THEORY OF RELIABILITY IN BIOLOGY: RELIABLE SYSTEMS FROM UNRELIABLE ELEMENTS

Koltover V.K.

Institute of Problems of Chemical Physics, RAS, Chernogolovka, Moscow Region, Russia
E-mail: koltover@icp.ac.ru

Biological systems perform their functions in the presence of a great number of random factors which disturb all functional strata. Therefore, similarly to technical devices, they are not perfectly reliable in operation. The field of systems biology and biophysics, in dealing with the problem of reliability, incorporates the theoretical and experimental investigations of quantitative characteristics and mechanisms of failures and renewal processes. It also includes elaboration of methods for testing reliability and predicting failures in biological systems. The reliability problems are closely related with aging and the problems of resistance of biosystems to deleterious environmental factors including ionizing radiation. The regular conferences, which were initiated to deal with the problem of reliability of biological systems, starting from 1975 in the former USSR, have given a strong impetus to research in this direction. It has also spurred the similar studies on reliability of biological systems (under the style of “robustness”) on the other side of the former "iron curtain". In this report, to illustrate the ideas of the reliability trend, I present the results of application of the systems reliability approach to the problem of aging. The approach is based on the simple general principles that (i) all biomolecular constructions are designed in keeping with the genetic programs in order to perform the programmed, preset functions; (ii) all of them operate with the limited reliability; (iii) the timely replacement or prophylaxis of unreliable functional elements, i.e. the metabolic turnover, is the main line of assuring the high systems reliability; and (iv) there is a finite number of critical elements which perform the supervisory functions over the preventive maintenance but these “supervisors” also operate with the limited, preset, reliability. On this basis, the universal features of aging, such as the exponential growth of mortality rate with time and the correlation of longevity with the species-specific resting metabolism are naturally explained. The stochastic malfunctions of the mitochondrial electron transport nanoreactors, that produce the superoxide radical ($O_2^{\bullet -}$), seem to be of first importance. Basing on the reliability-theory approach, one can estimate that the longevity of human brain could reach 250 years should the antioxidant defense against the free-radical failures be perfect. Thus, aging inevitably occurs as the consequence of the programmed, genetically preset, deficiency in reliability of the biomolecular constructions while the free-radical timer serves as the effective stochastic mechanism of realization of the program. Furthermore, the systems reliability approach provides heuristic methodology for novel preventive medicine including novel radiation protectors based on the stable magnetic isotopes. [Supported by RFBR, project no. 14-04-00593a].

References.

1. Koltover V.K. Theory of reliability in systems biology: aging versus reliability. // Recent Advances in Systems Biology Research. – New York: Nova Science Publishers Inc., 2014. pp. 109-130.