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VIII ВСЕРОССИЙСКАЯ НАУЧНО-ПРАКТИЧЕСКАЯ КОНФЕРЕНЦИЯ С МЕЖДУНАРОДНЫМ УЧАСТИЕМ, ПОСВЯЩЕННАЯ 50-ЛЕТИЮ ОСНОВАНИЯ ИНСТИТУТА ХИМИИ НЕФТИ

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ON NONLINEAR DYNAMICS OF BIOLOGICAL SYSTEMS IN THE PRESENCE OF MICROGRAVITY

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Cells in microgravity undergo dramatic changes in their dynamics and morphology, leading to two alternative phenotypes. This spontaneous transition from one to two contemporary present phenotypes is enacted by the mere changes in the gravitational field. The behavior of complex living systems is largely determined by their nonequilibrium dynamics and may be accompanied by qualitative changes in the "plasticity" occurring in the force field. The latter are similar to consistent changes corresponding to epithelial-mesenchymal transitions (EMT) in living cells. Mechanobiological aspects of cell behavior as out-of-equilibrium critical systems were studied using in-situ laser microscopy data and are the basis for the microgravity effect analysis with application to the changing cell phenotypes. Different human cell lines (epithelial cells, osteoblasts, cancer cells) show significant changes in their morphology, both in the real and in laboratory conditions that mimic microgravity. It is noted that 24 hours after exposure to microgravity, the homogeneity of the cell shape is disturbed and two morphological phenotypes appear corresponding to quantitatively different morphological parameters and genetic expression dynamics.

The existence of two populations cannot be considered as a transitional effect: the cells remain viable and continue to proliferate, while the other part of the two morphological classes remains unchanged for a rather long period (more than 7 days) under microgravity conditions. It is also fundamentally important that both phenotypes restore their original morphology within 6-24 hours when returning to the normal gravitational state. The impact of microgravity destabilizes the gene expression in relation to the traditional gravitational “dynamic scenario”, which leads to a sharp increase in the variability of gene expression in the vicinity of some “critical states”. In contrast, in cells exposed to hypergravity (3 g), no significant changes in the structure of gene expression were observed.

Nonlinear dynamics in the absence of gravitational constraints allows spontaneous appearance of various phenotypes, previously “sorted” by the presence of a “gravitational” attractor (stochastic gene activity). It was established that the “decision” of a cell on the direction of evolution is realized as a result of a monotonous change in the value of a certain bifurcation parameter, which controls the change in the epigenetic landscape providing the specific “attractors” through bifurcations. Such scenarios are noted in experimental studies when the system approaches symmetry breaking in a normal gravitational field.

The influence of microgravity on the mechanisms that initiate the change of cell phenotypes under the conditions of the “bifurcation dynamics” of the mechanobiological state is the basis for considering these processes in the context of the general EMT patterns taking into account the defect (open complex) induced cytoskeleton reorganization. Mechanobiological approaches based on a multiscale analysis of the dynamics of “open complexes” using data from laser microscopy of living cells were developed. This made it possible to substantiate the method of differential diagnosis, reflecting the epigenetic and morphological features of the behavior of cellular structures. The basis of the approach is the quantitative determination of space-time invariants (scaling exponents) characterizing the multiscale dynamics of open complexes with changing phenotypes caused by critical damage (open complex) dynamics.

Comparison of laser microscopy and fluorescent analysis data, implemented simultaneously “in-situ” on some cellular structures, will allow to establish a connection between the critical “kinematic” modes of cell dynamics caused by the collective dynamics of open complexes with the collective dynamics of expression, which also reveals signs of critical dynamics in the behavior of cells. It is advisable to conduct laboratory studies using a clinostat (Random Positioning Machine) with the subsequent application of methods for calculating space-time invariants according to laser microscopy and fluorescence analysis, aimed at determining the quantitative characteristics of each of the co-existing phenotypes with subsequent verification of the results based on received on the orbital station.

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