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RESULTS OF INVESTIGATION OF THE EFFECT OF COSMIC RADIATION AND OTHER FACTORS OF COSMIC FLIGHT ON LYSOGENIC BACTERIA AND HUMAN CELL CULTURES

by

N. N. Zhukov-Verezhnikov, I. N. Mayskiy, et al.

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ABSTRACT: Single-layer cultures of normal human cells (fibroblasts and amniotic cells) and human cancer cells (Hela strain), together with cultures of lysogenic bacteria (E. coli K-12), have been consistently used as radiation indicators on Soviet spacecraft. Results of these experiments have shown that repeated exposure of a culture of Hela cells to spaceflight factors on the "Vostok-4" and "Vostok-6" flights produced changes in experimental cells as compared with laboratory controls and with Hela cells exposed on one spaceflight only. A longer latent period of recovery of growth capacity and other characteristics [not named] were noted in twice-flown cultures. In addition, the coefficient of proliferation for Hela cells exposed on both "Vostok-4" and "Vostok-6" was one-half that for intact controls and for Hela cells exposed to spaceflight only once. These data suggest that spaceflight factors have a direct dependence of biological effect on length of spaceflight exposure has not been established in experiments with the other radiation indicator, the lysogenic bacteria E. coli K-12 (λ). It is interesting to note that when the same Hela cells used on "Vostok-4" and "Vostok-6" were also exposed on "Voskhod-1," a well-defined drop in the proliferation coefficient was observed in comparison with intact cultures. Other reliable differences [~~not enumerated~~] were also found between intact controls and thrice-exposed cultures. However, no reliable differences could be detected between thrice-exposed Hela cells and a control strain used only on "Vostok-6." It is suggested that the biological effect of spaceflight may be the result of the combined influence of radiation, vibration, and weightlessness. English translation: 4 pages.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

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RESULTS OF INVESTIGATION OF THE EFFECT OF COSMIC RADIATION AND OTHER FACTORS OF COSMIC FLIGHT ON LYSOGENIC BACTERIA AND HUMAN CELL CULTURES*

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The use of microbiological and cytological models for indicators of the biological effects of the factors of cosmic flight is of considerable interest in connection with the future completion of the space program.

The high sensitivity of the lysogenic bacteria to the action of radiation (x-rays, γ-rays, high-energy protons, fast neutrons) is associated with the presence in these organisms of a prophage, intimately linked to the genetic structures of the bacterial cell and acting as the carrier of the genetic information of the phage. The presence of prophage as a genetic marker in the cells is a potentially lethal character for the lysogenic bacteria, for if exposed to even small doses of ionizing radiation the bacterial cell dies as a result of realization of the genetic phage information by the development of a productive reaction.

For this reason the lysogenic bacteria may be used both as biological dosimeters of cosmic radiation and as genetic indicators, or marking factors, capable of giving rise to genetic changes of a pathological character.

Monolayer cultures of human cells are also sensitive to the action of ionizing radiation. Because of this, beginning with the flight of the second cosmic ship and in later experiments, in addition to other objects, lysogenic bacteria and cultures of normal and malignant human cells (strains of fibroblasts, amnion and HeLa cells) have been used.

The experiments have shown that with an increase in the duration of the cosmic flights there was in increase in the phage-producing activity of the lysogenic strain E. coli K-12 (λ), expressed by an increase in the number of phage particles in the experimental specimens by comparison with the spontaneous phage formation in the control. The biological action of the factors of cosmic flight was also manifested on the other objects used and, in particular, on the culture of human cells. Important evidence of this is obtained from the fact that during the relatively short flights of Yu. A. Gagarin and G. S. Titov, no inductive action of ionizing radiation on lysogenic bacteria could be detected.

Cultures of human cells exposed on the same craft were essentially indistinguishable in viability and in such criteria as the coefficient of proliferation, the percentage of dead cells, and the morphological, antigenic and cultural properties, from control cultures kept at the lauching site or in the laboratory. However, analysis of the cultures of lysogenic bacteria after the flights of the cosmic ships "Vostok-3" and "Vostok-4" showed that the number of phage particles in the experimental specimens was 4.6 and 1.9 times respectively larger than the spontaneous level of phage production in the control group. The inductive effect was greater in the experiments on the ship "Vostok-3," evidently because of the longer duration of its flight.

The importance of the longer exposure and of repeated exposures to the factors of cosmic flight is also demonstrated by the results of the study of the properties of strains of normal and malignant human cells. It was found that after repeated flights on the cosmic

ships "Vostok-4" and "Vostok-6" the latent period of recovery of ability to grow and of certain other properties was longer in a culture of HeLa cells than in cells of the same line exposed only once to the factors of cosmic flight or in control cells left in the laboratory. This difference was particularly obvious when a quantitative index such as the coefficient of proliferation (the number of times by which the number of growing cells exceeds the number of seeded cells) was compared: for a culture of HeLa cells exposed twice (on "Vostok-4" and "Vostok-6") it was nearly 50% lower than for an intact line of cells or for cells exposed only once.

These results suggest the occurrence of cumulation of the biological action of the factors of cosmic flight by the human cell cultures, although in subsequent experiments on lysongenic bacteria no direct, clear relationship could be found between the biological effect and the duration of exposure in cosmic space. Comparison of the results of the experiments carried out on lysogenic bacteria in the conditions of flight on "Vostok-3" and "Vostok-4" with the results of the experiments on the ships "Vostok-5" and "Vostok-6" showed that, despite the longer flight of the ship "Vostok-5" the degree of induction of the exposed lysogenic bacteria was almost the same as in the experiments on the cosmic ship "Vostok-3."

Analysis of the data for the phage-producing activity of the lysogenic strain E. coli K-12 (λ) exposed on the cosmic ship "Voskhod" shows no significant increase in the induced phage production in the specimens kept in the cabin of this ship over that observed in the controls. These results agree with those obtained in the experiment on the cosmic ship "Vostok-2," demonstrating the identity of the effects of the factors of flight on these two ships.

When a culture of human HeLa cells, previously exposed during flight on the ships "Vostok-4" and "Vostok-6", was exposed on the ship "Voskhod-1," it was found that it differed from an intact culture by its lower coefficient of proliferation, the more compact character of growth of its cells in colonies, the number of dead cells in the population, and

in several other properties. These differences were clear and stable. However, no noticeable and significant differences could be found between this experimental line of cells and the control line previously used in experiments on the ship "Vostok-6."

The biological effect found in the experiments on the cosmic ships is probably due to the combined action of the factors of cosmic flight, and especially of radiation, vibration and weightlessness. Terrestrial experiments have shown that vibration facilitates sensitization of the cells of a lysogenic culture to the action of γ-radiation (Co^{60}).

The further study of the genetic effect of these factors on various biological objects will be of great importance to the evaluation of the danger of flights and to the investigation of the problem of the stability of the ecologic system during prolonged flights.

FOOTNOTES

p. 1. *Given at the Jubilee Symposium of the Institute of Biological Physics, Academy of Sciences of the Czechoslovak SSR, held in Brno in May, 1965.