Biological Robustness and Fragility

SHAO Xinru

1 Definition

Biological robustness refers to a characteristic that a biological system maintains its structure and function stable when disturbed by uncertain factors such as external disturbances or internal parameter perturbations[1], and it generally exists in biological groups, wholes, organs, cells, molecules, etc. in various levels.

Biological Fragility refers to the sensitivity and vulnerability to external disturbances at a specific time-space scale, which is an inherent property of biological systems.

2 Examples of Robustness and Fragility

Bacterial chemotaxis refers to a kind of directional movement of bacteria, which is a basic attribute of survival in adapting to environmental changes. It enables bacteria to find food sources and escape from toxic environments, and has a competitive advantage in survival. Here, we refer to the most classic E. coli chemotaxis experiment[2].

The experiment focuses on how response and adaptation to attractant signals vary with systematic changes in the intracellular concentration of the components of the chemotaxis network. From the final results, steady-state behavior and adaptation time reflect Fragility, and the precision of adaptation reflects Robustness out.This is consistent with a recently proposed molecular mechanism for precision adaptation, where robustness is a direct consequence of network structure.

3 The Importance of Biological Robustness

The importance of biological robustness is mainly reflected in the adaptation of organisms to the environment. Continuous use of positive and negative feedback adjustments enables them to maintain a stable internal environment and survive in a constantly changing external environment. Biological robustness is widely used in real-world scenarios, such as bacterial chemotaxis, cell cycle, cell signal communication, gene mutation, biological development, gene network, etc. Stability robustness and quality robustness are two important propositions in biological robustness research, and mathematical models are an important means of biological robustness research. Understanding biological robustness is of great significance to the occurrence, development and treatment of cancer, AIDS, diabetes and other diseases.

4 Consequences of Fragility and Solutions

Biological fragility makes organisms unable to maintain the stability of internal parameters in a changing environment, resulting in chaos, disorder, and unpredictable consequences. In order to minimize the adverse consequences brought about by the biological fragility of an individual organism, the rate of change of external environmental parameters should be controlled as much as possible, so as to ensure the stability of the internal environment of the organism to the greatest extent.

Diseases can be thought of in terms of the exposed fragility of robust yet fragile systems. The design of effective countermeasures requires proper understanding of a system's behavioural and failure patterns. Diabetes mellitus, cancer and HIV infection represent the typical failure of such a system that requires systematic countermeasures to control robustness of an epidemic state. Countermeasures include systematic intervention to control a system's dynamics, attack fragility or introduce decoys to re-establish control[3].

Therefore, by increasing the robustness of complex networks and minimizing perturbations, mutations, and accidents, it is a solution to minimize the consequences of biological fragility.

Reference

[1] Bing, Z., Jiali, B., Lei, Y., Progress of biological robustness,2010
[2] Alon U, Surette MG, Barkai N, Leibler S., Robustness in bacterial chemotaxis. Nature, 1999
[3] Hiroaki K., Biological robustness.Nature,2004