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PRELIMINARY RESULTS OF THE SCIENTIFIC EXPERIMENTS  
ON THE KOSMOS-936 BIOSATELLITE

[Anonymous]

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16. Abstract The scientific equipment and experiments on the Kosmos-936 bio- satellite, including various ground controls and the lab unit for studies at the descent vehicle landing site, are described. Preliminary results are presented on the physiological experiment with rats, biological ex- periments with drosophila and higher and lower plants and radiation physics and radiobiology studies for the planning of biological protection on future space flights. The main conclusion from the preliminary data is that rats tolerate space flight better with an artificial force of gravity.			
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PRELIMINARY RESULTS OF THE SCIENTIFIC EXPERIMENTS  
ON THE KOSMOS-936 BIOSATELLITE

[Anonymous]

Introduction

The artificial earth satellite Kosmos-936, intended to continue studies of the effect of space flight factors on living organisms, was in space from 3 to 22 August 1977. /3\*

The Kosmos-936 satellite was injected into an orbit with the parameters: initial orbital period 90.7 min; maximum distance from the surface of the earth (at apogee) 419 km; minimum distance from the surface of the earth (at perigee) 224 km; orbital inclination 62.8°.

Biological objects and scientific equipment of the Union of Soviet Socialist Republics, Czechoslovakian Socialist Republic, United States of America and France were placed aboard the satellite.

Physiological, biological, radiobiological and radiation physics experiments were conducted during this flight. A detailed description of the purposes, tasks and methods of conduct of these experiments was presented in the plan pamphlet Scientific Experiments in the Flight of Biological Satellite 1977.

Examination of the biological objects at the landing site of the biosatellite descent vehicle began 3 1/2 hours after landing.

The flight experiment was accompanied by a number of ground control experiments, including a synchronous experiment conducted in a biosatellite mockup, which duplicated all conditions of the experiment, with the exception of weightlessness.

To ascertain the role of the rotation factor in changes in the physiological functions of the animals which were under an artificial force of gravity, an additional ground control experiment was conducted in a special centrifuge, which had the minimum possible radius of rotation for the life support systems used. Both of these control experiments were started 4 and 7 days after the start of the flight.

Besides, there was a special group of animals, which were under /4

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\*Numbers in the margin indicate pagination in the foreign text.

vivarium conditions, the vivarium control, during the entire period of the flight experiment.

Specialists of the NRB, VNR, GDR, PNR, SRR, USSR, ChSSR, USA and France participated in study and processing of the experimental biological material obtained during the flight.

The data presented in the report are especially preliminary, and they do not cover all the results of the studies or all the procedures used.

To a great extent, this is connected with the complexity and lengthiness of processing of the biological material and dosimeters, as well as with the short time which has elapsed since the end of the flight and the writing of this report.

L.I. Scientific Research Equipment Complex and Conditions of Maintenance of Biological Objects Aboard Biosatellite

To support the planned program of scientific investigations, a set of scientific research equipment was installed aboard the Kosmos-936 biosatellite, composed of:

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1. Four Bios units, intended to maintain 20 experimental animals (rats) under weightless conditions.

2. Two biological centrifuges (Fig. 1), intended to maintain 10 (5 in each) experimental animals (rats) under artificial gravity conditions.

3. Biological studies unit (Fig. 2), in which the following equipment was installed:

Four automatic biological fixatives (Biofiksator) for experiments with higher plant seeds and fungi;

Thermostat for maintenance of a temperature of  $8 \pm 1^\circ\text{C}$ , during conduct of the Soviet-French Bioblok SF-2 radiobiological experiment;

Apparatus produced in the ChSSR (Fig. 3), for conduct of the Heat Exchange-1 experiment, to study the effect of weightlessness on heat exchange processes between a heated surface and the surrounding medium (air);

Container with dosimetric assemblies, for conduct of the joint Soviet-American Iondo experiment.

4. Onboard tape recorder, intended for recording motor activity and body temperature parameters of the animals, as well as information from the Heat Exchange-1 experiment.

5. Atmosphere regeneration system with supplementary purification unit, to provide the biological material with oxygen and to remove carbon dioxide and other gaseous impurities.

6. Conditioning system, intended to provide the necessary temperature and humidity conditions within the descent vehicle.

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7. Two sets of gas analyzers for oxygen, carbon dioxide and water vapor.

8. Scientific equipment control block.

9. Set of containers housing radiobiological and biological assemblies not requiring thermostating.

10. Two direct reading S-1 dosimeters, one of which was installed on the outer shell of the satellite.

A feature of the Kosmos-936 biosatellite was the presence aboard of two centrifuges with 10 rats. Five cages were installed in each centrifuge, to maintain the experimental animals (Fig. 4). The diameter of each centrifuge was 760 mm, and the rotation rate was  $53.5 \pm 3$  rpm; at a radius of 320 mm (provisional longitudinal axis of the animal), there was a g-force of 1 g. During the entire flight, the centrifuges functioned normally, with the exception of two body temperature measurement channels, which failed, due to breakdown of individual connecting elements.

The design of the Bios units differed negligibly from those used in the flights of the preceding biosatellites, and they basically fulfilled their purpose, with the exception of observations on operation of the animal feed system, as well as recording of their motor activity and body temperature.

The biological fixatives (Fig. 5) were specially built for growing higher plant seedlings and lower forms of fungi under weightless conditions, at a temperature of  $+25^{\circ}\text{C}$ . Turning on of the apparatus and supply of water and fixing fluid were carried out automatically, by programs and by one-time commands. The apparatus functioned normally during the experiment. /7

During the entire experiment, the thermostat maintained the assigned temperature ( $+8^{\circ}\text{C}$ ) in the working chamber, and it completely fulfilled the requirements placed on the instrument.

The ChSSR equipment, intended for conduct of a biophysical experiment, functioned normally. In this case, the information, recorded on magnetic tape, was decoded and sent to Czechoslovakian specialists for analysis of the results.

Supply of oxygen to the experimental animals, removal of carbon dioxide from the atmosphere and maintenance of the required air temperature and humidity were accomplished by systems similar to those used in preceding biosatellites.

In order to improve the parameters of the gaseous environment in composition of harmful trace impurities, a supplementary purification system was installed, which was turned on on day 10 of the experiment, by a one-time command from the earth.

The following conditions were maintained in the biosatellite descent vehicle during the flight:

Oxygen content 145-210 mm Hg;

Carbon dioxide content, not over 14 mm Hg;

Air temperature 21.5-24°C;

Relative humidity, 80-90%.

The pattern of change in these parameters is presented in Fig. 6.

The scientific apparatus complex was controlled by the control and switching block, in accordance with the planned cyclogram. Besides, a supplementary programming device was incorporated in the block, which controlled the operation of the tape recorder. The block functioned normally during the flight, and it ensured the passage of all planned commands and the taking of telemetry information. After the descent vehicle landed, a search and rescue complex was deployed to the landing site. It consisted of: a UAZ-452 4-wheel drive motor vehicle, intended for the transportation of laboratory equipment; a pneumatic isolation room for disassembly work, in which the satellite descent vehicle and 10 work places for scientific studies were arranged; a pneumatic isolation room for biomedical studies, in which 40 work places were arranged; a 12 kW power and illumination system; a ventilation and heat regulation system, intended for ventilation and maintenance of the air temperature in the pneumatic isolation rooms no lower than +18°C, under any weather conditions (Figs. 7,8). /8

The Kosmos-936 satellite descent vehicle landed at 6:27 a.m., 22 August 1977. The mobile field laboratory, scientific equipment and maintenance and scientific personnel were delivered to the landing site by helicopters, in the time period from 7:02 a.m. to 7:32 a.m. At 7:15 a.m., the descent vehicle was placed in the disassembly isolation room, and maintenance personnel proceeded to open the hatches and disassemble the scientific research apparatus. By 10 a.m., the field laboratory was completed deployed and ready for the conduct of scientific studies, which began at 10 a.m., after disassembly of the first Bios block, and it ended at 1 a.m., 23 August. At 8:07 a.m., 23 August, all the biological materials, accompanied by the group of scientific colleagues, were dispatched from the landing site to the base airport, and they were delivered to Moscow at 5:24 p.m.

Together with processing of the biological material, a preliminary analysis of the onboard systems was carried out right at the landing site. Subsequently, the onboard systems of the scientific equipment complex were delivered to Moscow, where they underwent more thorough analysis and testing, to confirm the reliability of evaluations of the inflight telemetry information.

In parallel (with a 4 day shift) with conduct of the flight experiment, a synchronous control experiment was conducted in a full scale mockup of the biosatellite descent vehicle (Fig. 9). /9



Its purpose was to simulate the effects of all space flight factors except weightlessness on the biological objects.

In this case, the parameters obtained by telemetry from aboard the biosatellite were maintained to within, with respect to the rated:

Oxygen content,  $\pm 2\%$ ;

Carbon dioxide content,  $\pm 2\%$ ;

Temperature,  $\pm 1\%$ ;

Relative humidity, 5-10%.

The content of some primary gaseous impurities during the controlled experiment is presented in Table 1.

In connection with malfunctions in operation of the animal feed system in one centrifuge, the hatch of the mockup was opened on day 16 of the control experiment. Since the possibility of rapid repair or replacement of the failed block was completely excluded, the 5 animals and this centrifuge were eliminated from the experiment. In this case, the total depressurization time of the mockup was 2 hours.

In parallel with the control experiment in the biosatellite mockup, an experiment with 10 rats was conducted (with a 7 day shift), in two centrifuges with a small radius of rotation (Bios-Omega) (Fig. 10). The animal maintenance conditions in these centrifuges were similar to the conditions in the inflight and biosatellite mockup centrifuges. The radius of rotation of the Bios-Omega centrifuge was 92 mm, with a rotation rate of  $53.5 \pm 3$  rpm.

The purpose of this control experiment was to study the effect of angular accelerations on the animals.

## II. Physiological Experiment with Rats

The tasks of the physiological experiment with mammals were further study of the processes of adaptation of the functional systems of the body to the effect of weightlessness and study of the biological effects of an artificial force of gravity.

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The second aspect of the artificial gravity experiment can be considered more broadly, namely, to estimate the possibility of its use for the prophylaxis of the unfavorable effects of weightlessness. On consideration that the animals were subjected to an acceleration of 1 g during rotation in the centrifuge, this experiment can also be used as the "purest control" of the space flight conditions endured.

TABLE 1. CONTENT OF SOME PRIMARY VOLATILE PRODUCTS OF METABOLISM IN ATMOSPHERE OF SEALED CABIN OF KOSMOS-936 BIOSATELLITE MOCKUP DURING CONTROL EXPERIMENT

a. COMPONENT NAME (RUSSIAN)	b. ДИОКЛАМЕНТАЛЬНОСТЬ ВЭКСПЕРИМЕНТА (DAYS)																	
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Аммиак d (MP/M <sup>3</sup> )	0,6	0,1	0,55	0,35	0,4	1,0	0,62	0,65	0,8	1,9	1,8	2,3	2,4	2,1	5,0	4,0	5,0	2,0
2. Ацетон f (MP/M <sup>3</sup> )	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Формальдегид г (MP/M <sup>3</sup> )	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. Сероводород h и e (MP/M <sup>3</sup> )	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Соединения i с азотом (MP/M <sup>3</sup> )	60	48	-	-	-	108	-	-	132	-	-	-	-	144	-	-	-	108

[Translator's note: Commas in tabulated figures are equivalent to decimal points].

- Key: a. Component determined
- b. Duration of experiment (days)
- c. Baseline
- d. Ammonia, mg/m<sup>3</sup>
- e. Not detected
- f. Acetone, mg/m<sup>3</sup>
- g. Aldehydes (as formaldehyde) mg/m<sup>3</sup>
- h. Organic acids, mg/m<sup>3</sup>
- i. Organic Compounds, mgO<sub>2</sub>/m<sup>3</sup>

ORIGINAL PAGE IS OF POOR QUALITY

Preparation of the artificial gravity experiment was based on the fact that, even at a level of artificial weight equal to that on the earth, the animals would be in a fundamentally different biologically effective force environment than on the earth. The precession and Coriolis accelerations which develop during movements in the rotating system cause unusual stimuli of the vestibular apparatus (first and foremost, of the semicircular canal receptors). This leads to changes in the tone of the limbs, locomotor acts and visual-motor coordination.

Studies conducted on the animals, which completed the flight in the Kosmos-782 satellite, demonstrated a considerable effect of weightlessness on motor functions and vestibular motor responses.

Therefore, in setting up the physiological experiments aboard the "Kosmos-936" biosatellite, together with the traditional methods of evaluation of the overall resistance of the animals' bodies, particular attention was paid to study of the condition of the vestibular function and to broader examination of the equilibrium function.

#### 1. Preparation of Animals for Experiment

For conduct of the experiments in the Kosmos-936 biosatellite, /12 300 male Wistar rats, free of pathogenic microflora (FPF), were made available to the Institute of Endocrinology, Slovakian Academies of Science (Bratislava, ChSSR).

The lots of the animals consisted of 150 rats weighing up to 110 g, aged 35-36 days, and 150 rats weighing 90-100 g, aged 32-33 days.

The older animals were used for the flight experiment and vivarium control groups, and rats born 2-4 days later, for the control experiments in the biosatellite mockup and in the centrifuge with the small radius of rotation.

In the preflight period, the animals were kept under vivarium conditions, with 5 rats in each cage, at an ambient temperature of  $22 \pm 2^\circ\text{C}$ , relative humidity  $80 \pm 5\%$  and a 12 hour light day.

Fifteen days before the start of the flight and synchronous experiments, the animals were transferred from pelleted to a specialized pasty feed, which was given once, at a rate of 40 g per animal per day.

Selection of the animals for the experiments was carried out, on the basis of the data of the daily clinical examination, study of the body weight increase pattern, evaluation of the morphological composition of the peripheral blood, results of microbiological examination of the mouth and the bactericidal activity of the skin

of the tail, as well as of the results of study of the behavioral responses of the animals.

The selection was carried out during the entire period of preparation of the animals for the experiments. It consisted of an initial stage, when a group of clinically healthy animals of approximately the same weight was selected from the entire lot. These animals were transferred to specialists, for the preparation of given specific experiments. In the intermediate stage of selection, portions of the animals had to be screened, in connection /13 with various manipulations and surgical interventions, and the final stage of selection was carried out, after completion of all types of actions, recording of baseline data and completion of training.

The animals which were prepared for the flight and synchronous experiments were trained to stay in working mockups of the maintenance condition systems and in the use of the feeders and fountains. All the animals prepared for the experiments successfully passed a 30 hour training period. The calendar plan of preparation of the animals for the flight and synchronous experiments is presented in Table 2.

In the preflight period, implantation of body temperature transmitters (10 and 14 July), implantation of a decalcified, lyophilized bone matrix under the fascia of the anterior wall of the abdomen (12 and 18 July) and delabyrinthization (14 and 19 July) were carried out on the animals, and <sup>14</sup>C glycine (15 and 19 July), declomycin (31 July) and a 10% suspension of sheep erythrocytes (25 and 28 July) also were injected intraperitoneally.

The distribution of the animals into the experimental groups is presented in Table 3.

The animals of experimental groups Ts<sub>1</sub>, N<sub>1</sub> and N<sub>2</sub> were killed on day 0 at the biosatellite landing site, for subsequent conduct of biochemical and morphological examinations, and the remaining rats were left for study of the readaptation period. After completion of the studies on day 25 after landing, the rats of experimental groups Ts<sub>2</sub> and N<sub>3</sub>, as well as 3 rats from group N<sub>4</sub>, were killed.

A portion of the delabyrinthized animals (group N<sub>4</sub>) were left for subsequent observation (2 rats from the flight and 4 each from the synchronous experiment and vivarium control).

## 2. Inflight Condition of Animals

During the experiment, the motor activity (MA) and body temperature (BT) of the rats were recorded aboard the biosatellite. Both of these parameters, combined with some other physiological

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TABLE 2. SCHEME OF PREPARATION OF ANIMALS FOR EXPERIMENT

Группа животных	Поступление в виварий	Перевод на спец. рацион	Иммунизация	Глицин С <sup>14</sup> (цин X)	Выведение из эксперимента	Операция	Декламинация	Виварий	Тренировка	Начало эксперимента
Полет <sup>8</sup>	6.УП.	20.УП.	15.УП.	25.УП.	31.УП.	10.УП.	12.УП.	14.УП.	30-часовая тренировка	3.УП.
Виварийный контроль	6.УП.	20.УП.	15.УП.	28.УП.	31.УП.	10.УП.	12.УП.	14.УП.	-	3.УП.
Синхронный эксперимент	6.УП.	24.УП.	19.УП.	28.УП.	31.УП.	14.УП.	18.УП.	19.УП.	30-часовая тренировка	7.УП.
"БМОС-СМЕТА" <sup>t</sup>	6.УП.	24.УП.	19.УП.	-	31.УП.	14.УП.	-	-	30-часовая тренировка	10.УП.

X) 26 August, repeated administration of declomycin to animals with implanted temperature transmitters and the intact vivarium control animal group.

- Key: a. Animal group  
 b. Entry into vivarium  
 c. Transfer to special ration  
 d. Injection  
 e. Operation  
 f. Training in Bios  
 g. Start of Experiment  
 h. <sup>14</sup>C glycine  
 i. Immunization  
 j. Declomycin X)  
 k. Body temperature transmitter implantation  
 l. Ectopic ossicle implantation  
 m. Delabyrinthization  
 n. Flight  
 o. Jul  
 p. 30 hour training  
 q. Aug  
 r. Vivarium control  
 s. Synchronous experiment  
 t. Bios-Omega

[Translator's note: Roman numerals (VII, VIII) represent months (July, August).

TABLE 3. DISTRIBUTION OF ANIMALS INTO EXPERIMENTAL GROUPS

Experimental Group	Artificial Gravity			Weightlessness		
	Ts-1	Ts-2	N-1	N-2	N-3	N-4
Number of Animals	5	5	5	5	5	5
Operation	Body temperature transmitter implantation in abdominal cavity			Implantation of decalcified lyophilized bone matrix under fascia of anterior abdominal wall	Body temperature transmitter implantation in abdominal cavity	Bilateral labyrinthization
Injection	dechloromycin	dechloromycin	dechloromycin	dechloromycin	dechloromycin	dechloromycin
		<sup>14</sup> C glycine			<sup>14</sup> C glycine	
				10% sheep erythrocyte suspension		
		Repeated dechloromycin administration			Repeated dechloromycin administration	

characteristics, can be used for qualitative evaluation of the level and structure of energy consumption of the body in space flight.

According to the initial hypothesis, the energy consumption structure of the body in weightlessness can be changed (a larger amount of movement with a smaller force load, change in the temperature balance point of the body).

Recording of the MA of each of the 30 animals was accomplished on odd days of the experiment, in the form of the stress levels corresponding to the total movement in each 2 hours, as well as in 24 hours (total motor activity, TMA).

It was determined beforehand in ground experiments that the pattern of the TMA level of the animals, during prolonged rotation of them in the centrifuge in the maintenance blocks (MB), differs from the analogous indication for rats in stationary MB. In the Bios-Omega centrifuge with a small radius of rotation (1.1 g under ground conditions), the TMA level of the animals increased initially, gradually decreasing during the experiment and, nevertheless, remaining above the initial level during the entire period of rotation. The pattern of the TMA level of the animals in the centrifuge with the larger radius of rotation (about 1.4 g under earth conditions) was the opposite. In the initial period of rotation, this characteristic decreased from the initial values, gradually increasing by the end of the experiment, but it did not reach the initial level.

Only a preliminary qualitative conclusion can now be drawn from the results of the flight, in connection with some technical failures in the motor activity recording system. It is that the TMA level of the animals in weightlessness proved to be significantly higher than the same characteristic for the animals in the onboard centrifuge. /15

The BT of the animals was measured in the experiment, under various conditions listed in Table 4.

Only a part of the expected BT information was successfully obtained during the flight.

Preliminary analysis of the results showed that the lowest BT were recorded in the animals in weightlessness (group 1). The BT of the animals in the inflight centrifuge (group 2) was somewhat higher than that of the group in the stationary MB on the ground (group 3). However, the majority of the average daily group 2 animal BT obtained did not differ significantly from the analogous values for group 3. /16

TABLE 4. GROUP DISTRIBUTION OF ANIMALS WITH IMPLANTED BT TRANSMITTERS

a Условия содержания животных в эксперименте	b Факторы воздействия	c Количество животных	d Группы	e Обозначение группы
f BIOS-неподвижный	g Невесомость	5	1	h N <sub>3</sub> полет
i BIOS-центрифуга	j ИИСТ 1,0 g, угловая скорость	5	2	k Ts <sub>2</sub> полет
l BIOS-неподвижный	m Земная сила тяжести	5	3	n N <sub>3</sub> синхр.
o BIOS-ОМЕГА (вращение с малым радиусом)	j ИИСТ 1,1 g, угловая скорость	5	5	p BIOS-ОМЕГА
q BIOS-центрифуга	j ИИСТ 1,4 g, угловая скорость	5	4	r Ts <sub>2</sub> синхрон.
s Клетки вивария (группы по 5 крыс)	-	9	6	t Вивариный контроль

- Key: a. Animal maintenance conditions in experiment  
 b. Active factor  
 c. Number of animals  
 d. Group Number  
 e. Group designation  
 f. Stationary Bios  
 g. Weightlessness  
 h. N<sub>3</sub> flight  
 i. Centrifuge BIOS  
 j. Artificial gravity, angular acceleration  
 k. Ts<sub>2</sub> flight  
 l. Stationary BIOS  
 m. Earth gravity  
 n. N<sub>3</sub> synchronous  
 o. Bios-Omega (rotation with small radius)  
 p. Bios-Omega  
 q. Centrifuge Bios  
 r. Ts<sub>2</sub> synchronous  
 s. Vivarium cages (groups of 5 rats)  
 t. Vivarium control



The data obtained, on the change in TMA and BT of the rats in the Kosmos-936 biosatellite experiment, are sufficiently in agreement with the basic results of the preceding experiments. Evidently, the energy consumption connected with the external mechanical work of the animals in weightlessness, despite the greater amount of movement accomplished by the animals in weightlessness, at least does not exceed the corresponding characteristics for ground conditions. This assumption can be made, on the basis of a downward displacement of the temperature balance point of the animals' bodies in flight.

### 3. Postflight Clinical and Physiological Condition of Animals

After the landing of the biosatellite descent vehicle, the mobile laboratory complex was deployed to the landing site. This permitted conduct of initial examination of the biological objects under field conditions.

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Examination of the rats began 3 1/2 hours after the landing of the biosatellite. In external examination of a number of animals from experimental groups N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub> and N<sub>4</sub>, which were in weightlessness during the space flight, soiling of the fur and skin of the tail were found, the abdomen and tail were wet, and there were bloody scabs on the nose and the floor of the auricle. The color of the fur of all the animals of these groups was yellow-brown. Edema of the left or right rear limb was noted in 5 animals.

All of the animals of groups N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub> and N<sub>4</sub> were sluggish, with a sharply changed gait. The characteristic movements and postures connected with orienting reactions (standing on the rear paws, overcoming obstacles, active search for an exit from the tunnel, looking outside the cage, etc.) were absent (Fig. 11).

The animals which were in artificial gravity during the flight (experimental groups Ts<sub>1</sub> and Ts<sub>2</sub>), upon external inspection were clean, with a dry white fur; the tail, paws, floors of the auricles and visible mucosa were without deviations from normal. An exception was one rat of group Ts<sub>1</sub>, which was stiff and sluggish, with dishevelled fur, and looked very exhausted.

The animals of experimental groups Ts<sub>1</sub> and Ts<sub>2</sub> were active they negotiated obstacles well, they stood on the rear paws, and their gaits differed little from normal (Fig. 12).

The rats in the synchronous experiment in the small radius centrifuge (Bios-Omega), as well as in the vivarium did not differ from each other in outward appearance or behavior.

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It is known that one important indication which characterizes the general condition of the body is a change in body weight.

Data on the change in body weight of the various experimental groups of animals in the flight and ground control experiments are presented in Table 5. It follows from this table that the animals in practically all the experimental groups reliably gained weight in the period of the experiment. The absence of significant differences in group Ts<sub>1</sub> of the flight experiment is connected primarily with the fact that one rat lost 101 grams in weight, in connection with technical malfunctions in the animal feed system.

It must be noted that the animals in the stationary Bios blocks of groups N<sub>1</sub>-N<sub>4</sub> obtained somewhat more feed per day during the flight than the rats in the centrifuges (Table 6).

A more complete idea of the changes in body weight can be obtained from Table 7, where the pattern of this characteristic for individual animals is given. The change in body weight of the animals in the readaptation period is presented in Fig. 13. It should be noted that, in the postflight period, the group Ts<sub>2</sub> rats gained weight better than the group N<sub>3</sub> rats.

On the day the biosatellite landed, the morphological composition of the peripheral blood was characterized by a small increase in erythrocyte content, which was more pronounced in the group N<sub>3</sub> and N<sub>4</sub> animals (Tables 8, 9). A significant decrease in the total number of leukocytes was noted on this day, in animal groups N<sub>3</sub> and N<sub>4</sub>. A typical stress response pattern was observed in the animals of these groups, which was expressed by a significant increase in percentage content of segmented nucleus neutrophils, lymphopenia and eosinopenia, with respect to the vivarium control. Similar changes in the white blood of the group Ts<sub>2</sub> animals were expressed significantly less. /19

Upon examination of the animals on day 3 of the readaptation period, practically complete return to normal of the morphological composition of the blood was noted.

Determination of erythrocyte resistance was carried out in vitro, in curves of hemolysis in NaCl solutions in decreasing concentrations, from 0.60 to 0.48%. As is seen from Table 10, a tendency was observed in the animals in weightlessness towards a decrease in erythrocyte resistance. These changes were not found in the rats in the onboard centrifuge and in the ground control experiments.

After completion of the flight, a study was made of the mouth microflora of the rats of experimental groups Ts<sub>2</sub>, N<sub>3</sub> and N<sub>4</sub>, according to indications of conditionally pathogenic microflora (B. Coli, Proteus v.).

For the rats under artificial gravity during the flight (group Ts<sub>2</sub>), no conditionally pathogenic microflora were found in the mouth on day zero after the flight (Table 11). At the same time, Proteus v.

were scattered in all animals of groups N<sub>3</sub> and N<sub>4</sub>. This can indicate a reduction in the nonspecific immunoreactivity of the body, as a result of weightlessness. On day 3 of the readaptation period, the number of microorganisms screened from the mouths of these animals decreased significantly.

Investigation of the gas and energy metabolism of the N<sub>3</sub> and Ts<sub>2</sub> group animals was carried out by the closed chamber method, in the baseline period and in the readaptation period (Table 12).

On day 3 after the end of the flight experiment, for the group N<sub>3</sub> animals, a decrease in oxygen consumption, carbon dioxide release and respiratory quotient, as well as a reduction in energy consumption were recorded (P<0.001). /20

For the group Ts<sub>2</sub> animals, the changes in gas exchange were less marked. A significant decrease occurred only in the carbon dioxide release and respiratory quotient characteristics.

No significant differences were found in the gas and energy metabolism characteristics, between the animals of experimental groups N<sub>3</sub> and Ts<sub>2</sub>. This was determined, to a great extent, by the small number of animals in the groups. The decrease in gas and energy metabolism after the experiment, compared with the initial data, is the result of increase in weight of the animals during the flight, since the identical changes were obtained for the vivarium control group rats.

For study of metabolism after the flight and the ground control experiments, the delabyrinthized animals of group N<sub>4</sub> were put in special cages, which provided the possibility of accounting for the food eaten, water drunk, as well as collecting the experiments for subsequent biochemical analyses.

Study of metabolism was carried out on days 1-2 and 12-13 after completion of the flight and ground control experiments. The results obtained are presented in Table 13.

On days 1-2 after completion of the flight and synchronous experiment, a tendency was noted towards increase in water consumption by the animals, compared with readaptation days 12-13 (with considerable individual variations).

The opposite regularity was observed in amount of urine excreted, a decrease in excretion of urine in the first days of readaptation, compared with days 12-13 of examination of the flight and synchronous experiment animals.

TABLE 5. WEIGHT CHANGE OF ANIMALS (IN GRAMS) DURING EXPERIMENTS (Mm,p)

Flight Experiment	Synchronous Experiment				Small Radius Centrifuge Experiment				Vivarium Control	
	Before Start of Experiment 31 Jul	After End of Experiment 22 Aug	Before Start of Experiment 26 Aug	After End of Experiment 7 Aug	Before Start of Experiment 7 Aug	After End of Experiment 29 Aug	Before Start of Experiment 31 Jul	After End of Experiment 22 Aug	Weight Gain	Weight Gain
Ts-1	209,3± 3,1	264,3± 4,1	55,0	216,0± 4,0	281,2± 6,4	65,2	255,5± 5,6	321,5± 10,9	66,0	
	<0,00I	<0,00I		<0,02	<0,02		<0,02			
Ts-2	216,8± 1,6	281,2± 4,3	64,4	-	-	-	232,8± 3,5	311,6± 8,2	78,8	
	<0,00I	<0,00I					<0,00I			
N-1	207,3± 2,4	282,0± 8,7	74,7	214,4± 3,2	293,8± 9,8	79,4	-	-	-	190±
	<0,00I	<0,00I		<0,00I	<0,00I					275,4±
N-2	206,8± 2,1	285,6± 33,2	78,8	210,8± 3,8	320,2± 8,6	109,4	-	-	-	9,6
	<0,00I	<0,00I		<0,00I	<0,00I					<0,00I
N-3	214,8± 1,6	286,2± 5,8	71,4	214,0± 3,7	292,4± 20,6	78,4	-	-	-	215,5±
	<0,00I	<0,00I		<0,00I	<0,00I					2,4
N-4	202,8± 5,2	268,6± 4,4	65,8	194,0± 7,1	282,8± 6,5	88,8	-	-	-	<0,00I
	<0,00I	<0,00I		<0,00I	<0,00I					<0,00I

x) In flight experiment group Ts1 and small radius centrifuge experiment.  
 x) In flight experiment group N1, account was not taken of the weights of two animals, which gained 118 g and 171 g, because of the larger food feed, in connection with irregularities in operation of the food pumps.  
 x) (without temperature transmitters) account was not taken of the weights of 2 animals, which lost 101 g and 33 g, respectively, in connection with malfunction in the food feed system.

TABLE 6. FOOD CONSUMPTION IN FLIGHT AND SYNCRHONOUS EXPERIMENTS

a Вид эксперимента	b Средние данные по экспериментальным группам в г.					
	c N <sub>1</sub>	c N <sub>2</sub>	c N <sub>3</sub>	c T <sub>1</sub>	d T <sub>1</sub>	d T <sub>2</sub>
e Полетный эксперимент	54,5	51,4	49,2	45,4	35,2	39,4
f Синхронный эксперимент	48,5	54,8	45,4	50,6	35,0	
g Центрифуга с малым радиусом					33,8	39,3

- Key: a. Experiment type  
 b. Average data by experiment group in g  
 c. N  
 d. Ts  
 e. Flight experiment  
 f. Synchronous experiment  
 g. Small radius centrifuge

TABLE 7. INDIVIDUAL WEIGHTS OF ANIMALS BEFORE AND AFTER EXPERIMENTS

		Flight Experiment		
Rat #	Experimental	Weight Before	Weight After	
Upon	Killing Group	Experiment in	Experiment in	Weight Change:
		Grams, 31	Grams, 22	(in grams)
		Jul	Aug	
1.		204	265	+61
2.		206	287	+81
3.	<u>N-1</u>	216	334	+118
4.		208	379	+171
5.		212	294	+82
6.		208	246	+38
7.		199	290	+91
8.	<u>N-2</u>	208	286	+80
9.		207	306	+99
10.		212	300	+88
11.		210	270	+60
12.		212	276	+64
13.	<u>N-3</u>	216	292	+76
14.		218	302	+84
15.		218	291	+73
16.		213	276	+63
17.		206	105	-101
18.	<u>Ts-1</u>	200	264	+64
19.		212	258	+46
20.		212	259	+47
21.		216	270	+54
22.		218	282	+64
23.	<u>Ts-2</u>	212	291	+79
24.		222	273	+51
25.		216	290	+74
26.		214	260	+46
27.		196	268	+72
28.	<u>N-4</u>	210	278	+68
29.		208	279	+71
30.		186	258	+72

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TABLE 7 (continued)

## Synchronous Experiment

No.	Experimental Group	Weight Before Experiment in Grams, 3 Aug	Weight After Experiment in Grams, 26 Aug	Weight Change in Grams
I.		210	262	+52
2.		210	273	+63
3.	<u>TS-1</u>	210	282	+72
4.		220	282	+62
5.		230	302	+72
6.		202	270	+68
7.		206	287	+81
8.	<u>N-1</u>	212	296	+84
9.		232	303	+71
10.		230	313	+83
II.		202	296	+94
12.		202	308	+106
13.	<u>N-2</u>	218	338	+120
14.		220	341	+121
15.		212	318	+106
16.		224	290	+66
17.		214	278	+64
18.	<u>N-3</u>	204	292	+88
19.		220	306	+86
20.		208	296	+88
21.		192	286	+94
22.		178	300	+122
23.	<u>N-4</u>	200	286	+86
24.		182	260	+78
25.		218	282	+64

TABLE 7. (continued)

Ground Experiment in Small Radius Centrifuge				
No.	Experimental Group	Weight Before Experiment in Grams, 3 Aug	Weight After Experiment in Grams, 26 Aug	Weight Change in Grams
1		244	294	+50
2		248	216	-32
3	<sup>a</sup> БИОС-ОМЕГА	250	314	+64
4	<sup>b</sup> без температурных <sup>c</sup>	264	342	+78
5	<sup>d</sup> передатчиков	264	336	+72
-----				
6		232	308	+76
7	<sup>e</sup> БИОС-	224	294	+70
8	ОМЕГА	244	340	+96
9	<sup>f</sup> с температурными <sup>g</sup>	238	318	+80
10	<sup>h</sup> передатчиками	226	298	+72
-----				

Key: a. Bios-Omega  
 b. Without  
 c. Temperature  
 d. Transmitters  
 e. Bios-Omega  
 f. With  
 g. Temperature  
 h. Transmitters

#### Vivarium Control With Implanted Body Temperature Transmitters

No.	Experimental Group	Weight in Grams, 31 Jul	Weight in Grams, 22 Aug	Weight Change in Grams
1.	<sup>a</sup> ВИВАРИЙНЫЙ	210	302	+92
2.	<sup>b</sup> КОНТРОЛЬ	217	310	+93
3.		208	300	+92
4.		222	324	+102
5.		214	300	+86
6.		222	318	+96

Key: a. Vivarium b. Control



TABLE 8. CHANGE IN HEMOGLOBIN CONTENT, NUMBER OF ERYTHROCYTES AND HEMATOCRIT OF PERIPHERAL BLOOD OF ANIMALS (Mim)

Показатели гемоглобина в гр %	Эритроциты млн/мм <sup>3</sup>	Гематокрит в %
Фон	Фон	Фон
0-сутки	0-сутки	0-сутки
3-сутки	3-сутки	3-сутки
I4, 2±0,3 I	7, 0±0, I4	47±0, 76
I4, 7±0, 36	7, 4±0, I	46±I, 82
	0, I > p > 0, 05	
I4, 2±0, 3 I	7, 0±0, I4	47±0, 76
I5, 3±0, 59	7, 8±0, 2 I	49±0, 54
	p < 0, 02	
I4, 2±0, 3 I	7, 0±0, I4	47±0, 76
I4, 7±0, 47	7, 8±0, I5	49±0, 59
	p < 0, 01	
I4, I±0, 3	6, 9±0, I5	47±0, 76
	6, 5±0, 29	48±I, 3 I

y: a. Characteristic, Experimental Group h. Flight experiment

i. Ts

j. N

k. Vivarium control

b. Hemoglobin in g %

c. Erythrocytes 10<sup>6</sup>/mm<sup>3</sup>

d. Hematocrit in %

e. Baseline

f. Day 0

g. Day 3

TABLE 9. CHANGE IN DIFFERENTIAL BLOOD COUNT OF PERIPHERAL BLOOD OF FLIGHT GROUP AND VIVARIUM CONTROL ANIMALS

	a. Лейкоциты тыс./мм <sup>3</sup>		б. Сегментоядерные нейтро- филы %		в. Эозинофилы %		г. Эозинофилы абс в мм <sup>3</sup>	
	0 сутки	3 сутки	0 сутки	3 сутки	0 сутки	3 сутки	0 сутки	3 сутки
г <sub>12</sub>	3,1±0,47	9,8±0,63	22±1,92	22±9,82	73±1,82	73±3,24	24±3,87	62±7,6
							p < 0,02	
г <sub>13</sub>	5,9±0,91	9,8±0,84	45±7,68	22±2,76	50±7,3	70±2,0	16±3,74	62±7,6
			p < 0,02		p < 0,02		p < 0,001	
г <sub>14</sub>	11,1±1,49	8,0±0,89	38±1,81	22±1,94	58±2,31	72±1,77	24±6,7	64±13,7
			p < 0,01				p < 0,02	
г <sub>15</sub>	8,1±0,43		16±1,67		79 ±1,93		52±1,31	

г<sub>15</sub> - г<sub>16</sub> - г<sub>17</sub> - г<sub>18</sub> - г<sub>19</sub> - г<sub>20</sub> - г<sub>21</sub> - г<sub>22</sub> - г<sub>23</sub> - г<sub>24</sub> - г<sub>25</sub> - г<sub>26</sub> - г<sub>27</sub> - г<sub>28</sub> - г<sub>29</sub> - г<sub>30</sub> - г<sub>31</sub> - г<sub>32</sub> - г<sub>33</sub> - г<sub>34</sub> - г<sub>35</sub> - г<sub>36</sub> - г<sub>37</sub> - г<sub>38</sub> - г<sub>39</sub> - г<sub>40</sub> - г<sub>41</sub> - г<sub>42</sub> - г<sub>43</sub> - г<sub>44</sub> - г<sub>45</sub> - г<sub>46</sub> - г<sub>47</sub> - г<sub>48</sub> - г<sub>49</sub> - г<sub>50</sub> - г<sub>51</sub> - г<sub>52</sub> - г<sub>53</sub> - г<sub>54</sub> - г<sub>55</sub> - г<sub>56</sub> - г<sub>57</sub> - г<sub>58</sub> - г<sub>59</sub> - г<sub>60</sub> - г<sub>61</sub> - г<sub>62</sub> - г<sub>63</sub> - г<sub>64</sub> - г<sub>65</sub> - г<sub>66</sub> - г<sub>67</sub> - г<sub>68</sub> - г<sub>69</sub> - г<sub>70</sub> - г<sub>71</sub> - г<sub>72</sub> - г<sub>73</sub> - г<sub>74</sub> - г<sub>75</sub> - г<sub>76</sub> - г<sub>77</sub> - г<sub>78</sub> - г<sub>79</sub> - г<sub>80</sub> - г<sub>81</sub> - г<sub>82</sub> - г<sub>83</sub> - г<sub>84</sub> - г<sub>85</sub> - г<sub>86</sub> - г<sub>87</sub> - г<sub>88</sub> - г<sub>89</sub> - г<sub>90</sub> - г<sub>91</sub> - г<sub>92</sub> - г<sub>93</sub> - г<sub>94</sub> - г<sub>95</sub> - г<sub>96</sub> - г<sub>97</sub> - г<sub>98</sub> - г<sub>99</sub> - г<sub>100</sub>

Key: a. Leukocytes, 10<sup>3</sup>/mm<sup>3</sup>  
 b. Segmented nucleus neutrophils, %  
 c. Lymphocytes, %  
 d. Eosinophils, absolute number per mm<sup>3</sup>  
 e. Day 0  
 f. Day 3  
 g. Ts  
 h. N  
 i. Vivarium control

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TABLE 10. OSMOTIC RESISTANCE OF RAT ERYTHROCYTES ON DAY 3 AFTER EXPERIMENT

Группа животных	резистентность эритроцитов - % целых эритроцитов в растворах NaCl		концентрации:			
	0,48%	0,50%	0,52%	0,54%		
Вивариумный контроль	7	8,9±0,8	14,3±0,8	24,0±2,5	34,3±3,3	59,0±5,2
e "неподвижная" группа	5	5,6±0,5 p > 0,001	13,5±0,9 p > 0,1	19,4±1,8 p > 0,1	23,8±1,0 p > 0,01	65,1±5,3 p > 0,1
f центрифуга	5	7,9±1,2 p > 0,1	14,0±2,0 p > 0,1	19,9±3,5 p > 0,1	24,5±3,6 p > 0,05	59,8±8,9 p > 0,1
g Санкционей эксперимент "неподвижная" группа	5	6,4±1,0 p > 0,05	12,5±2,8 p > 0,1	19,8±3,3 p > 0,1	31,4±6,1 p > 0,1	67,9±8,5 p > 0,1
h "БИСС - ОМЕГА"	5	7,4±0,9 p > 0,1	16,4±1,4 p > 0,1	23,3±1,9 p > 0,1	29,8±2,6 p > 0,1	57,7±3,1 p > 0,1

Key: a. Animal group

b. Erythrocyte resistance, % whole erythrocytes in NaCl solutions of concentrations:

c. Vivarium control

d. Flight

e. "Stationary" group

f. Centrifuge

g. "Stationary" group synchronous experiment

h. Bios-Omega

TABLE 11. STUDY OF MOUTH MICROFLORA OF FLIGHT GROUP ANIMALS

	аИ <sub>4</sub>		аИ <sub>3</sub>		бЦ <sub>2</sub>	
	0-е сутки <sup>с</sup>	3-е сут- <sup>д</sup> ки	0-е сутки <sup>с</sup>	3-е сут- <sup>д</sup> ки	0-е сутки <sup>с</sup>	3-е сут- <sup>д</sup> ки
	еФон	f Полет	еФон	f Полет	еФон	f Полет
В КОЛ-ВО АННОТН. С ДИСБАК- ТЕРИОЗОМ ПО B. Coli	2	0	0	0	I	0
аИ <sub>4</sub> О Д -ВО АННОТН. С ДИСБАКТЕР. ПО Proteus	0	5	I	2	5	I
					3	0

Key: a. N

b. Ts

c. Day 0

d. Day 3

e. Baseline

f. Flight

g. Number of animals with B. Coli bacteriosis

h. Number of animals with Proteus bacteriosis

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TABLE 12. GAS AND ENERGY METABOLISM OF ANIMALS BEFORE FLIGHT AND ON DAY 3 AFTER ITS END (Mim)

а	б	в	г	д	е	ж	з
Потребление кислорода мл/100г веса в 1 мин.	Выделение углекислоты мл/100г веса в 1 мин.	Дыхательный коэффициент	Энерготраты ккал/100г веса в сутки	Ректальная температура	Вес животных на момент обследования		
3,53 ± 0,11	2,93 ± 0,08	0,84 ± 0,02	24,6 ± 0,7	37,65 ± 0,03	176,3 ± 2,4		
3,02 ± 0,45 > 0,05	2,13 ± 0,27 < 0,01	0,72 ± 0,05 < 0,05	20,4 ± 2,9 > 0,05	38,00 ± 0,30 > 0,05	286,7 ± 1,7 < 0,01		
2,58 ± 0,14 < 0,01	1,79 ± 0,10 < 0,01	0,70 ± 0,06 < 0,01	17,3 ± 0,8 < 0,01	38,10 ± 0,19 > 0,05	278,0 ± 5,3 < 0,01		
2,77 ± 0,11 < 0,05	1,66 ± 0,06 < 0,05	0,61 ± 0,03 < 0,05	18,2 ± 0,7 < 0,05	37,92 ± 0,27 > 0,05	336,0 ± 10, < 0,01		

Key: a. Characteristic/Examination period and experimental group

b. Oxygen consumption, ml/100 g weight per min

c. Carbon dioxide release, ml/100 g weight per min

d. Respiratory quotient

e. Energy consumption, kcal/100 g weight per day

f. Rectal temperature, °C

g. Animal weight at time of examination

h. Baseline

i. Postflight day 3

j. Ts2

k. N3

l. Vivarium control

TABLE 13. RESULTS OF METABOLIC STUDIES IN FLIGHT AND GROUND CONTROL EXPERIMENTS

а Названия экспериментов	б Сутки исследования	в Питьевая вода мл	г Емделенная моча мл	д Кол-во съеденного корма (г)	е Кол-во выделен. кала (г)	ж Усвояемость в %	з Коэффициент гидратации
И О Л С Т И И И эксперимент	I-2	3,8 ± 2,1	14,8 ± 2,2	16,1 ± 0,6	0,48 ± 0,04	87,0 ± 0,3	0,71 ± 0,08
	I2-I3	1,9 ± 0,9	17,1 ± 0,4	17,0 ± 0	0,58 ± 0,08	83,6 ± 0,1	0,57 ± 0,0
Синхронный эксперимент	I-2	3,3 ± 0,9	14,0 ± 1,5	14,5 ± 1,1	0,42 ± 0,04	87,1 ± 0,1	0,65 ± 0,0
	I2-I3	1,4 ± 0,5	19,7 ± 1,2	16,4 ± 0	0,60 ± 0,07	86,3 ± 0,4	0,48 ± 0,0
Контрольный эксперимент		2,2 ± 0,4	22,7 ± 1,5	16,4 ± 0	0,79 ± 0,04	95,2 ± 0,2	0,40 ± 0,0

Key: a. Experiment name  
 b. Examination day  
 c. Water drunk, ml  
 d. Urine excreted, ml  
 e. Amount of food eaten, g  
 f. Amount of feces eliminated, g  
 g. Assimilability in %  
 h. Hydration coefficient  
 i. Flight experiment  
 j. Synchronous experiment  
 k. Vivarium control

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TABLE 14. AVERAGE NUMBER OF REFUSALS (IN %) TO "WORK" IN LABYRINTH BEFORE AND AFTER EXPERIMENT BY ANIMALS OF DIFFERENT GROUPS

Название эксперимента	Среднее из 2-х последн. опытов полета					После полета (или перерыва)			Среднее из 5-ти опытов полета
	3 сутки полета	6 сутки	8 сутки	11 сутки	14 сутки	3 сутки	6 сутки	8 сутки	
Полетный эксперимент №2	0	40,0	53,3	33,3	33,3	40,0	53,3	33,3	40,0
№3	0	33,3	53,3	20,0	26,7	33,3	20,0	20,0	30,7
Синхронный эксперимент №3	0	46,7	46,7	6,7	20,0	46,7	6,7	0	24,0
Центрифта с малым радиусом	0	41,7	41,7	25,0	16,7	41,7	25,0	8,3	26,7
Вивариумный контроль	0	33,3	20,0	6,7	0	33,3	6,7	0	12,0

- Key: a. Experiment name  
b. Average of last 2 preflight tests  
c. Postflight (or break)  
d. Average of 5 postflight tests  
e. Day  
f. Flight experiment  
g. Ts  
h. N  
i. Synchronous experiment  
j. Small radius centrifuge  
k. Vivarium control

The hydration coefficients of the flight and synchronous experiment animals (especially on days 1-2) were significantly higher than those of the vivarium control animals. In this case, the hydration coefficient of the flight group animals was the highest. The differences of the flight and control animals in this characteristic were preserved until days 12-13 of the readaptation period. By this time, the hydration coefficient of the synchronous group animals approached that of the vivarium control. /21

Food assimilability of the flight and synchronous group animals was significantly higher than that of the vivarium animals, in the entire period of study of metabolism.

Study of the effect of flight conditions aboard the Kosmos-936 biosatellite on the working out of behavior algorithms by the rats was carried out before and after the flight and ground control experiments, in labyrinths of various degrees of complexity.

A preliminary analysis of the results obtained permits only the number of refusals to solve the problems in the labyrinth to be presented (in % of the total number of problems presented).

It is seen from Table 14 that, in the baseline examination period, refusals to solve problems in the labyrinth were practically not noted in a single group of animals examined. After the flight and the end of the control experiments, refusals were observed in all groups. However, there were more of them in the flight experiment animals than in the vivarium control groups. True, during the first two days of the recovery period, the number of refusals in the synchronous experiment animal groups did not differ from that in the flight experiment groups. However, on succeeding days of the readaptation period, the synchronous experiment animals clearly refused to work in the labyrinth more rarely.

The nature of the changes observed in the flight group animals indicates some difficulty in recovery of the skills developed, compared with that of the control group animals. At this stage, it does not appear possible to evaluate the effect of artificial gravity on working out behavior algorithms. /22

Before and after the experiments, an estimate was made of the static endurance of the animals, from the maximum time of holding on to rods hanging vertically down from a platform fastened on a 180-200 mm high support. In the baseline period, the static endurance of the group N3 and Ts2 animals did not differ from the proper values for animals of the corresponding weight; it was  $198 \pm 12$  sec. On readaptation period day 3, endurance of animals of both groups was reduced approximately 6 times from the baseline values and 3 times from the proper values.



On subsequent examination days, a gradual recovery of static endurance was observed. Significant differences from the proper values were not found for the group Ts<sub>2</sub> animals, beginning on day 6 of the readaptation period. At the same time, the static endurance of the group N<sub>3</sub> animals differed significantly from normal (114±6 sec) on day 24; it was 87±9.8 sec.

The equilibrium function was evaluated, from the ability of the animals to balance on a beam and from the search time for a horizontal position on a swinging platform.

Vestibular reactions were evaluated by the lift reflex, which is characteristic of all animals, and which is characterized by a rapid straightening of the limbs, in response to progressive downward movement. The reflex is caused by a shift of the otoliths of the vestibular apparatus, and it reflects one typical vestibulo-motor reaction.

Besides, the function of the vestibular apparatus was evaluated /23 by the electronystagmographic method, which is used to record the vestibular-ocular motor reflex from the semicircular canals (Nystagmus), as well as by means of motion picture photography, from the nature of change in the turning and landing reflexes.

As a result of the examination, no significant differences were found in the overall vestibular nystagmus characteristics (latent period, number of impulses, duration and purity) in the animals in weightlessness and the control synchronous experiment animals during the entire period of readaptation. The duration and number of nystagmus pulses of the animals in artificial gravity, on day 3 after landing, were sharply reduced (training effect). Beginning on day 7, none of the nystagmus parameters differed from normal.

The ability of the animals of both groups to preserve equilibrium on the beam was reduced, but somewhat less for the group Ts<sub>2</sub> animals (Fig. 14). These animals also spent less time in searching for a stable horizontal position. By the third day of examination, the differences between both groups were leveled out and, on day 15, the characteristics were close to baseline (≈100 sec).

The lift reflex of the animals of both groups was preserved, but it differed from the baseline data in latent period (≈35 msec). The latent period of the group N<sub>3</sub> animals increased to 47-50 msec on the first day after landing, while it decreased to 27-30 msec for the group Ts<sub>2</sub> animals.

#### 4. Results of Pathoanatomical Autopsy of Animals

##### Flight Experiment

I. Rats killed at landing site of Kosmos-936 biosatellite 4.5-9.5 hours after satellite landing.

Group Ts1 (No. 16, 17, 18, 19, 20).

Upon external inspection of the animals before killing, the good condition of the rats, with the exception of rat No. 17, was established. The fur of the majority of animals was relatively clean and dry, and the visible mucosa and skin of the paws, tail and ears were without peculiarities and were clean. Upon autopsy of the rats, no macroscopic, visible changes of the internal organs or support-motor apparatus were found. Otitis was absent. /24

Rat No. 17 was severely exhausted, cachexic (weight 103 g), had little mobility and the fur was dishevelled and clean; the visible mucosa and skin of the rat were clean. Upon autopsy of the animal, a complete absence of subcutaneous fat cells and fat deposits in the abdominal cavity, as well as complete atrophy of the thymus gland, attracted attention. No pathological changes were found in the remaining internal organs and support-motor apparatus.

Group N-1 (No. 1, 2, 3, 4, 5).

Upon external inspection of the rats, soiling and wetness of the fur were noted. Rats No. 1, 2 and 4 had some edema of the rear limbs.

Upon autopsy of the animals, a fresh fracture of the right tibia of rat No. 1 was found, with massive hemorrhage in the cavity of the right knee joint and soft tissues of the shank, and a fresh fracture of the right femur of rat No. 4, with hemorrhage in the surrounding tissues. No changes in the internal organs or otitis were noted in the group N1 rats.

II. Rats killed at landing site of Kosmos-936 biosatellite 11-13 hours after satellite landing.

Group N-2 (No. 6, 7, 8, 9, 10).

Upon external inspection, great soiling and wetness of the fur and skin of the rats were noticed. /25

Upon autopsy, fresh fractures of the right femur of rats No. 6 and 10 were found, with massive hemorrhages in the surrounding soft tissues. As to the internal organs, with the exception of rat No. 9, in which fine focus bronchial pneumonia was noted in both lungs, no pathological changes were found. There was no otitis.

III. Rats killed 25 days after end of space flight.

Group Ts-2 (No. 21, 22, 23, 24, 25).

External appearance: fur clean, visible mucosa and skin clean, without peculiarities.

Upon autopsy of the animals, no pathological changes of the internal organs or support-motor apparatus were found, with the exception of rat No. 24, in which fine, grayish foci were observed in the lungs under the pleura (bronchial pneumonia). No otitis.

Group N-3 (No. 11, 12, 13, 14, 15).

External appearance: fur clean, mucosa and skin clean, without peculiarities.

In the pathoanatomical study, multiple grayish, miliary, small nodes were found under the pleura under the lungs of rats Nos. 11, 12 and 14 (focal bronchial pneumonia?) and, in rat No. 15, an old fracture of the right femur with a bony callus which had developed at the site of the break. No other pathological changes, including otitis were found in the rats of group N-3.

#### Synchronous Experiment

I. Rats killed 4.5-9.5 hours after end of experiment.

Group Ts-1 (No. 41, 42, 43, 44, 45).

External appearance: fur clean and dry, mucosa and skin clean, /26 without peculiarities.

Upon autopsy of the animals, small, miliary, grayish nodes were found under the pleura in the lungs of only rat No. 41 (focal bronchial pneumonia?); no macroscopically visible changes were found in the internal organs or support-motor apparatus of the remaining rats. No otitis.

Group N-1 (No. 26, 27, 28, 29, 30).

External appearance: fur clean, dry; visible mucosa and skin without peculiarities.

Upon autopsy of the rats, with the exception of rat No. 29, no pathological changes were found in the animals. A fresh fracture of the right humerus, with hemorrhage in the surrounding soft tissues, was established in rat No. 29, and multiple, grayish, miliary subpleural nodes of the lungs also were found (focal bronchial pneumonia?). No otitis was found in the rats of group N-1.

II. Rats killed 11-13 hours after end of experiment.

Group N-2 (No. 31, 32, 33, 34, 35).

External appearance: fur clean and dry, visible mucosa and skin without peculiarities.

In the pathoanatomical study of the animals, no changes were found in the internal organs or support-motor apparatus, with the exception of rat No. 35, in which a fine focus bronchial pneumonia was found. No otitis.

III. Rats killed 25 days after end of synchronous experiment.

Group N-3 (No. 36, 37, 38, 39, 40).

External appearance of animals: fur clean and dry, visible mucosa and skin clean, without peculiarities. /27

Upon autopsy of the animals, small, grayish miliary nodes were found in the lungs of rats No. 38 and 40 (focal bronchial pneumonia?). No pathological changes were observed in the remaining animals.

#### Vivarium Control

I. Rats killed after end of experiment

Group VK-1 (No. 51, 52, 53, 54, 55) and group VK-2 (No. 56, 57, 58, 59, 60).

External appearance: fur clean, visible mucosa and skin without singularities.

Upon autopsy of the animals, a large focus of confluent bronchial pneumonia was found in the right lung of rat No. 55 and small, multiple foci of bronchial pneumonia in rats Nos. 57 and 58. No other pathological changes in the internal organs or otitis were found.

II. Rats killed 25 days after end of experiment.

Groups VK-3 (No. 66, 67, 68, 69, 70) and groups VK-4 (No. 71, 72, 73, 74, 75).

External appearance: fur clean, visible mucosa and skin without singularities.

In the pathoanatomical study, multiple, miliary, grayish tissue consolidations were found in the lungs of rats Nos. 67, 69, 70, 72 and 73 (find focus bronchial pneumonia?). No other

pathological changes were found in the internal organs or support-motor apparatus. No otitis.

#### Experiment in Centrifuge with Small Radius of Rotation

Group OB-1 (No. 61, 62, 63, 64, 65) and group OB-2 (No. 76, 77, 78, 79).

Group OB-1 (killed immediately after end of experiment and group OB-2 after 24 days).

Upon autopsy of the animals, fine focus bronchial pneumonia was detected in rats No. 63, 65 and 76. /28

Thus, the results of the pathoanatomical study showed that, in 5 of the 15 rats examined, of the flight group in weightlessness, fractures of the right femur (4 rats) and right tibia (1 rat) were observed. The presence of fresh hemorrhages in the soft tissues surrounding the fracture site, noted in 4 rats killed at the biosatellite landing site indicates that the bone fractures occurred, in all likelihood, at the time of landing of the biosatellite. In one rat, killed on day 25 after landing of the biosatellite, a bony callus was found at the site of fracture of the right femur, which formed in the readaptation period. No traumatic bone injuries of the rats of the flight group in artificial gravity were noted.

In the synchronous experiment animals, a fresh fracture of the right humerus was observed in 1 rat, and its occurrence should evidently be connected with the effect of impact overload.

Fine foci of bronchial pneumonia? were noted in the lungs of 21 of the 74 rats examined.

A final diagnosis will be exactly defined, after conduct of microscopic examination.

One rat killed at the biosatellite landing site was extremely exhausted. This was connected with nutritional insufficiency, since, upon autopsy of the animal, pathological changes were not found, which could have been caused by cachexia.

On the whole, in autopsy of the rats, with the exception of the traumatic injuries mentioned above, no macroscopically visibly changes were found, which could have been attributed to the effect of space flight factors.

#### 5. Conclusion

The program of physiological, morphological and biochemical studies in the experiment with rats in the Kosmos-936 biosatellite was executed, practically in full measure. /44

The complex of scientific research equipment basically provided for conduct of all planned experiments aboard the biosatellite.

The examination of the animals at the landing site of the biosatellite descent vehicle enables the condition of the animals to be acknowledged as good.

Upon external inspection of the animals and the inner surfaces of the cages after landing, somewhat poorer sanitary and hygienic conditions were found in the Bios systems than in the centrifuges.

Preliminary analysis of the clinical and physiological examination results after the end of the experiment make it possible to note a number of functional changes in the bodies of the animals, due to exposure to space flight factors.

The stay of the animals under weightless conditions resulted in:

An increase in the percentage of errors in performing tasks in various labyrinths, which indicates the development of fatigue in the central nervous system;

The development of marked stress responses, according to the data of morphological composition of the peripheral blood;

A reduction in body temperature;

A decrease in peripheral blood erythrocyte resistance;

An increase in provisionally pathogenic microflora in the mouths of the animals;

An increase in water consumption and a decrease in diuresis and an increase in the hydration coefficient;

/45

A decrease in oxygen consumption, carbon dioxide release and energy consumption;

A reduction in static endurance which was not restored before the end of the readaptation period;

A reduction in ability to preserve equilibrium on the beam and an increase in the search time for a stable horizontal position;

An increase in the latent period of the lift reflex.

In the animals under artificial gravity, the changes noted were less marked or completely absent. Thus, for example, they

had no marked changes in the morphological composition of the peripheral blood, which characterizes the development of a stress response, erythrocyte resistance was unchanged, provisionally pathogenic microflora were completely absent in the mouth, the gas and energy metabolism characteristics changed less, the reduced static endurance returned to the proper values by day 6 of the readaptation period, and the reduction in ability to preserve equilibrium on the beam and the increase in search time for a stable horizontal position occurred in them in a significantly smaller magnitude.

Thus, the preliminary results of the research indicate more favorable tolerance of space flight by the animals under artificial gravity.

### III. Biological Experiments

#### 1. Experiment with Drosophila

Fertile Oregon-R line Drosophila melanogaster flies were among the other objects aboard the biosatellite. The fertile flies of this line were obtained 18 December 1976, from the NASA Ames Research Center, USA. From this time on, the line was maintained in a laboratory insectarium at a temperature of 25°C. /46

The experiment was conducted according to a coordinated program, with specialists from the NASA Ames Research Center, USA.

The purpose of the Soviet part of the experiment was to study the effect of weightlessness on the development of structural changes of the chromosomes and gene mutations in the male and female sex chromosome.

Aboard the biosatellite were cultures with Drosophila males, aged 24 days (23 test tubes with 25 specimens in each), 1-7 days (7 test tubes with 25 specimens in each), as well as cultures with virgin females (3 test tubes with 20 females in each), with mature males and females (4 test tubes with 10-15 specimens in each) and cultures with eggs laid by the flies 3 days before the flight of the biosatellite (8 test tubes). All the cultures were placed in three BB-2M containers, in test tubes with nutrient medium. The test tube dimensions were 110x20 mm. The composition of the nutrient medium was the following: 1 l tap water, 40 g raisins, 36 g manna-croup, 40 g sugar, 8 g agar and 0.8 ml of propionic acid.

After the biosatellite landed, a careful inspection of the material was carried out, which showed that the flies were in good condition, were mobile and, in those cultures which were intended for obtaining progeny, there were 80-100 specimens in each test tube. The weight of ten males was 6.7 mg, 6.9 mg and the weight of ten females, 7.8 mg, 8.0 mg. Since the flight of the biosatellite /47

lasted 18.5 days, there was a mixture of specimens of the first and second generations in these cultures. There were isolated deaths of the flies. At the landing site of the biosatellite, a portion of the specimens returned from the flight was hybridized with specimens of the test line of the opposite sex, having the gene sequence ywctfB in the sex chromosome.

In Moscow, a portion of the cultures from the flight and synchronous experiments (a total of 35 cultures) was sent to an Ames Research Center colleague. The composition of the flight material was the following: 5 cultures of medium age imagos, 5 cultures of young imagos and 5 cultures of imagos which developed in weightlessness. The synchronous experiment material consisted of 5 cultures of medium age imagos and 5 cultures of young imagos. In addition, 10 cultures of Drosophila imagos from the laboratory control were sent. There were 25-28 males in each culture.

The Soviet specialists set up hybridization according to the following tests:

1. Frequency of the development of deletions in the sex chromosome;
2. Frequency of development of visible mutations;
3. Frequency of development of recessive, sex-linked lethal mutations.

For calculation of the frequency of development of deletions, Oregon-R males were hybridized with test line ywctfB virgin females. Heterozygote females of normal phenotype and males mutant in all five genes were obtained in the progeny.

The mutation rate is calculated from the number of "exceptional" males having a deleted X chromosome; besides, the number of mutant characteristics which developed in the phenotype, which should appear in the case of dropping out of the normal alleles of the corresponding genes, was calculated. /48

Oregon-R females were hybridized with test line males. Heterozygote females of normal phenotype and normal males also were obtained in the progeny. The deletions were calculated in the same manner as for the males, i.e., the number of "exceptional" specimens in the progeny was counted.

Determination of the rate of development of recessive, sex-linked lethal mutations of the Drosophila males and females is done by the standard Myeller-5 method.

According to the preliminary results, the rate of development of mutant ywctfB genes in the female offspring hatched from eggs in flight and in the synchronous experiment females is as follows.



TABLE 15. RATE OF DEVELOPMENT OF MUTANT GENES

а КОЛИЧЕСТВО ПРОСМОТРЕННЫХ ОСОБЕЙ		б ЧАСТОТА ПРОЯВЛЕНИЯ МУТАНТНЫХ ГЕНОВ							
		γ	% ± m	ω	% ± m	ϕ	% ± m	f	% ± m
с Опыт	2613	35	1,33 ±0,22	37	1,41 ±0,23	40	1,53 ±0,25	44	1,65 ±0,27
д Синхрон.	533	6	1,19 ±0,48	6	1,19 ±0,48	7	1,31 ±0,52	7	1,31 ±0,52

Key: a. Number of specimens examined  
 b. Mutant gene development rate  
 c. Test  
 d. Synchronous

The rate of development of mutant genes in the female progeny from the flight experiment was practically the same as the rate of development of these genes in the synchronous experiment females.

The rate of development of recessive lethal mutations in the *Drosophila* females from the flight experiment, synchronous experiment and laboratory control is as follows.

TABLE 16. RATE OF DEVELOPMENT OF RECESSIVE LETHAL MUTATIONS

	а ЧИСЛО ХРОСОМ	б ЧИСЛО ЛЕТАЛЬНЫХ МУТАЦИЙ
в Опыт	1000	1
д Синхрон.	1000	1
е Лабораторный контроль	1000	1

Key: a. Number of chromosomes analyzed  
 b. Number of lethals  
 c. Flight experiment  
 d. Synchronous experiment  
 e. Laboratory control  
 f. None

2. Experiment with Higher Plants

The purpose of the experiment with *Crepis* was to study the

effect of weightlessness on the duration of individual stages of the mitotic cycle and on the spontaneous mutation process. The purpose of the experiment with corn was to study the effect of weightlessness on the nature of the ultrastructural organization of the basic organelles of the meristem cells.

The object of study were Crepis and corn seedlings, grown during the flight from air dry seed, in specially constructed Biofixative apparatus. The design of the apparatus permits the seed to be wetted and the sprouts fixed by command from earth at various times. Checking and preparation of the apparatus for operation was carried out on 28-30 July 1977, and it included the following operations:

1. Cleaning and sterilization of the inner and outer surfaces of the biological holders and apparatus walls;
2. Filling of one container of each biological holder except the tenth with a mixture of alcohol and acetic acid in a 3:1 ratio (apparatus No. 1 and No. 2) and a 2% solution of glutaraldehyde (apparatus No. 3); 4 ml of fixing fluid was poured into each;
3. Filling of two containers in ten biological holders with 3 ml of distilled water each;
4. Autoclaving of some parts of the apparatus for 1 hour at 2 atm;
5. Placing the loaded apparatus in a sterile box under a bactericidal lamp for 1 day.

Fifty colchicine treated Crepis seeds were placed in each planting chamber of Biofixative No. 1, except chamber No. 10, which was intended for study of the duration of various phases of the mitotic cycle. 100 untreated seeds were placed in chamber No. 10. Biofixative-2 was intended for study of chromosome rearrangements, as well as the anatomy and morphology of the seedlings. 100 each colchicine treated seeds were placed in the first 3 planting chambers of this apparatus. 100 each untreated seeds were placed in the remaining 7 chambers. The colchicine treatment was carried out 5 days before assembly of the apparatus. The treatment was conducted with 0.3% colchicine solution for three hours. Five corn seeds were placed in each planting chamber of apparatus No. 3.

Immediately after injection of the biosatellite into orbit, the first water feed to all the planting chambers of the biofixative was carried out. According to the cyclogram for apparatus No. 1, the first fixing should have been carried out after 24 hours. The following chambers should have been fixed every two hours. The seedlings in the last chamber, No. 10, should not have been fixed.

In fact, the first and all remaining fixings were carried out four hours earlier.

According to the cyclogram for apparatus No. 2 and No. 3, the second water feed should have been carried out on day 10 of the flight. Chamber fixing should have been carried out on days 2, 4, 6, 8, 10, 13, 16 and 19. This cyclogram was executed, with the exception of the last fixing, which was carried out a day early.

The temperature inside the apparatus during the entire experiment was  $25 \pm 1^\circ\text{C}$ .

An inspection of the equipment was carried out in the field laboratory 6 hours after the end of the flight. A total of 14 seeds germinated in apparatus No. 1. Of them, one seed germinated in chamber No. 2, three seeds in chamber No. 7 and ten seeds germinated in chamber No. 10. The seeds in the remaining chambers swelled, but they did not sprout. The average length of the sprouting rootlets which grew from the seed in chamber No. 10 was 2.5 cm. Of course, determination of the individual phases of mitotic cycle could not be carried out with this amount of material. In apparatus No. 2, 104 seeds germinated in 10 biological holders. By the end of the flight, the sprouts reached the stage of appearance of cotyledenous leaflets. The roots and sprouts of the developed seedlings went in different directions and formed a straight axis. The fixed Jrepis sprouts were transposed from each biological holder to containers with fresh fixative. The unfixed sprouts were planted in the laboratory, in Knop nutrient solution, for their further growth and development.

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All of the corn seeds germinated, without exception. The average rootlet length in the first chamber was  $1.5 \pm 0.3$  cm; in the next four chambers (10 days germination), where fixing was carried out every other day, the rootlets added  $0.2 \pm 0.4$  cm in length. However, in the 5 remaining chambers, further growth was not observed. After inspection of the material and morphometry of the corn seedlings, the rootlets and coleoptiles were removed from the seeds and transferred to marked containers with fresh fixative, tightly covered and sent to the laboratory for further treatment.

In an experiment with testing of the satellite mockup, in apparatus No. 1, of 1000 Crepis seeds in all chambers, 219 germinated. In this experiment, there also was a 4 hour change in the cyclogram, in transmission of the fixing command. The length of the rootlets which grew in 20 hours was 2.5 mm. In apparatus No. 2, 572 seeds of 1000 germinated in 18.5 days. In this time, the rootlets grew from 2 mm to 2.2 cm.

In the synchronous control, not a single seed germinated in apparatus No. 1. The seeds were in the swelling state. 34 seeds

sprouted in apparatus No. 2 of this control. The rootlets grew here from 2 mm to 2.5 cm.

At the present time, "squashed" preparations, stained with acetocarmine, are being prepared from the fixed Crepis rootlets and sprouts with leaflets, and cytological analysis of the meristem cells is being conducted. The frequency of chromosome irregularities in the first and second cell divisions in K-metaphases is being calculated. Calculation of aberrations in subsequent cell divisions is being made in the anaphases. The following preliminary data have been obtained.

TABLE 17. CYTOLOGICAL ANALYSIS OF CHROMOSOME REARRANGEMENTS IN MERISTEM CELLS

	a	b	c	d	e	f	g	h	i	j
1	4	4	21	-	3118	74	2,1			
2	5	5	11	-	2357	21	,			
3	4	4	-	-	2091		,			
4	5	5	-	-	1339	11	,			
5	5	5	-	-	1116	-				
6	5	5	100	-	3444	272	,			

- Key: a. Chamber No.  
 b. Number of rootlets inspected  
 c. Number of metaphases analyzed  
 d. Mitotic index  
 e. Normal  
 f. Irregular  
 g. Number of interphases  
 h. Number of divided cells  
 i. Flight  
 j. Test

It is evident that no structural irregularities of the chromosomes were found, either in the flight material, or in the test material. However, the mitotic index was higher in the control.

In the test, 7 rootlets in the second chamber were analyzed cytologically. In this case, 216 diploid metaphases and 40 tetraploids were found. No chromosome aberrations were found in these cells.

For comparison of the difference in anatomical structure of the Crepis rootlets of the flight material and the material obtained in the satellite mockup test, the number of root hairs on the rootlets was determined (in one field of view) in the "squashed" preparations, after staining with acetocarmine. Besides, the time of formation of vessels was recorded. In the preparations made from the coytledenous leaflets, the number of stoma was counted. Only preliminary data on the number of rootlet hairs has been obtained at present. The root hairs form at some distance from the root tips. This is explained by the fact that the section of the root between the hairs and the root [word illegible] experiences greater stretching. In fixing the material, the root hairs fail to form. Therefore, material of the fourth fixing was analyzed. Here, a rhizoderm layer with a large number of root hairs is distinguished. Inspection of the material showed the following results.

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TABLE 18. QUANTITATIVE ANALYSIS OF ROOT HAIRS

	<sup>a</sup> Общее кол-во корневых волос- ков	<sup>b</sup> Кол-во полей зрения	$M \pm m$
<sup>c</sup> Опыт	143	15	9,5 ± 2,5
<sup>d</sup> Контроль	105	15	7,0 ± 1,8

Key: a. Total number of root hairs  
 b. Number of fields of view  
 c. Test  
 d. Control

It is evident that the differences are not statistically significant. However, with a three or four times increase in amount of material examined, the differences between the test and control become real, with preservation of the existing tendency. Moreover, it was noted that the root hairs develop somewhat earlier in the flight material. There was sufficiently many of them on the seedlings from the third planting chamber.

The fixed corn material was dehydrated, in alcohols of increasing concentrations and a mixture of alcohol and acetone, fixed in 1% OsO<sub>4</sub> solution, stained with uranyl acetate, placed in EPON-812 epoxy resin, poured into capsules, polymerized and prepared for electron microscope analysis.

### 3. Experiment with Lower Plants

The purpose of the experiment with lower plants was to study the morphological characteristics of a representative of the Mucor fungus Phycomyces blakesleeenans, the basic stages of growth of which, beginning with spore germination on a nutrient substrate, occurred in weightlessness. Biofixative No. 4 was used for this experiment. The preflight preparation of the apparatus included sterilization of its basic parts in contact with the biological material and the nutrient medium, pouring the fixing fluid (3.5 ml) and spore suspension (2 ml) into the corresponding chambers and 10 ml of 2% of wort agar onto the bottom of the culture chambers. The chamber walls also were coated with a thin layer of wort agar. A spore suspension at a concentration of 50000 units/ml was used in the experiment. 2% glutaraldehyde was used as the fixative. Final assembly of the apparatus took place in a sterile box. Three days before launch, the apparatus was prepared for installation onboard. The cyclogram of the flight experiment provided for inoculation of the fungus spore suspension on the first day of the flight and subsequent fixing of the biological material on days 2, 4, 6, 8, 10, 13, 16 and 19. Growth of the Phycomycete was carried out at a temperature of  $25 \pm 1^\circ\text{C}$ . At the end of the experiment, a visible evaluation of the resulting material was conducted at the landing site of the biosatellite, after opening the apparatus. Mycelia of the fungus grown from spores were found in only one chamber, fixed on day 10 of the flight. In the synchronous experiment, the fungus mycelia were contained in chambers Nos. 4, 8, 9 and 10. The lack of growth of the mycelia in the remaining chambers, both in flight and in the control, can apparently be explained by the penetration of fixing fluid into their interiors. The fungus colony grown until day 10 of the flight was similar to a matted gray bloom in outward appearance and it occupied  $4/5$  of the entire surface of the substrate. Well expressed aerial mycelia rise 1.0-1.5 mm above the wort agar. The matted form of the colony gives a large number of dwarf sporangiophores. Approximately 1-3 of them have mature brown or yellow sporangia. The sporangiophores themselves reach a height of 1.0-1.5 mm, and they have the appearance of silvery filaments. The other portion of the sporangia spores have immature white, light yellow, light brown or light green sporangia. The sporangiophores bend and twist away from the substrate. In the synchronous experiment, the formation of sporangiophores was not noted, and growth of the mycelia was noticeably depressed by the penetrating glutaraldehyde.

In conduct of the preliminary studies of the biological material grown until day 10 of the experiment, in both the synchronous test and in flight, the branching angles of the mycelia of the fungus were measured, to determine the characteristics of its distribution over the surface of the substrate in weightlessness and on the earth. A total of 120 measurement was made. During the preliminary studies, it was determined that the average branching

angle of the mycelia of Phycomyces blakesleeanus in the biosatellite experiment was  $\sim 83.1^\circ$  and, in the synchronous,  $79^\circ$ . The resulting data showed that statistically significant differences were not observed between the branching angles in weightlessness and on the earth.

#### IV. Radiation Physics Studies

The primary areas in which experimental studies were conducted in the Kosmos-936 biosatellite according to this section of the program was radiation dosimetry and protection from cosmic rays. A portion of these studies was conducted with the cooperation of American and French specialists. /56

The purpose of the Iondozi radiation dosimetry experiment (experiment K-206) was to study the dosimetric and spectrometric characteristics of cosmic rays in space near the earth, as well as to study the passage of charged cosmic ray particles through protective material and biological tissue. Besides, measurements were made of the spectra of linear energy losses, charge composition and dose characteristics of cosmic rays inside and outside the biosatellite. In the experiment, special attention was given to study of the characteristics of heavy galactic cosmic ray (GCR) nuclei, for planning future radiobiological experiments in space and in accelerators. The dosimetric studies were conducted, by means of two S-1 analysers, located on the outside of the instrument compartment and inside the descent vehicle (DV) of the biosatellite, and a dosimetric container with passive detectors, installed inside the DV. The container included Soviet and American nuclear photographic emulsions, plate detectors, thermoluminescent dosimeters and foils with fissioning elements. During the experiment, operational dosimetric monitoring was carried out in the biosatellite, from the readings of the S-1 analyser installed inside the DV. The information was transmitted by the telemetry measurement system. At the end of the experiment, the dosimetry container and S-1 analyser installed inside the DV were dismantled and the American detectors were delivered to USA specialists for processing. The telemetry information obtained during the experiment from the S-1 analysers, and processing of the detectors in the dosimetry container is now being carried out. /57

According to the preliminary results, the integral dose recorded by the S-1 analyser inside the DV was 670 mrad, of which 200 mrad was the galactic cosmic ray dose and 470 mrad was the dose from radiation of the inner radiation belts of the earth. Information was obtained on the pattern of accumulation of the daily and orbital doses. The maximum recorded orbital dose is 10 mrad. The dose recorded by the thermoluminescent glass dosimeters installed on the S-1 instrument was  $520 \pm 10$  mrad inside the DV. The dose on the upper plane of the K-206 dosimetry container (A5 plane) measured by the thermoluminescent glass detectors, was  $680 \pm 40$  mrad. The dose on the lower plane (A6) was  $570 \pm 60$  mrad.

Besides dose measurements inside the biosatellite DV, an experiment was conducted, to estimate the dose on the surface of the biosatellite with thermoluminescent (TL) dosimeters. The measurement results are presented in Table 19.

TABLE 19

a Защита в угле $2\pi$ , $X_T/\text{cm}^2$	0,02 + 0,2	1,1	1,25
b Доза, миллирад	11800 ± 20500	1070 ± 20	920 ± 30

x) The protection from the other half plane can be estimated as  $\sim 15 \text{ g/cm}^2$ .

Key: a. Protection in angle  $2\pi$ ,  $\text{g/cm}^2$   
b. Dose, millirad

Test development of the emulsions showed that, in 18.5 days of the flight, the track density in the relativistic BR-2 emulsion proved to be so high, that it hampered measurement of the individual track characteristics extremely. A considerable gamma background also was observed. In this connection, part of the layers was subjected to an electrical field, by means of which the gamma background and relativistic particles were successfully removed. Measurement of the GCR heavy nucleus fluxes was started from these layers. Processing of the flight and calibration type PR-2 emulsions also was begun, by the two potential development method.

The American nuclear emulsions from the common part of container S have now been developed. The track density in the G-5 relativistic emulsion also is very high. The less sensitive K-2 emulsion is completely suitable for measurements.

The preliminary change in fluence (here, this term means the number of particles penetrating a unit area of the detector in all directions during the entire flight) was determined from dielectric track detectors. For this, parts of the nitrocellulose detectors were etched for 12 hours in 2.5 N NaOH solution, at a temperature of  $40 \pm 0.2^\circ\text{C}$ . The fluence measurements of particles with  $\text{LEL}_{350} \geq 200 \text{ keV}/\mu\text{m}$  were  $2.9 \text{ cm}^{-2}$  and  $7.6 \text{ cm}^{-2}$ , close to the base of block A (planes A5 and A6) of the dosimetry container.

The basic purpose of the Soviet-French Bioblok experiment aboard the Kosmos-936 biosatellite was to study the biological



effect of heavy cosmic ray nuclei on single celled organisms, cell colonies and plant seeds, as well as to obtain data on the fluxes and spectra of heavy cosmic ray nuclei in the places the instruments were installed and on the effect of nonradiation space flight factors on biological objects.

The experimental equipment included three blocks: BB-2A, BB-2B and BB-2C. Block BB-2A was in a special thermostat aboard the satellite. Blocks BB-2B and BB-2C were placed in one BBI container. The last two blocks consisted of two equal halves, one of which was processed in the USSR and the other, in France. /59

After dismantling block BB-2B, the dielectric track detectors were etched in 2.5 N NaOH solution, at a temperature of  $40.0 \pm 0.2^\circ\text{C}$ , for a period of 16 hours.

The detection of biological objects (lettuce, Lactuca sativa seeds), through which heavy charged particles passed, was accomplished during the joint inspection of the biological holder layers and the detectors immediately adjacent to them. The use of stereomicroscopes permitted all layers to be seen simultaneously. The particle passage coordinates were determined to within 50  $\mu\text{m}$ , which was sufficient to distinguish objects struck with dimensions of 100 microns or more. The following numbers of damaged seeds were found in the 5 "biolayers": 18, 22, 21, 19, 27. Thus, about 11% of the exposed seeds were damaged by heavy nuclei with  $\text{LEL}_{350} \geq 200 \text{ keV}/\mu\text{m}$ . Lettuce seeds were used in the experiment, embedded in cellulose nitrate plates, which simultaneously served as particle track detectors. The following alternate test versions were used: 1. flight; 2. background control; 3. transport control. Seeds damaged by heavy charged particles (HCP) were wetted and germinated. Seedlings were fixed 48 hours after wetting the seeds, as they germinated. A cytogenetic analysis of control seed and seed which were in the flight, but in which no HCP tracks were recorded, was carried out.

Besides the Bioblok experiment aboard the Kosmos-936 biosatellite, a similar experiment was carried out on seeds of this same batch, which were in an outside container, behind protection of no more than  $0.5 \text{ g}/\text{cm}^2$  in a  $2\pi$  angle (OpenSpace). After return to earth, the seeds were germinated and fixed, and a cytogenetic analysis of cells with aberrant chromosomes was carried out. Preliminary results of the cytogenetic analysis of the Bioblok and Open Space seed versions are presented in Table 20. As is evident from this table, twice as many aberrant cells were found in the Bioblok and Open Space seeds as in the control version. Moreover, multiple aberrations were found in the flight variants, while they were absent in the controls. /60

It can be assumed that the formation of multiple aberrations is a consequence of exposure to HCP, which is confirmed by the results of our preceding Bioblok experiment aboard the Kosmos-782 biosatellite. Processing of the experiment is continuing.

TABLE 20.

	<sup>a</sup> Варианты	<sup>b</sup> Количество просмотр. клеток	<sup>c</sup> Процент повреж- ден.кле- ток.	<sup>d</sup> Множественные абerrации (кол-во)
	<sup>e</sup> Контроль	1098	2,2	-
	<sup>g</sup> "Биоблок"	1010	4,2	2
<sup>f</sup> Полет	<sup>h</sup> "Открытый космос"	3198	4,0	5

Key: a. Alternate versions  
 b. Number of cells examined  
 c. Percent damaged cells  
 d. Multiple aberrations (number)  
 e. Control  
 f. Flight  
 g. Bioblok  
 h. Open Space

Model studies of the basic characteristics of autonomous operating conditions of an electrostatic shield, with simulation of the fluxes of the radiation belts of the earth by means of an electron gun, and measurements of the gas pressure near the surface of the biosatellite were conducted, as well as tests of electronic products under space flight conditions. The studies were conducted, by means of the MEGI-4 scientific research equipment complex, individual blocks of which were placed, both on the outer surface of the biosatellite instrument compartment, and inside the DV.

The model ESS was on the outer surface of the instrument compartment. It included an electrode system with shift mechanism and charger, electron beam gun, pressure gauges outside and inside the model ESS, high voltage vacuum gap current meter, a meter for the leakage current from the high voltage electrode through the insulator, an electron beam collector current meter and a high voltage electrode potential meter. /61

An integrated circuit block also was located on the surface of the instrument compartment. The model ESS program-time control unit, current meters, low voltage power pack, electron beam gun control and integrated circuit block program-switching control unit were located inside the instrument compartment.

Besides, a unit with electronic products, to be studied in the passive mode, was located on the outer surface of the DV.

During the experiment in the space medium, studies were conducted in the following areas:

1. The possibility of charging the high voltage electrode of the model electrostatic shield with a beam of electrons, with energies of up to 100 keV;
2. Charge (potential) retention time on the model and its rate of decrease with the electron beam gun turned off;
3. The possibility of increasing the potential difference between the electrodes, by means of mechanical change in the capacitance of the electrode system;
4. Measurement of the leakage currents through the high voltage vacuum gap and through the insulator and structural materials;
5. Measurement of the pressure near the surface of the ESS and inside the working space of the model;
6. Study of the reliability of electronics products and the effect of space flight conditions on it.

In the experiment, the possibility of charge accumulation on the high voltage electrode of the model, exposed to an electron flux, /62 was experimentally confirmed for the first time. The possibility of obtaining a high voltage (increase in the potential difference, by means of mechanical change of the distance between the high voltage electrode and the screen) was demonstrated. The voltage increase reached 50% in the experiment. The decrease in potential on the insulated high voltage electrode of the model per day ( $\sim 23$  hours) was approximately 7-15%. The current density through the high voltage gap was similar to that measured in the Kosmos-690 and Kosmos-782 biosatellites and, after establishing static conditions, it was not over  $10^{-13}$  A/cm<sup>2</sup>. The leakage currents through the insulators under static conditions were not over  $10^{-13}$  A.

The model ESS functioned 1.5 hours per day for 14 days. The total operating time was  $\sim 23$  hours. During the entire experiment, the electron beam gun functioned normally and according to the assigned program. The electron beam formed by the electron beam gun had the assigned parameters. The total time of irradiation of the model during the flight, in accordance with the program, was  $\sim 530$  min.

The pressure gauges functioned simultaneously with the model ESS, and their readings were  $10^{-6}$ - $10^{-7}$  mm Hg for the outside gauge and on the order of  $10^{-4}$ - $10^{-5}$  mm Hg for the gauge located inside the working space of the model.

Dynamic tests of the electronic products were carried out continuously for a period of 14 days. The absence of malfunctions demonstrated the high reliability of operation of the integrated circuits (type 1LB333) under space flight conditions.

The primary results from the electrostatic shield on the Kosmos-936 biosatellite are reduced to the following:

The pattern of charge accumulation in the space environment, on the model ESS exposed to an external electron flux, was studied for the first time;

Data were obtained for the first time, on the pressure near the biosatellite and inside the model ESS;

Information was obtained on the amount of current leakage through the structural materials (insulators) in the vacuum surrounding the biosatellite; /63

The possibility was studied of increasing the potential difference, by means of mechanical increase in the distance between electrodes;

The conditioning of insulated high voltage electrodes by charging them with an external electron flux was studied;

Information on conduction currents of the high voltage vacuum gap was refined;

Reliability of operation of integrated circuits under space flight conditions was studied;

Information was obtained on the effect of space flight factors on the materials used in the production of electronics products.

The possible energy characteristics of an actual electrostatic shield operating autonomously were determined from the model ESS data obtained.

By means of a dielectric shield, studies of the stability of the electrical space charge in special dielectrics under open space conditions were continued. Such studies are one stage of work to determine the possibilities of the use of dielectrics in the radiation protection of space vehicles or separate elements of them.

The dielectrics were placed in four type KNA-1207 scientific

equipment containers, installed, as in the preceding experiments in the Kosmos-690 and Kosmos-782, on the outer surface of the descent vehicle. Each container consists of a bottom and a cover, closing in front of the descent vehicle. Special plates with compartments, in which specimens of the dielectrics under study were attached, were installed in the bottoms of the containers. The specimens had the shape of flat discs, each 5 mm thick and 40 mm in diameter. The total number of specimens exposed was  $N=24$ .

/64

There was a space charge of  $\sim 10^{-6}$  kl/cm<sup>3</sup> in a portion of the specimens beforehand. It was produced in them, by means of irradiation with 200 keV electrons, in the accelerator of the neutron physics laboratory, Joint Institute of Nuclear Research in Dubna. The other portion of the specimens was not charged, and it was used to obtain comparative data.

Besides the dielectrics, dosimetric assemblies (DA) and track detectors (TD) and solar battery cells were installed in the containers. The DA and TD were used to measure the radiation factors of space flight. Inspection of the containers after their return to the earth showed the following. The container surfaces were severely charred and the protective foil covering the outer surface of the containers was almost completely burned up. The containers were in air tight condition. The objects placed inside the containers were undamaged. An exception was the portion of the plates placed in the container covers. The brief effect of high temperature  $T > 102^{\circ}\text{C}$  was recorded on the TD plates in two of the four containers. Concerning the objects placed on the bottom of these KNA, no appreciable changes were noted by external inspection.

Ground processing of the experimental data is now being conducted, and measurements of the potential in the specimens and dosimetric measurements are being made.

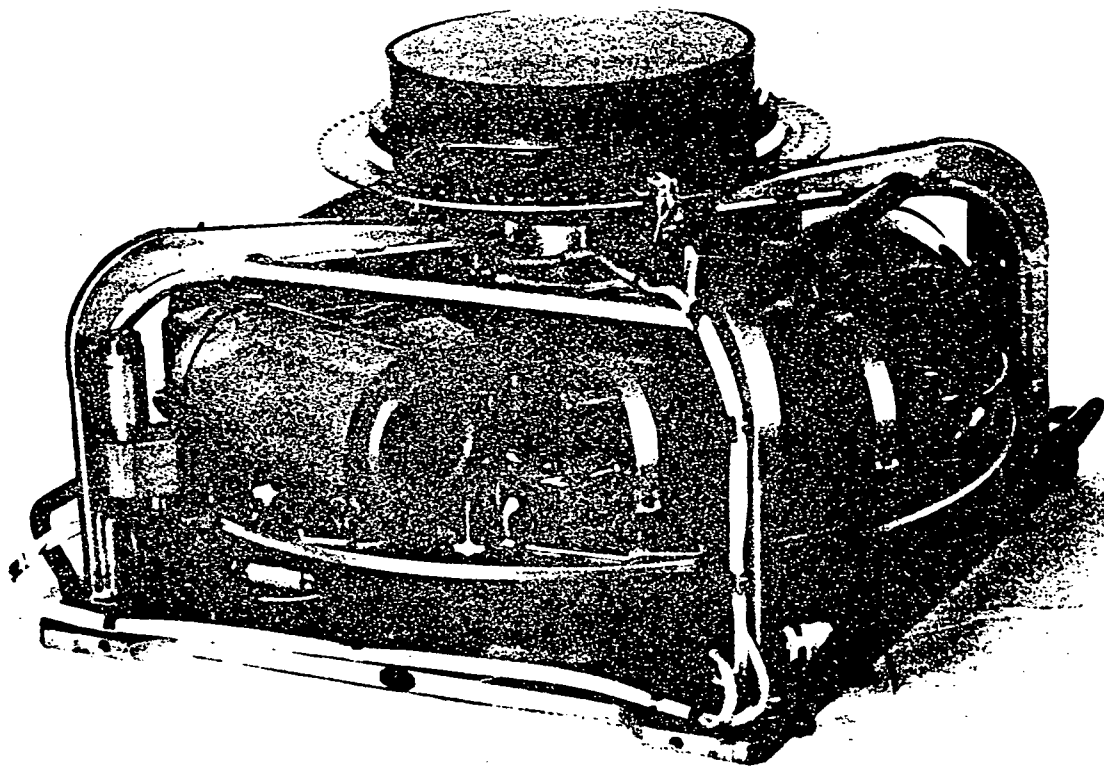


Fig. 1. Centrifuge for individual maintenance of 5 laboratory animals.

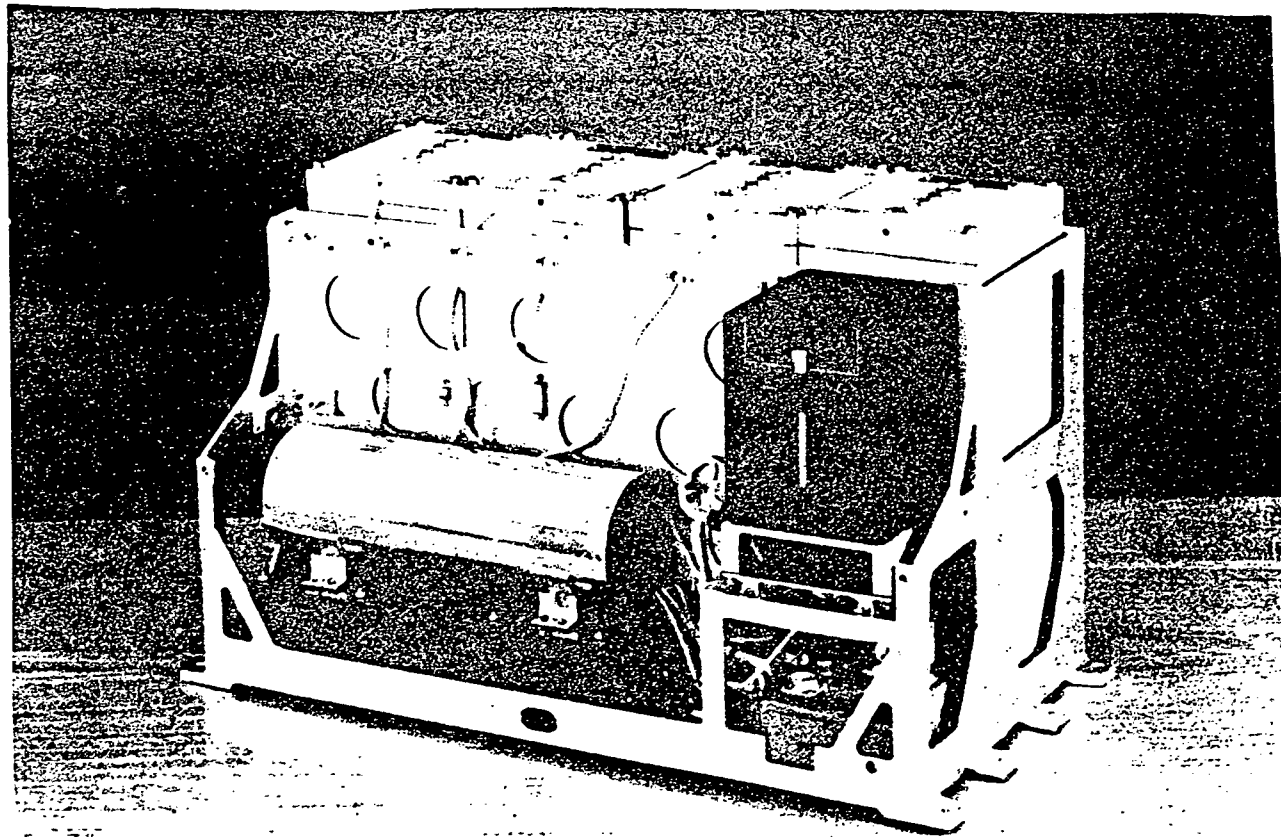


Fig. 2. Biological studies block

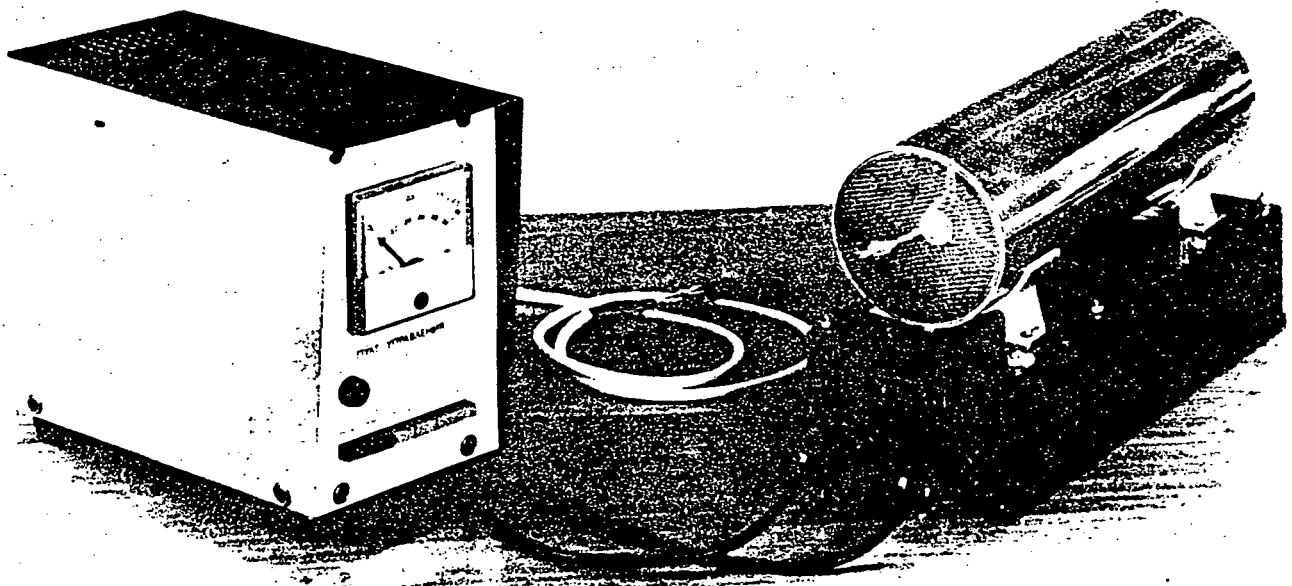


Fig. 3. ChSSR apparatus for study of heat exchange processes.

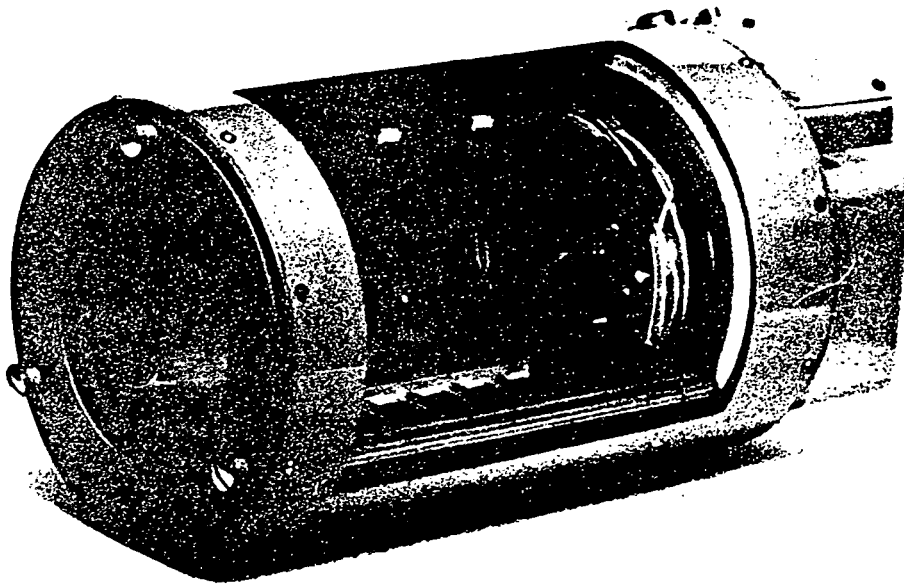


Fig. 4. Cage placed in centrifuge.

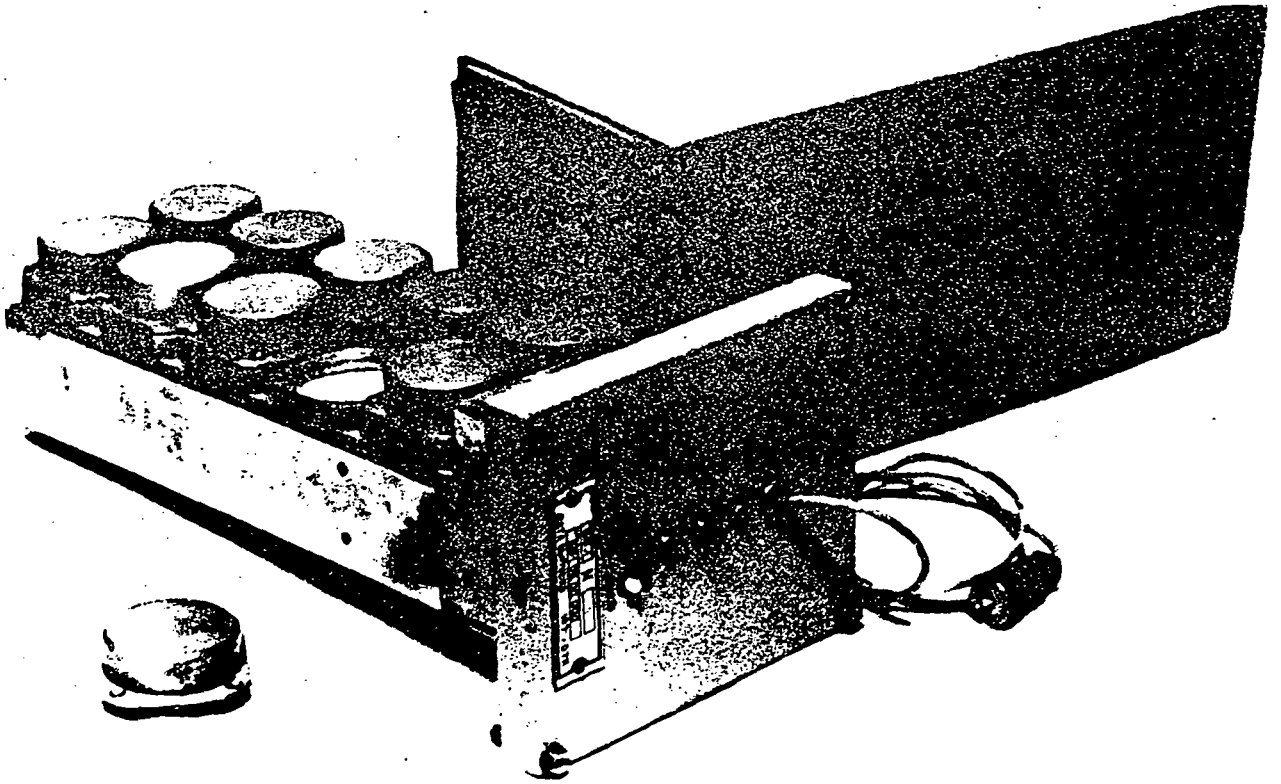


Fig. 5. Biological fixative.



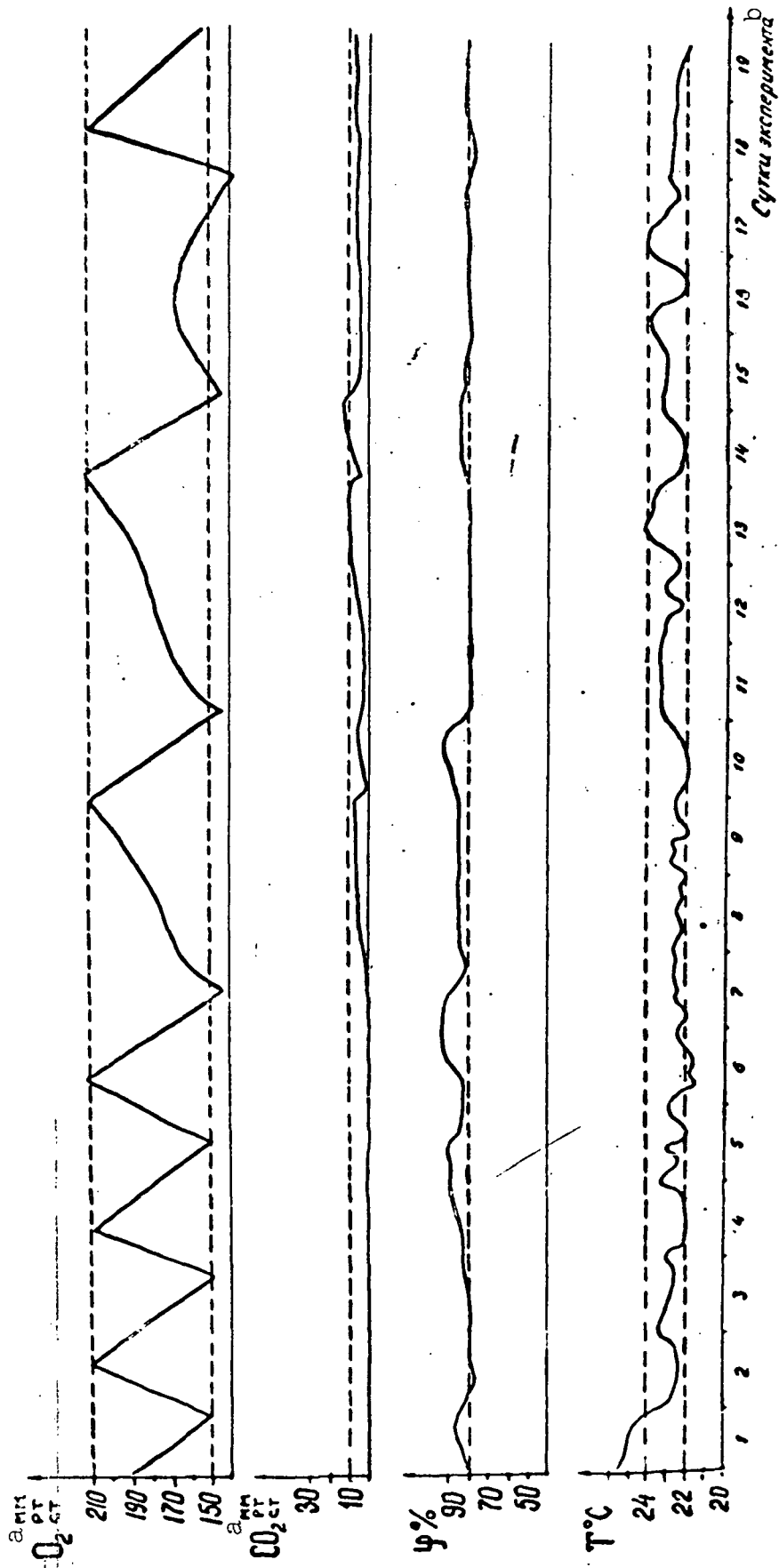


Fig. 6. Graphs of change in gaseous environment parameters in descent vehicle.

Key: a. mm Hg  
 b. Day of experiment



Fig. 7. Research complex model.

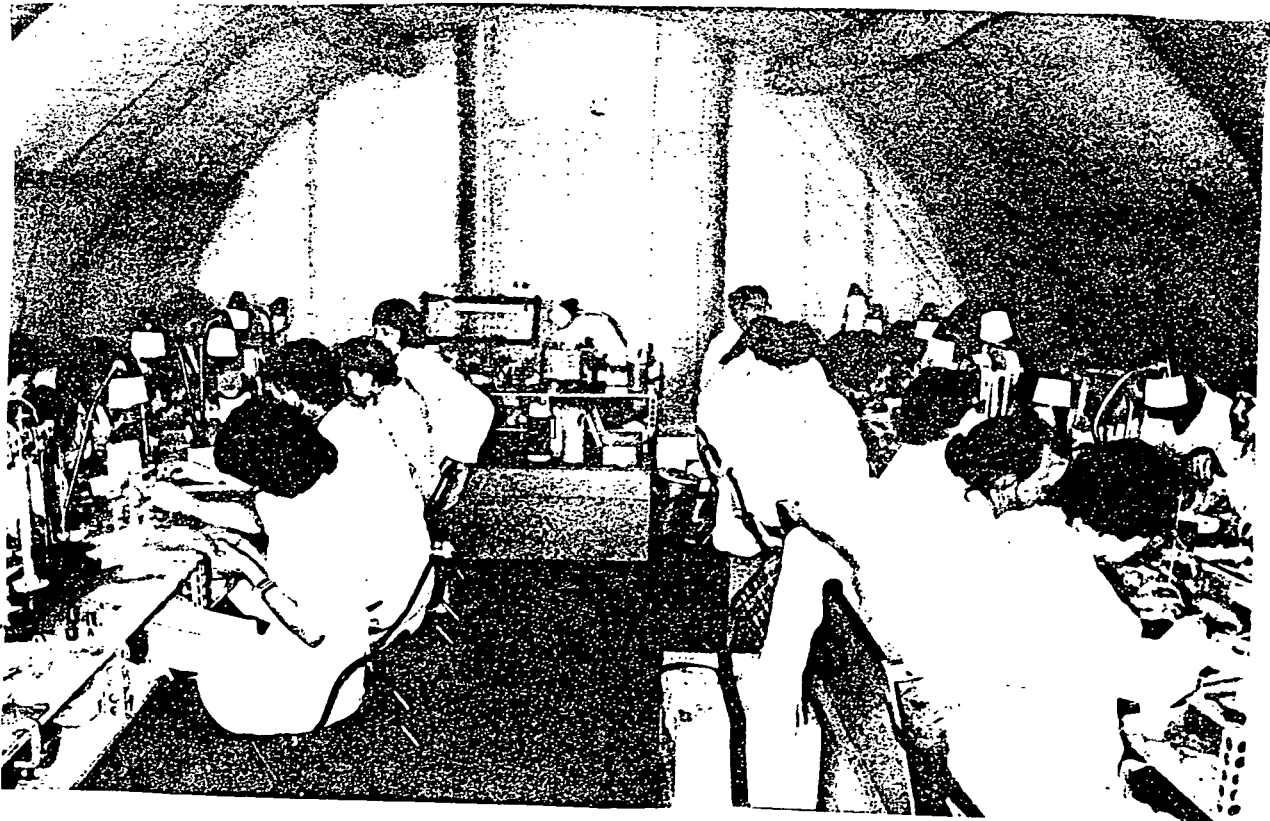


Fig. 8. General view of chamber for conduct of morphological and biochemical studies at biosatellite descent vehicle landing site.

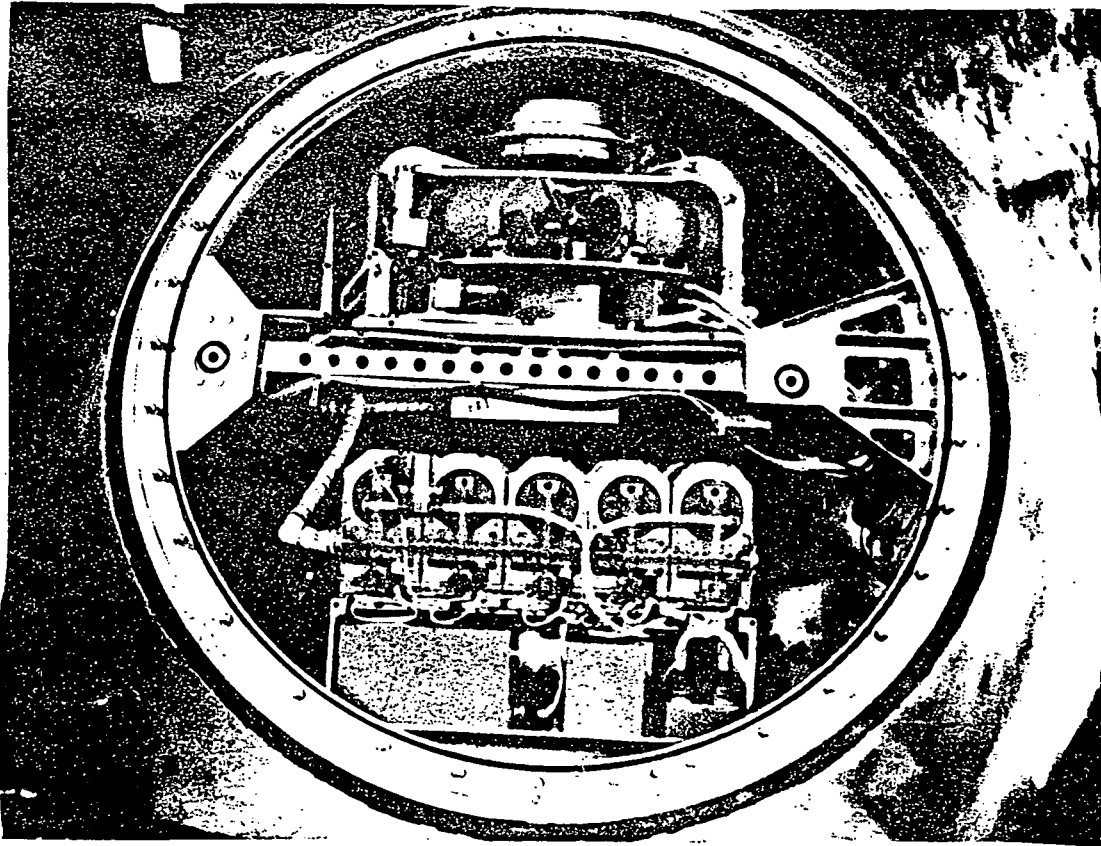


Fig. 9. Satellite descent vehicle mockup.

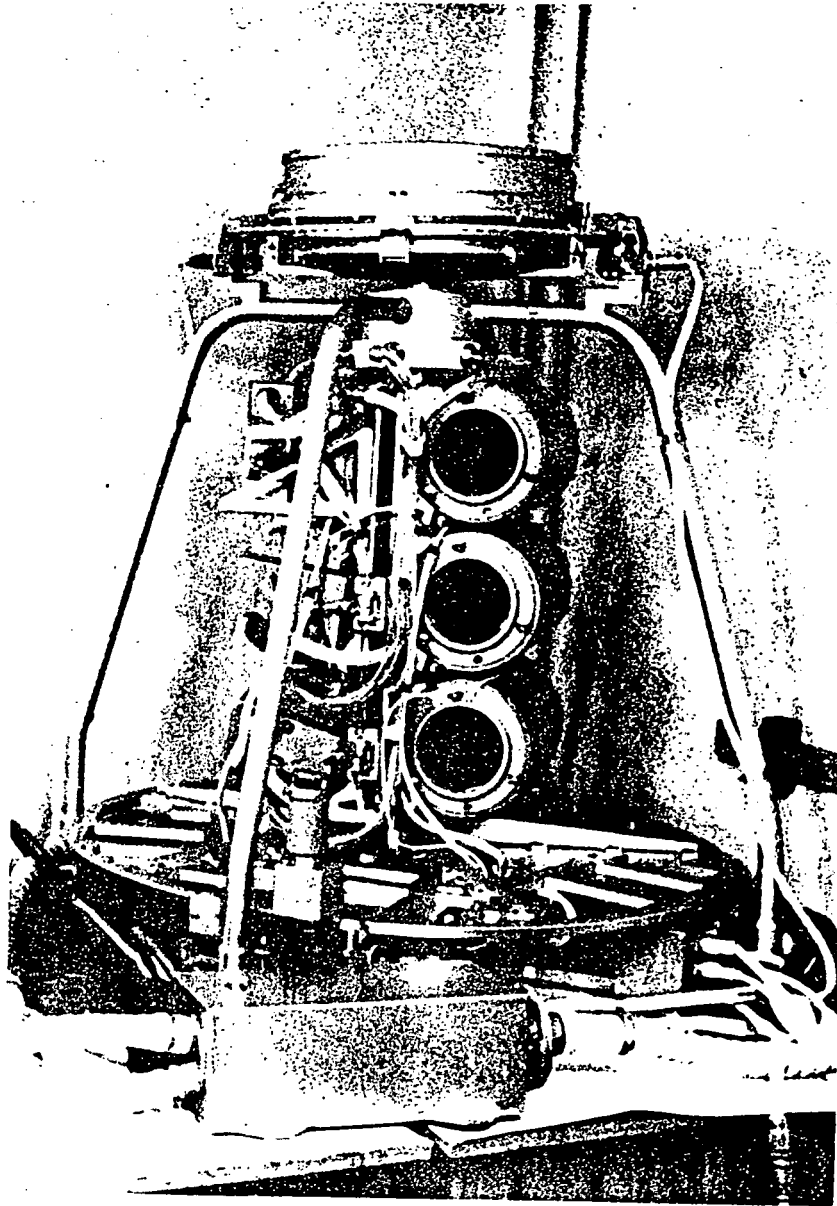


Fig. 10. Centrifuge with small radius of rotation (Bios-Omega).

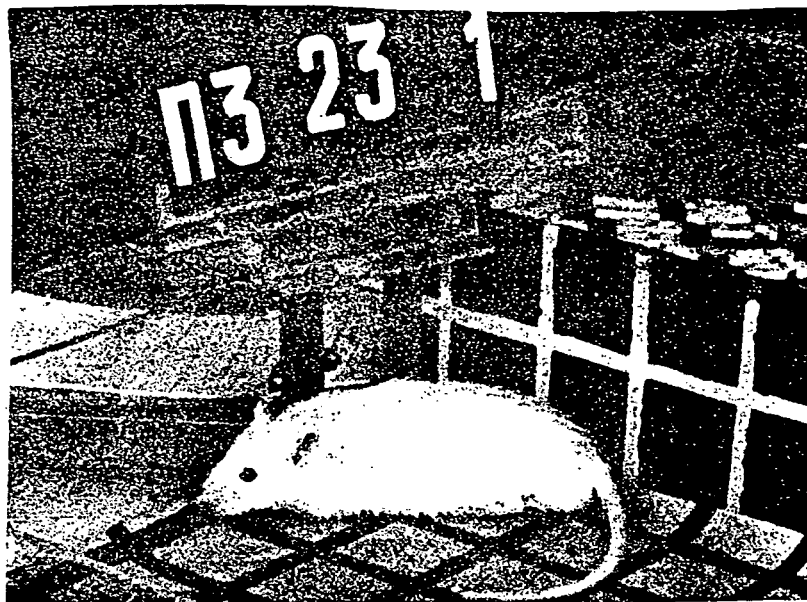


Fig. 11. General view of animal on landing day after stay in weightlessness; rat is indifferent to surrounding situation, slightly active, with disshevelled fur, it lies prone, pressed down to the floor of the area.

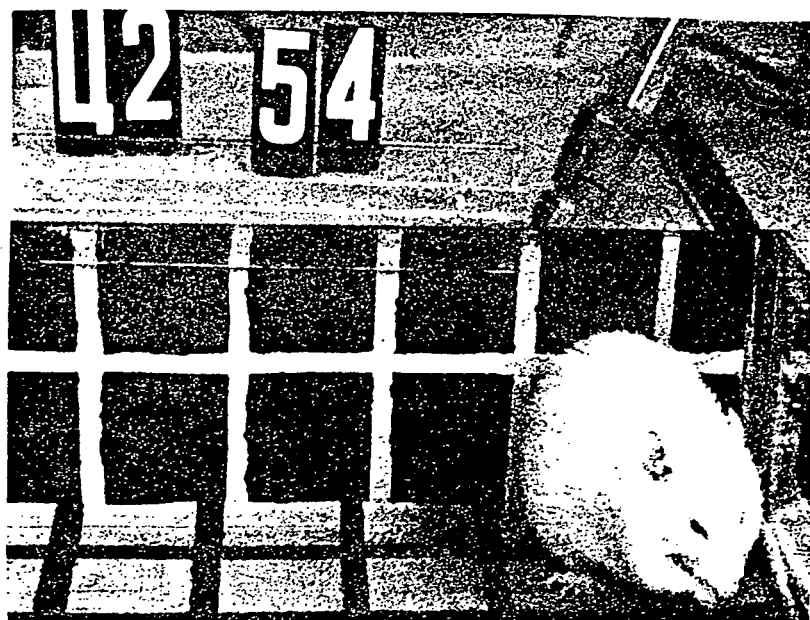


Fig. 12. General view of animal on landing day after stay under artificial gravity (1 g) in space flight; rat freely feels itself under earth gravity conditions, is active, "it washes itself."

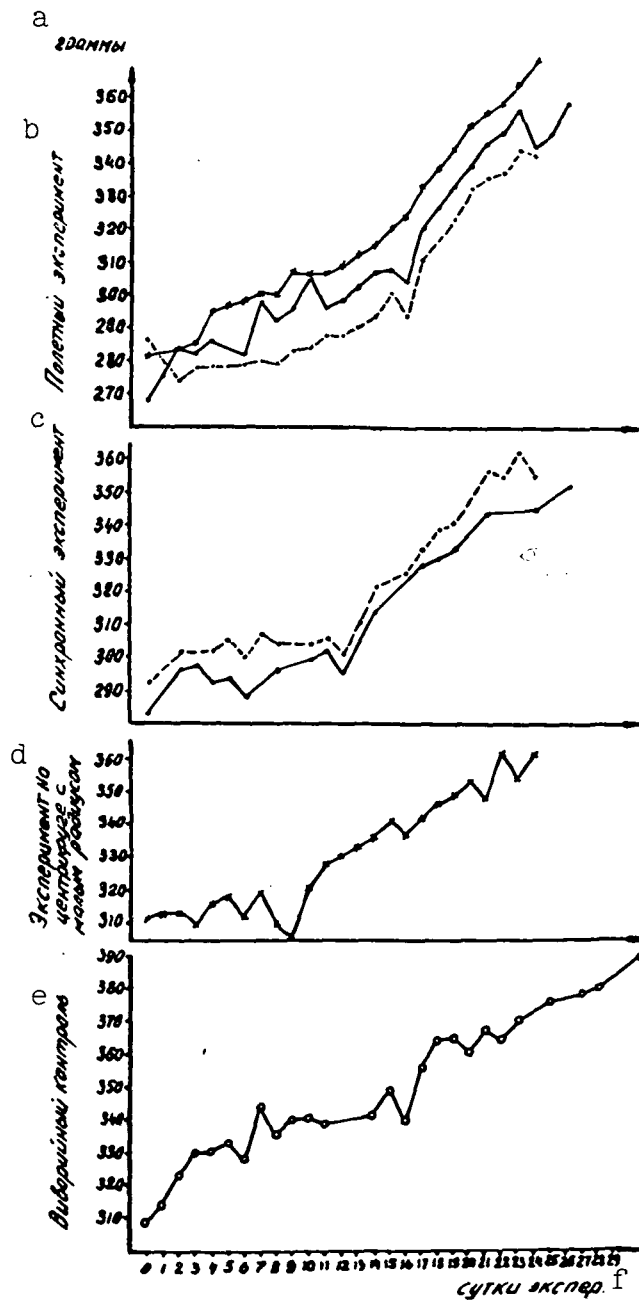
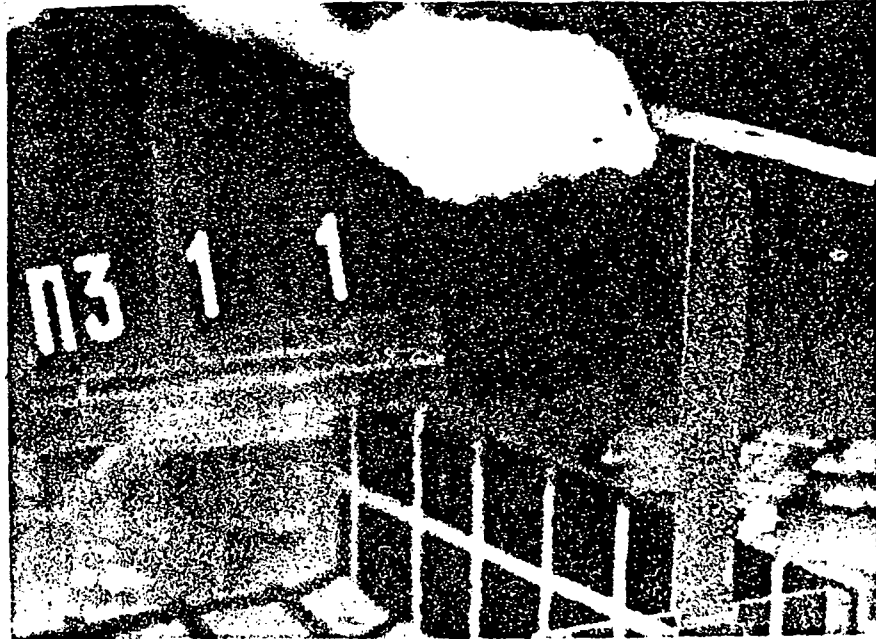


Fig. 13. Change in body weight of animals in readaptation period:

XXXXXX Group Ts<sub>2</sub>.  
 ————— Group N<sub>4</sub>  
 -.-.-.- Group N<sub>3</sub>  
 o-o-o-o- Vivarium control

Key: a. Grams  
 b. Flight experiment  
 c. Synchronous experiment  
 d. Small radius centrifuge experiment  
 e. Vivarium control  
 f. Day of experiment

a)



b)

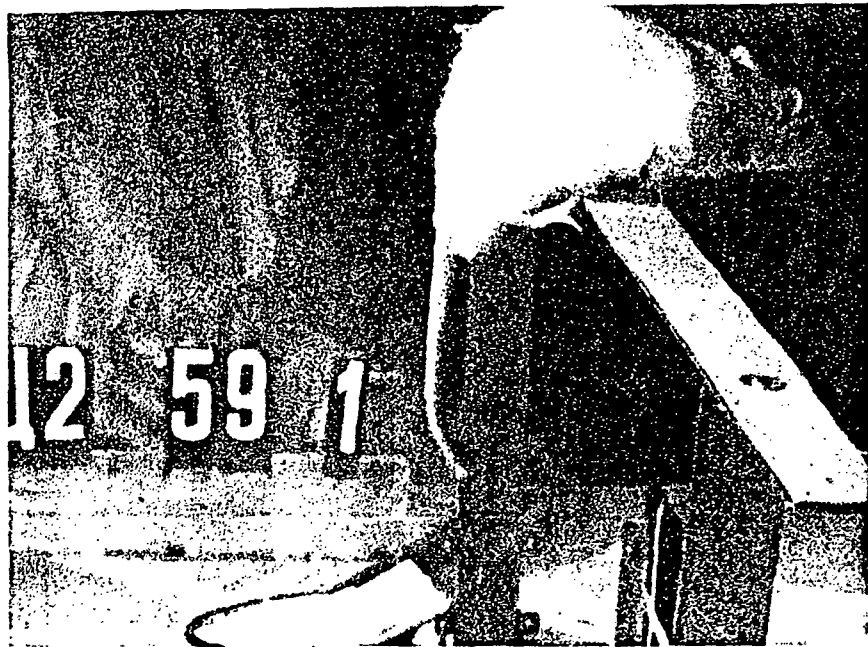


Fig. 14. Ability of rat to preserve equilibrium on beam on landing day: a. rat which was in weightlessness cannot hold on to the beam; b. rat which was under artificial gravity during flight preserves equilibrium.