RESULTS AND PROSPECTS OF MICROBIOLOGICAL STUDIES IN OUTER SPACE

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Abstract. The domestic and foreign literature on microbiological studies in outer space from 1935 through 1970 is reviewed, with separate references to results obtained with balloons, high-altitude rockets and artificial earth satellites. The results of most experiments warrant the conclusion that spaceflight factors do not interfere with growth, development, cellular and nuclear division or mutagenesis in microorganisms, nor exert a modifying action on the radiation effect. In those cases where effects are observed they are as a rule attributed not to spaceflight factors but to differences in the maintenance conditions of the control and flight series of microorganisms in the period from their shipping from the laboratory till their return for study.

One exception are the experiments carried out on twelve spacecraft by Zhukov-Verezhnikov and his co-workers in the U.S.S.R. and the experiment performed on Bios 2 by Mattoni in the U.S.A. These studies show that spaceflight factors appear to affect the subcellular processes in the lysogenic bacteria *E. coli* and *Salmonella typhimurium*. The evidence obtained by Soviet investigators indicates that bacteria exhibit increased phage production. Mattoni’s experiments show that spaceflight factors reduce or repress the phage production of lysogenic bacteria even under in-flight exposure to γ rays in doses of 265, 645 and 1640 rad.

Both those two groups of results are statistically significant and appear to be true to fact. However, it is difficult as yet to give preference to any of them and to explain the differences observed. From a theoretical viewpoint, of greatest interest is the study of the mechanism leading to impairment of subcellular processes in bacteria (be it induction or repression) reproduced in weightlessness.

It is concluded that it is desirable that microbiological studies in outer space should employ only those microorganisms that have received a detailed study in physiological, cytological, biochemical and genetic aspects.

Three problem areas are formulated to be concentrated on by space microbiology: (1) Study of bacterial growth in weightlessness; (2) Study of chromosome-episome interaction in bacteria during development in weightlessness; and (3) Elucidation of the selective role of weightlessness in populations of microorganisms.

The authors believe that in general the so-called problem of the 'effects of spaceflight factors on microorganisms' no longer exists at the present time. For that reason, experiments with microorganisms in outer space should have a specific, clearly formulated objective.

Microorganisms are widely used in space flight experiments along with animals and higher plants. The results of microbiological studies were partly summed up in 1967 (Parfenov) without, however, giving a detailed analysis of their scientific value.

The purpose of this paper is to assess the earlier as well as more recent experimental evidence and to outline the objectives and methodology of microbiological studies in outer space.

1. Experiments in Balloons and High-Altitude Rockets

The first microbiological study in space was undertaken in 1935 in the stratosphere Explorer 2 (Stevens, 1936) which attained a record altitude of 25 km 286 m. Scientific research was concerned with the effect of conditions practically equivalent to outer
space on the survival of spores of seven fungal species. The material was placed in small quartz tubes closed with cellulose wool at both ends. The tubes were fixed in place outside the stratosphere. The flight lasted four hours, with the spores exposed to low temperature, light and ultraviolet rays, low barometric pressure, and cosmic radiation. After the flight, the survival rate of five fungal species did not alter, while the death rate of *Cladosporium sporogenes* was high; no data on the seventh species were reported.

The sounding of upper atmospheric layers using balloons with biological objects aboard was resumed in the late forties. Balloons flew altitudes of up to 35 km, that is to the upper limit of penetration of primary heavy cosmic particles. The light duration and exposure time increased to 24 h. Apart from animals and higher plants, various species of microorganisms were used in some flights.

The neurospora exposed to space did not exhibit detectable genetic changes (Simons and Parks, 1956). No detailed description of these experiments is contained in the available literature.

The results of sounding the lower radiation belt by a rocket with neurospores aboard, carried out according to the NERV Project, were ambiguous in many respects (de Busk, 1961). The rocket went vertically to a height of 1900 km and was in the range of the radiation belt for a period of 26 min. The test material exhibited 200 hundred times as many mutations as the controls. The mutants proved to be auxotrophic in amino acids, vitamins, and purine and perimidine bases. Physiological disturbances were also noted, consisting in the inability of most cells (97%) of the test series to grow on a minimal medium. Addition of amino acids, vitamins, citrate, succinate, ketoglutarate or organic acids to the medium increased (from 16–100%) cell survival and germination rates. The low percentage (3.2%) of surviving test cells showed a poor correlation with the effect of flight factors, being primarily due to cell drying before contact with millipore filters. Following such drying, only 4.4% of cells survived in the control. Temperature in the capsule did not rise above 45°C. No information on the radiation situation was reported.

Experiments concerned with the environmental effects, which in many respects were similar to those prevailing in outer space, were carried out by Hotchin and his co-workers during flights of two balloons and two high-altitude rockets (Hotchin et al., 1965; Lorenz et al., 1966).

The poliomyelitis virus, phage T-1, and spores *Penicillium roguiforti* and *Bacillus subtilis* were used. The balloons attained a height of 35 km, and the flight lasted about 6 hours. The rockets flew to a height of 160 km. The biological material on the surface of millipore filters was brought to the outside by means of a special device. Some of the material was unprotected and some was screened by aluminum foil 38 μ thick. Microorganisms stayed outside for 90 min during one balloon flight and for 120 min during the other. The outer exposure during rocket flights to altitudes of 60–124 km and 82–160 km was 206 and 143 s respectively. The experiments confirmed the results of A. Stevens that short-term exposure to the cosmic environment (high vacuum, ultraviolet and cosmic radiation, and large temperature variations, from +24°C to