice irradiated by carbon ions, the first signs of cataracts occurred 6 weeks after irradiation at doses of 0.1-0.5 Gy and after 14 weeks when doses were 0.03-0.04 Gy. After  $\gamma$ -irradiation the first signs of clouding of the lens were noted 8-10 weeks after doses of 6.0-4.0 Gy and 15 weeks after doses of 0.4-2.0 Gy. As time after irradiation increased the frequency and severity of the effect increased. Formation of different stages of clouding of the lens was analogous in mice irradiated with both forms of radiation, but the doses evoking equal effects differed by an order of magnitude. The "dose-effect" curve for carbon ions had the form of a saturation function, while for  $\gamma$ -radiation it was close to linear.

The results suggest that for carbon ions, a dose of 0.05 Gy is the threshold with respect to incidence of formation of cataracts in mice. For  $\gamma$ -radiation the threshold dose is close to 2.0 Gy.

The relative biological effectiveness (RBE) of carbon ions computed by juxtaposing equally effective doses with  $\gamma$ -radiation was 30.4, 29.3, 11.3, 11.1 for the research period and 20, 30, 40, and 50 weeks after irradiation, respectively.

**Conclusions.** Accelerated carbon ions ( $E=300$  MeV/nucleon) have high cataractogenic effectiveness. Variation of the RBE coefficients in a wide range suggests that small doses of carbon ions can be very hazardous and that there is increased risk of development of cataracts in remote periods after exposure to radiation.

P1527(33/91) Vorozhtsova SV.

***Cytogenetic changes in the cells of the corneal epithelium of mice irradiated with helium ions of varying LET.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

Moscow: 1991.

Pages 83-84.

Genetics, Cytogenetic Changes, Corneal Epithelium, RBE

Mice, Male

Radiobiology, Helium Ions,  $\gamma$ -Radiation, LET, Dose-Effect Curves

**Introduction.** The goal of the present work was to study the effects of linear energy transfer (LET) of radiation on the damage to the chromosome apparatus of cells in the corneal epithelium in mice.

**Procedure.** Experiments were performed on 800 male mice of the F<sub>1</sub> line (CBA+C<sub>57</sub>B<sub>16</sub>) weighing 16-18 g. The animals were irradiated with helium ions with energies of 4.0, 6.0, 9.7, and 4000 MeV/nucleon and  $\gamma$ -rays from <sup>60</sup>Co in doses of 50-600 cGy. LET of the radiation was 370, 273, 198, and 8.8 MeV/g/cm<sup>2</sup>, respectively. The animals were sacrificed 24 hours after irradiation. Frequency and type of structural damage to the chromosome apparatus of the corneal epithelium were studied in total preparations of the cornea.

**Results.** It was shown that helium ions induced damage to the chromosome apparatus of cells that was analogous to destruction resulting from  $\gamma$ -radiation. However, irradiation with helium ions led to the formation of a greater number of aberrant cells than exposure to  $\gamma$ -radiation in corresponding doses. Frequency of aberration was a function of dose and LET of the helium ions. The dose-effect curves revealed relatively high levels of effect per unit dose under exposure to low doses of radiation and a gradual decrease in rate of increase as doses increased. The greater the LET, the steeper the curve and vice versa. With irradiation by helium ions in doses starting at 50 cGy, this curve has an exponential shape, suggesting that a single hit caused these effects. At higher doses of charged particles the dose effect function is more complex, suggesting the likelihood of heterogeneity in radiosensitivity of cells of the basal level of the corneal epithelium. The relative biological effectiveness (RBE) of helium ions, computed through juxtaposition of equally effective doses of helium ions and  $\gamma$  rays under exposure to which 50% of the dividing cells lacked chromosome aberrations 24 hours after irradiation, ranged from 2.2 to 4.3. The values of the RBE increased with LET of the radiation. The dose at which equivalent effects were juxtaposed had a strong influence on the value of LET coefficients of heavy charged particles. Morphological analysis of chromosome fragments showed that a peculiarity of the effects of helium ions is the high production of bridges, whose frequency exceeded the number of cells with fragments by a factor of 2.5-5.

**Conclusions.** The RBE of helium ions was a direct function of the LET of radiation. Twenty-four hours after irradiation of animals with helium ions with energy of 4.0, 6.0, 9.7, and 4000 MeV/nucleon, RBE was equal to  $4.3 \pm 0.2$ ,  $3.1 \pm 0.1$ ,  $2.6 \pm 0.1$ , and  $2.2 \pm 0.1$ , respectively.

## RADIOBIOLOGY

P1524(33/91) Vernigorova LA, Glushkov VA, Andrushchenko VN, Pospishil M, Pantev T, Chertkov KS.

***Antiradiation effects of riboxin and phosphaden: A comparative study.***

Affiliation: Institute of Biophysics, USSR Ministry of Health, Institute of Biophysics, Czechoslovak Academy of Sciences, Institute of Nuclear Medicine, Radiobiology and Radiohygiene, Bulgaria

In: ***Abstracts of papers presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

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Pages 84-86.

Radiobiology, Radioprotective Effects, Hematology

Laboratory Animals

$\gamma$ -Radiation, High Energy Protons, Radiation Protection, Riboxin, Phosphaden

**Introduction.** In the process of searching for agents suitable for use on space flights for protection from the effects of ionizing radiation, two preparations were identified: riboxin (a nucleoside of purine and ATP precursor) and phosphaden (adenosine-5'-monophosphate AMP). Both drugs are manufactured in tablet form and have protective effects, which, however, are not equally strong. A comprehensive experimental study was needed to identify the advantages of these drugs.

**Procedure.** Research was performed on small (mice, rats, guinea pigs) and large (dogs, monkeys) laboratory animals under conditions of short-term, prolonged and fractionated exposure to lethal and sublethal doses of  $\gamma$ -radiation and high energy protons. Various time periods, techniques, and doses of these drugs were studied. Various tests were used to evaluate their efficacy. For sublethal dose, criteria used included cytological, cytogenetic, and certain other types of analysis specially developed for testing low doses of radiation. For lethal doses the major criterion was survival of the experimental animals.

**Results.** Analysis of the experimental material showed that during short-term irradiation of mice at LD<sub>75-100</sub>, the radioprotective effect of phosphaden was somewhat weaker than that of riboxin. Under optimal conditions of administration the survival of mice exceeded that in the control conditions by 50 and 65-85%, for phosphaden and riboxin, respectively. More stable results from administration of riboxin were also obtained in guinea pig experiments. An identical effect was observed with exposure to protons with energy of 9 GeV: survival of the protected mice was 30% higher than in the control. The beneficial effect of both drugs was also found with sublethal irradiation (0.5-4 Gy), as assessed using hematological parameters (weight of the spleen, cell count in bone marrow, magnitude of the mitotic index, absolute number of mitoses) and concentrations of nucleic acids in leukocytes. These effects were also seen in the lesser number of aberrant cells in protected animals compared with the controls.

Inconsistent results were obtained with prolonged irradiation: use of riboxin had a clear radioprotective effect (reliable increase in survival rate and mean duration of life of protected animals), but phosphaden did not.

The radioprotective effect of riboxin was also manifest in various types of fractionated irradiation for a wide range of total doses, from median lethal to sublethal.

The advantages of riboxin over phosphaden were also demonstrated in experiments on larger laboratory animals. When phosphaden was administered intramuscularly, dogs and monkeys showed a tendency for increased survival compared to the control. Enteral administration of the drug in tablet form was not effective. Antiradiation properties of riboxin were also revealed

## RADIOBIOLOGY

with peroral administration: survival of dogs given riboxin in tablet form was 41.7% at LD<sub>90</sub> for the control ( $p < 0.05$ ).

Tolerance data also favor riboxin. The mice displayed no toxic symptoms when it was administered in a dose (1000 mg/kg), which substantially exceeds the optimal radioprotective dose (300 mg/kg). Administration of phosphaden to mice and guinea pigs in optimal doses was accompanied by marked reactions (dyspnea, bristling of the pelt, decreased motor activity).

Conclusions. Comparison of the results of research on the antiradiation effects of phosphaden and riboxin showed that the latter has a number of advantages and may be considered as a "gentle" prophylactic measure for cosmonauts in case of exposure to ionizing radiation.

P1525(33/91) Chertkov KS, Sbinteva MF, Vernigorova LA, Andrushchenko VN, Glushkov VA.  
***Consequences of sublethal irradiation of mice using riboxin and hydroxyurea as protective drugs.***

Affiliation: Institute of Biophysics, USSR Ministry of Health

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Pages 91- 92.

Radiobiology, Protective Effects

Mice, Females

Sublethal Irradiation, Riboxin, Hydroxyurea

**Introduction.** There are no simple and reliable criteria for evaluating the radioprotective efficacy of drugs during and soon after exposure to radiation in low (sublethal) doses, such as are possible under conditions of space flight. For this reason, the remote effects that develop after sublethal irradiation were studied in this experiment.

**Procedure.** Experiments were conducted on female mice (CBACC<sub>57</sub>B<sub>1</sub>)F<sub>1</sub> irradiated in doses of 1, 2, and 4 Gy with dose rate of 1.71 Gy/min. Before irradiation the mice received optimal doses of riboxin (300 mg/kg over 15 minutes) or hydroxyurea (250 mg/kg over 48 hours) administered intraperitoneally.

**Results.** During a 10-month observation period, 10.2% of the animals died in the control (nonirradiated) group. Irradiation in a dose of 1 Gy did not affect the remote survival of the mice. After irradiation in doses of 2 and 4 Gy there was a tendency for death rate to increase to 22 and 30%, respectively. In the latter case, the difference was reliable compared to the control group. It is important that there were no statistically significant differences between any of the irradiated groups.

When riboxin and hydroxyurea were administered before irradiation, there was no effect on the death rate parameters, i.e. the death rate of the protected mice was at the level of the (irradiated) control.

After 3-4 months had elapsed from the beginning of the experiment, certain individuals displayed disorders of the coat, involving areas of shedding and graying, not associated with dose or use of radioprotector. The bald areas eventually grew hair again, but the gray areas increased in size with time. These changes were most pronounced in animals of all groups irradiated at 4 Gy.

Weight gain of irradiated mice (both control, and protected) was faster than in nonirradiated animals. At all three radiation doses, there were no significant differences in body weight between protected and unprotected animals.

**Conclusion:** Long-term observation of mice irradiated in sublethal doses failed to reveal any advantages from the use of the protective drugs riboxin and hydroxyurea. The results of this study cast doubt on the desirability of using these radioprotectors under conditions of exposure to low (sublethal) doses of radiation.



P1526(33/91) Glushkov VA, Sevanlayev AV, Malyutina TS, Nugis VYu, Feoktistova TP, Chirkov AA, Moiseyenko VV, Cherkov KS.

***Decrease in incidence of radiation-induced aberrations in human lymphocytes after use of riboxin as a radioprotector.***

Affiliation: Institute of Biophysics, USSR Ministry of Health, Institute of Medical Radiology, USSR Academy of Medicine

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Pages: 92-94.

Hematology, Lymphocytes, Genetics, Aberrations

Humans

Radiobiology, Radioprotector, Riboxin

Introduction. Previous research has established that for three species of animals, riboxin is a "gentle" radioprotector of short-term effect. To complete the development of this new prophylactic agent it was necessary to find the effective dose for humans, and when it should be taken.

Procedure. Healthy subjects ingested 12 tablets (2.4 g) on an empty stomach. Before taking the drug and 1 hour afterward their pulse rate and blood pressure were measured and blood was taken from the ulnar vein (25 ml) for cytogenetic, hematological and biochemical analyses.

The effect of riboxin on the frequency of radiation-induced chromosome aberration in human cells was studied in cultures of peripheral lymphocytes from 10 donor subjects. Samples of blood from each donor were taken before and 1 hour after internal administration of the drug and subjected to radiation in doses of 1, 2, 3, and 4 Gy. At each point (including control cultures) 100 metaphases each were analyzed for all types of aberrations, identified without use of karyotypes. The effect of the drug on frequency and type of radiation-induced chromosome aberrations was estimated on the basis of three major cytogenetic parameters: percentage of aberrant cells, total frequency of chromosome aberrations, and frequency of dicentric cells.

Results. Use of riboxin in the indicated dose was accompanied by very slight decreases in systolic blood pressure (by 6%) and pulse rate (by 8%). The changes observed did not affect the well-being of the subjects and were not accompanied by any side effects.

The total number of leukocytes in peripheral blood did not change significantly; however, the absolute and relative level of lymphocytes increased by 11.7 and 9.6%, respectively. Level of ATP in erythrocytes remained stable.

The use of this drug did not lead to increases in the frequency of aberrations of the chromatid type in cultures of either irradiated or nonirradiated cells. For all doses of irradiation, the radiation damage to cells taken after the drug was used was less than for "untreated" lymphocytes. After irradiation in the indicated dose range, in 10 out of 12 groups, differences between experimental and control samples were significant. The efficacy of the protector with respect to the parameter of total frequency of aberrations was (in increasing order of dose) 22, 24, 24, and 21%, and with respect to frequency of dicentric cells, 25, 31, 25, and 25%. A slight (6-9%), but significant effect was noted at 3 of the 4 doses with respect to frequency of aberrant cells.

Riboxin did not have a significant effect on the spectrum of aberrations, i.e. the same types of aberration were observed after irradiation in cells taken from subjects who had or had not taken the drug.

Conclusion. Riboxin taken internally in the maximal daily dose (2.4 g) did not have any side or mutagenic effects with respect to a test of structural mutation, and had a marked radioprotective effect on lymphocytes from peripheral blood taken 1 hour after administration of the drug and irradiated *in vitro* in doses of 1-4 Gy, which manifested itself in a decrease in proportion of aberrant cells, mean 25% decrease in frequency of chromosome aberration as well as in frequency of dicentric cells compared to irradiated lymphocytes obtained from subjects who had not ingested riboxin.

P1531(33/91) Abramova VM, Kuznetsova IV, Marenniy AM.

***Remote consequence of the effect of charged particles of galactic cosmic radiation on biological subjects with varying metabolic rates.***

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health, Moscow

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

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[227 pages]

Pages: 5-6.

Radiobiology, Remote Effects, Radiosensitivity, Metabolism, Metabolic Rate, Immunology  
Microbiology, Yeast, Botany, *Arabidopsis*, Seeds, *Wolffia*

Galactic Cosmic Radiation, Space Flight, COSMOS-613, -690, -782, Salyut

**Introduction.** The range of radiosensitivity of biological subjects makes it possible to study dosage absorbed from such forms of radiation as heavy ions and galactic cosmic radiation.

**Methods.** The most important methodology used in this study of the radiobiological effects of heavy ions with a charge of greater than 6 and linear energy transfer (LET) on the order of 150-200 keV/ $\mu\text{m}$  is the use of dielectric track detectors to examine every instance of a heavy ion passing through the biological subject. The remaining methods of research used are completely traditional for such biological subjects as colonies of yeast cells, *Arabidopsis*, and populations of *Wolffia arrhizia* (rootless duckweed). The range of radiosensitivity according to various criteria falls in the bound of  $2000 \pm 40$  Gy.

**Results.** Research on colonies of yeast and *Arabidopsis* seeds (COSMOS-613, -690, -782 satellites, Salyut space station) showed that lethal effects are associated with mass cell death at various times postflight and correspond to an extremely broad range of doses, up to a maximum of 1000-3000 Gy. The most widespread type of nonlethal effects of heavy ions was observed in *Arabidopsis* in M2 and M3. Various mutations, developmental anomalies, and dwarf forms with depressed fertility in the offspring were observed. Experiments on yeast and growing *Wolffia* plants suggested mass cell damage. The effective cross section of the heavy ion track may contain approximately 26,000 cells in a yeast colony and 50,000 *Wolffia* cells, corresponding to a volume of destruction of from 0.3 to 2 mm<sup>3</sup> of living tissue.

Although populations of the higher plant, *Wolffia arrhizia*, during the postflight period (COSMOS-1887, Mir) achieved a stable population homeostasis after 3 months, a whole spectrum of typical mutations arose: dwarfs, giants, fasciated plants and pigment variations. These anomalies appeared after 3-4 months, at a level corresponding to irradiation of *Wolffia* with  $\gamma$ -rays in a range of doses from 4 to 10 Gy. In a vegetatively growing population, in the absence of recombination, every mutation event may become the source of a microevolutionary transformation of the population.

**Conclusions.** The fact that the subjects used were commensurate in size with effective cross sections of heavy ion tracks made it possible to generalize to radiobiological processes in the most sensitive tissues of large plant and animal organisms. Based on the data obtained one may hypothesize that for a large organism the stochastic nature of local mass death of cells that vary in functional value may lead to strain on immune homeostasis.

P1543(33/91) Vikhrov AI, Dudkin, VYe, Potapov YuV, Benton EV.

***Experimental LET spectra on near-Earth orbits based on measurements made on COSMOS satellites.***

Authors' affiliation: Spacecraft Radiation Safety Research and Testing Center, USSR Ministry of Health; University of San-Francisco

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[227 pages]

Pages: 27-28.

Radiobiology, Equivalent Doses, LET Spectra

Dosimetry

Space Flight, COSMOS-782, -1129, -1571, -1600, -1757, -1887, -2044, Solar Activity Cycle

**Abstract:** Introduction. The effects of radiation on humans or other biological subjects can be characterized by the value of the equivalent dose, which takes into consideration the difference in the biological effectiveness of types of radiation with different spectra of linear energy transmission (LET). Measurement of LET spectra of space radiation was conducted on flights of COSMOS-782, -1129 1571, -1600, -1757, -1887, and -2044.

**Methods.** A number of devices were used to measure LET spectra. The first was a type BYa-2 low-sensitivity nuclear photoemulsion with a controlled threshold of sensitivity, which after the appropriate calibration produced integral LET-spectra of radiation in tissue in a range from 12 to 15 1.5.104 MeV/cm. To expand the range in the direction of lower LET a type BR-2 sensitive nuclear photoemulsion, which records relativistic protons with a minimal LET value in tissue of 2.0 MeV/cm, was also used. In addition, SR-39 track detectors containing nitrate cellulose and polycarbonate, which have a threshold of recording of LET in water of 40, 1000, and 2250 MeV/cm, respectively, were employed.

**Results.** The use of different methods made it possible to obtain integral LET spectra throughout a complete 11-year solar activity cycle with adequate reliability. The data obtained make it possible to analyze the functions relating spectra to period of solar activity, angle of inclination of the orbit, height of the orbit, and thickness of screening. Experimental data were compared to results of computing the spectra of LET of galactic cosmic rays.

**Conclusions.** 1. LET spectra are fairly well described by a power function of the type  $f(L)=\alpha L^{-\beta}$ , where  $L=LET$  in tissue, and  $\alpha$  and  $\beta$  are constants, differing in the area  $L<1000$  and  $L>1000$  MeV/cm.

2. Integral LET spectra are close for satellites with similar orbital parameters.

3. For various orbital angles the forms of integral LET spectra are similar, but the absolute values increase as the angle to the polar region increases.

4. The effect of solar activity on the form of the LET spectrum is not significant.

5. When experimental data are compared with computed data it is essential to know the thickness of screening behind which measurements were made.

P1544(33/91) Vikhrov AI, Dudkin VYe, Potapov YuV, Benton E.V., Rayts G.

***Fluxes and energy spectra of neutrons measured in near-Earth orbits.***

Authors' affiliation: Spacecraft Radiation Safety Research and Testing Center, USSR Ministry of Health; University of San-Francisco; Institute of Aviation Medicine, Koln, Germany.

In: Grigoryev AI (editor): ***COSMOS Biosatellites: Abstracts of Papers Presented at an International Symposium.***

Leningrad 12-15 August 1991.

Moscow: USSR Ministry of Health, USSR Academy of Sciences; 1991.

[227 pages]

Pages: 28-29.

Radiobiology, Neutrons, Flux, Energy Spectra

Dosimetry

Space Flight, Near-Earth Orbit, COSMOS-936, -1129, -1514, -1667, -1887, -2044

**Abstract:** Introduction. Fluxes of neutrons in near-Earth orbits are relatively small (at the level of a few percent of fluxes of charged particles); however, their contribution to the equivalent dose is significant; making it essential to investigate the characteristics of neutrons.

**Methods.** A low-sensitivity nuclear photoemulsion was used to measure the energy spectra of fast neutrons. The spectrum of fast neutrons was established from the energy spectrum of recoil protons, produced by elastic (n,p) scattering of neutrons on the hydrogen nuclei of the photoemulsion. Fluence of fast neutrons was evaluated by recording of fission fragments from a thin foil of thorium using plastic track detectors. Values of fluxes of thermal and resonance neutrons were inferred from the reaction of  ${}^6\text{Li}$  ( $n, \alpha$ ) with subsequent detection of alpha particles using plastic track detectors. Thermal neutrons were separated from resonance neutrons using a cadmium filter.

**Results.** Fluences and spectra of fast neutrons were measured on 10 COSMOS series biosatellites, including COSMOS-936, -1129, -1514, -1667, 1887, and -2044, for different orbital parameters in different periods of solar activity. The neutron spectra outside the biosatellites, as a rule, were "softer," the major contribution was made by albedo neutrons. Inside the satellite the fluence of neutrons was greater than outside due to fluence of neutrons generated in satellite structures. There was some correlation between total fluence of neutrons and solar activity, since the fluence of albedo neutrons is a direct function of the fluence of galactic cosmic rays. Flux density of fast neutrons was measured within limits of  $(4.5 \pm 1.7) \cdot 10^3$  and  $(1.2 \pm 0.4) \cdot 10^5$  neutrons/cm<sup>2</sup>/day. Equivalent dose rate here is from  $1.8 \pm 0.7$  to  $4.5 \pm 1.4$  mrem/day.

**Conclusions.** 1. The majority of energy spectra of neutrons have a characteristic "evaporative" form with a maximum in the area of 1.5 to 4.0 MeV.

2. Absorbed dose rate from neutrons is several percent of the total absorbed dose, while the contribution of neutrons to the equivalent dose reaches 20-30%, due to the high quality factor of neutron radiation (averaged along the spectrum, the quality factor is 7.5).

**PAPER:**

P1515(33/91) Shepelev YeYa, Meleshko GI, Guryeva TS, Dadasheva OA, Bodya K, Koshtyal L.  
***The reactions of adult quail to space flight conditions.***

Affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Institute of Animal Biochemistry and Genetics, Slovak Academy of Sciences

In: ***Abstracts of Papers Presented at the 24th Meeting of the Permanent Working Group of Space Biology and Medicine of Member Nations of Intercosmos.***

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Reproductive System, Reproductive Function, Neurophysiology, Motor Function

Quail, Females, Males

Space Flight, Mir, Life Support Systems

**Abstract:** Introduction. Study of the embryonic development of quail during a joint Soviet-Czechoslovakian experiment on the Mir orbital complex in March 1990 marked the first phase of the study of ontogenesis of this animal, which had appeared promising for use in future life support systems. This work demonstrated that it was not possible for the neonate birds to develop appropriate motor behavior in weightlessness soon enough, making it necessary to continue the research using adult birds. In August 1990 the Inkubator-2 experiment was conducted to study whether it was possible to maintain adult birds under space flight conditions.

**Procedure.** The flight condition used four adult birds — three females and one male — selected on the basis of sexual activity and productivity. The birds were 65-70 days in age. The experimental and control birds were readied for the experiment through a special procedure involving evaluation of overall condition, tracking dynamics of body weight, microbiological analyses, and familiarization of the animals with maintenance conditions. The animals were delivered to the station in a bird transport container, wearing special restraint vests that made it possible to maintain them in weightlessness. After transport to Mir, they were placed in an animal enclosure equipped with a self-contained life support system. A special pastelike food containing both dry components and drinking water had been developed for the birds. Duration of exposure to space on Mir was 7 days; duration of the entire experiment was 9 days. The birds were then returned to Earth and three were sacrificed for biochemical analyses.

**Results.** The birds began to feed actively immediately upon being placed in the enclosure after removal from the transport container. With respect to spatial orientation, video recordings show that when they were released from the restraint device, for the first few seconds they hung motionlessly, but after the first movement of their wings or feet they began a slow chaotic movement. However, unlike the chicks in a previous experiment, the adult birds were able to fly in a straight line.

Throughout the entire duration of the experiment, no bird in either the experimental or control condition laid an egg. Cessation of oviposition corresponded to a morphologically pronounced hypotrophy of the ovaries and oviducts observed postflight. These changes were nonspecific and are a consequence of stress. These disruptions in reproductive functioning of the ovulation cycle were reversible, and egg-laying resumed in the females on days 7-8 postflight. Normal offspring hatched from these first eggs.

**Conclusions.** This experiment showed that adult birds are able to adapt to conditions of weightlessness without a longer period of preliminary forced restraint.

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