Biology in flights of automatic space vehicles

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On April 12, 1961 with the space flight of Yuri Gagarin, the era of piloted cosmonautics was began.
Dog’s Space

50 launches of dogs aboard ballistic missiles were carried out in the USSR
USSR experiments with dogs in rocket flights
General Information

<table>
<thead>
<tr>
<th>Specific of flight</th>
<th>Launch, year</th>
<th>Amount of launches</th>
<th>Microgravity min.</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude 100-110 km /rocket P-2A/</td>
<td>1951</td>
<td>6</td>
<td>3,7</td>
<td>• Heart frequency</td>
</tr>
<tr>
<td></td>
<td>1954</td>
<td>3</td>
<td></td>
<td>• ECG</td>
</tr>
<tr>
<td></td>
<td>1955</td>
<td>3</td>
<td></td>
<td>• Arterial blood pressure</td>
</tr>
<tr>
<td></td>
<td>1956</td>
<td>3</td>
<td></td>
<td>• Skin temperature respiratory frequency</td>
</tr>
<tr>
<td>Altitude 212 km in /rocket P-2/</td>
<td>1957</td>
<td>5</td>
<td></td>
<td>• Behavior</td>
</tr>
<tr>
<td></td>
<td>1958</td>
<td>2</td>
<td>6,0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1959</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1960</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altitude 450-473 km /rocket P-5/</td>
<td>1958</td>
<td>3</td>
<td>10,0</td>
<td></td>
</tr>
</tbody>
</table>
USSR experiments with dogs in rocket flights
Main results

• Rocket flight does not lead to any significant changes in cardiovascular and respiratory systems, in performance and general state of health after flight

• The launch and reentry accelerations and microgravity are biological most significant factors of flight

• Radiation for short flights is not dangerous

• Developed life support systems are effective at the different stages of flight including ejection and parachuting from high altitudes
Dog Laika

50 years of anniversary of the first Earth inhabitant in space aboard the second satellite (November 1957)
The earth’s artificial satellite – 2 and capsule for dog Laika
The research in flight of Laika

Recorded parameters:
- respiration frequency
- arterial blood pressure
- ECG in one lead

- Planned duration of experiment - 7 days
- Real duration of experiment – 5 hours

Summary of results
The life in space is possible
The costume and waste collection system for Laika
Belka and Strelka are the first animals recovered from the orbit.

Ludmila Radkevich and Van Clibern with the flight dogs.

Belka and Strelka
### Animal flights aboard unmanned modifications of Vostok space crafts

/Space ships-satellites/

<table>
<thead>
<tr>
<th>Space craft-satellite (SCS)</th>
<th>Launch, year</th>
<th>Duration of flight, hr</th>
<th>Bioobjects</th>
<th>Recording parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSS-2</td>
<td>19.08.1960</td>
<td>27</td>
<td>2 dogs, rodents and others</td>
<td>• Heart rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Blood pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Breathing rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Body temperature</td>
</tr>
<tr>
<td>SSS-3</td>
<td>01.12.1960</td>
<td>24</td>
<td>2 dogs, rodents and others</td>
<td></td>
</tr>
<tr>
<td>SSS-4</td>
<td>09.03.1961</td>
<td>1.92</td>
<td>1 dog, rodents and others</td>
<td></td>
</tr>
<tr>
<td>SSS-5</td>
<td>25.03.1961</td>
<td>1.92</td>
<td>1 dog, rodents and others</td>
<td></td>
</tr>
</tbody>
</table>

Note: SSS-3 was burned up in the atmosphere upon reentry
Main results

- The flights demonstrated that man can go into space and survive
- The life support and medical monitoring system proved adequate

Summary

Human flight into space is possible
Physiological studies of two dogs during and after the 22 day demonstrated for the first time that it was necessary to develop and use countermeasures against the adverse effects of microgravity.
Bion program

Bion integrated physiological, morphological and biochemical studies using animals, plants, microorganisms and biosamples aboard the satellites specially designed for biological and biomedical research in space.
Bion program

1973 – 1997 - eleven biosatellites flights
Flight duration: 5 to 22.5 days
Launch Site: cosmodrome Plesetsk
Recovery Site: Kazakhstan
Participants: USSR/Russia, USA, France, Czechoslovakia, Poland, Hungary, Germany, Netherlands, Canada, China
Bion program
bioobjects and hardware

- rats
- monkeys
- reptiles and amphibia
- microorganisms
- insects
- worms
- cell and tissue cultures
- fish and fish eggs
- plants
- avian eggs
Biological experiments in Bion flights demonstrated that exposure to microgravity did not cause:

- gene and chromosome mutations
- cell division disintegration
- disruption of hereditary information transfer
- changes in ontogenetic development
- chronic stress
- non-reversible changes in physiological systems
- unfavourable aftereffects

Bion results did not reveal changes that may limit human presence in space
Rats experiments

212 rats were launched into space aboard Bion satellites.
## Experiments with rats on Bion biosatellites

<table>
<thead>
<tr>
<th>Mission</th>
<th>Year</th>
<th>Duration, days</th>
<th>Area of research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bion-1</td>
<td>1973</td>
<td>21.5</td>
<td>Microgravity effects /morphobiochemistry/</td>
</tr>
<tr>
<td>Bion-2</td>
<td>1974</td>
<td>20.5</td>
<td>Radiation sensitivity</td>
</tr>
<tr>
<td>Bion-3</td>
<td>1975</td>
<td>19.5</td>
<td>Microgravity effects /morphobiochemistry/</td>
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<tr>
<td>Bion-4</td>
<td>1977</td>
<td>18.5</td>
<td>Artificial gravity effects</td>
</tr>
<tr>
<td>Bion-5</td>
<td>1979</td>
<td>18.5</td>
<td>Microgravity effects /morphobiochemistry/</td>
</tr>
<tr>
<td>Bion-6</td>
<td>1983</td>
<td>5</td>
<td>Prenatal development</td>
</tr>
<tr>
<td>Bion-7</td>
<td>1985</td>
<td>7</td>
<td>Microgravity effects /morphobiochemistry/</td>
</tr>
<tr>
<td>Bion-8</td>
<td>1987</td>
<td>12.5</td>
<td>Microgravity effects /morphobiochemistry/</td>
</tr>
<tr>
<td>Bion-9</td>
<td>1989</td>
<td>14</td>
<td>Wound/bone fracture healing</td>
</tr>
</tbody>
</table>
Artificial gravity

The Russian scientist K. Tsiolkovskiy but forth a concept of the artificial gravity as a countermeasure which was used in 3 Bion flights.

Artificial gravity produced by rotation prevented unfavorable changes in muscles, bone and heart myocardium.
Radiobiology studies

In Bion-2 flight (20.5 days) two groups of rats were exposed to gamma radiation at a dose of 220 or 800 cGy from a 137 Cs source on flight day 10.

The study showed that radiation sickness and post-radiation recovery in space and on the ground developed in a similar manner.
Bion flights with monkeys

10 years of the last monkey flight in space aboard Bion-11

Oleg Gazenko
Former director of institute for biomedical Problems

Boris Lapin
Director of primate center of Russia

Rhesus monkey
# Experiments with monkeys on Bion biosatellites

<table>
<thead>
<tr>
<th>Mission</th>
<th>Year</th>
<th>Duration days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bion-6</td>
<td>1983</td>
<td>5</td>
</tr>
<tr>
<td>Bion-7</td>
<td>1985</td>
<td>7</td>
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<tr>
<td>Bion-8</td>
<td>1987</td>
<td>12.5</td>
</tr>
<tr>
<td>Bion-9</td>
<td>1989</td>
<td>14</td>
</tr>
<tr>
<td>Bion-10</td>
<td>1992</td>
<td>11.6</td>
</tr>
<tr>
<td>Bion-11</td>
<td>1996</td>
<td>13.7</td>
</tr>
</tbody>
</table>
Parameters recorded in monkey experiments on Bion biosatellites

- Neuronal electrical activity of vestibular nucleus
- Electrooculography
- Electrocorticography
- Head pitch movements
- Conditioned reflexes skills
- Electrocardiography
- pO₂ in brain cortex
- Arterial blood pressure
- Blood flow velocity in common carotid artery
- Rheopneumography
- Neck electromyography
- Calf electromyography
- Ankle tendon force
- Body movements
- Foot pedal function
- Body and skin temperature
- Electrogastrography
Gravitational physiology
Summary of results

Rat and monkey studies showed many reversible structural, functional and metabolic changes in muscles, bones, cardiovascular, neuroendocrine and neurosensory systems.

These changes were adaptive and can be viewed as the deconditioning syndrome.
Muscle and bone studies of rats and monkeys showed many changes in slow-twitch myofibers of antigravitational muscles and in weight-bearing bones. The results were used to develop exercises for training tonic muscles and loading of spine and extremities, which were incorporated in the crew fitness program.

Study of monkey vestibular system and vestibulo-ocular interaction contributed to the development of human engineering requirements and training programs that found application in human missions.
Animal experiments in space and medicine

“Medicine will become what it should be, i.e., deliberate and, consequently, always and fully expedient, only after it has passed the fiery test of experiment”

(I.P. Pavlov, first Russian Nobel prize winner, 1904)
General Conclusion

• Since the first flight of animal in rocket space biology especially Bion program contributed significantly to basic and applied life sciences

• “It is believed that space biology advancement will facilitate manned interplanetary voyages and space exploration. Moreover, it will help us gain a better insight into fundamental principles of life in the Universe”

BioCosmos (Bion-M) Program
(2006-2015 гг.)
Concept of Future Bion (BioCosmos) flights

The rodents are main priority biospecies for biomedical research.

The reasonable combining of phenomenological studies with narrow goal-directed experiments.

Utilization as much as possible of all animal tissues for research.

Use in scientific program of methods and technics based upon recent achievements of physics, chemistry and molecular biology.

The increase of flight duration up 45 days
The increase of energy supply for scientific hardware
The increase of orbit height in apogee and perigee
The international cooperation and data sharing
The Main Goals of Animal Research in Space Flights

Study of dependence of structural, metabolic and functional changes in organism upon duration of stay in microgravity.

Study of specificity of pathology and illness in space flights (bone and soft tissue trauma, antibacterial resistance, immunogenesis, oncogenesis, tolerance to drugs).

Radiobiological study.

Study of biological effects of artificial gravity.

Study of significance of age, sex and body mass in adaptive reactions.

Test of new methods and means of prophylaxis and medical monitoring of health.

Development of new technologies for ISS and missions to Mars and Moon.
**Russian experiments aboard “BION-M” №1**

**The launch-2012**
**Duration of flight-30 days**

<table>
<thead>
<tr>
<th>Type of experiment</th>
<th>Bioobjects</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study the systemic and cellular mechanisms of adaptation to microgravity</td>
<td>Mongolian gerbils-8, Mice-45, Geckons-10, Snails-20</td>
<td>Kontur-LM, MLG-01, BB-1 M, BB-1 M</td>
</tr>
<tr>
<td>Study the effects of microgravity and combined effects of microgravity and factors of opened space</td>
<td>Moss, Lichen, Microbes, Biosamples</td>
<td>BB-1 M, Biocont-B, KNA</td>
</tr>
<tr>
<td>Study the structural and functional changes of natural biota in space flight</td>
<td>Natural soils</td>
<td>Biocont-B</td>
</tr>
<tr>
<td>Study the microgravity effects upon cytoskeleton, potential of regeneration and gene expression of plant cells</td>
<td>Culture of plant tissue</td>
<td>Biocont-B</td>
</tr>
<tr>
<td>Study the microbial decomposition of organic substrates in space flight</td>
<td>Anaerobic microorganisms Cellulose</td>
<td>Fragmenter</td>
</tr>
<tr>
<td>Artificial meteorite and survival of simple forms of life during reentry</td>
<td>Microbes, Biopreparations</td>
<td>Artificial meteorite outside of spacecraft</td>
</tr>
<tr>
<td>Radiation dosimetry experiment</td>
<td></td>
<td>Dosimeters</td>
</tr>
</tbody>
</table>