Biological robustness and fragility

One of the scientific objectives of system biology is to discover the basic system-level principles that form the basis of complex biological systems [1]. Biological robustness and fragility are the systems-level phenomena that are commonly observed [2]. This essay will first define biological robustness and fragility with an example given respectively. And then will explain why biological robustness is an integral part of survival. Finally, the essay will discuss the consequences of fragility and how one can avoid it.

Biological robustness is a commonly observed property of biological systems, enabling the system to maintain its external and internal disturbances functionalities [2]. However, complex systems may be fragile to certain types of periodic perturbations or sudden perturbations, which is called biological fragility. In other words, biological fragility is the cost of improving biological robustness [2].

Take the chemotaxis of Escherichia coli as an example of biological robustness. Under different network-protein concentrations, the experiment found that some characteristics of Escherichia coli (such as the time of adaptation) present huge alterations with the change of network-protein concentrations [3]. However, the precision of adaptation is robust and does not change with network-protein concentrations [3]. Therefore, Escherichia coli can induce chemotaxis on a large scale of chemical attractant concentrations due to the integrated feedback to ensure well adaptation.

Moreover, the disease is one of the signs of fragility. For example, cancer infection is remained and even worse through the intrinsic robustness mechanisms of the individual due to the default of intrinsic mechanisms for fragility. The high level of genetic heterogeneity in the tumor generates inappropriate protection in both the cellular and the environment and accounts for the robustness of cancer [2]. Chromosome instability causes genetic heterogeneity and produces a high level of genetic heterogeneity in survival and promotion, which allows some malignant cells to can endure the treatment and re-form tumors [2].

As mentioned above, biological robustness enables the system to maintain its functionalities through external and internal disturbances from the individual's perspective, which is an integral part of survival. Moreover, from the perspective of biological evolution, robustness facilitates the evolvability of complex dynamic systems [2]. Evolution prefers a robust trait that is endured against environmental perturbations, which is similar to the properties of robustness. Additionally, biological robustness can provide useful guidelines for explaining a number of biological phenomena and treatment designs, which means that theoretically motivated conservatism may provide new treatment methods. For example, according to the theory of biological robustness and the principle of cancer, cancer treatment should be done by inducing tumor dormancy rather than aiming at eradicating the tumor [2]. One source of robustness is genetic heterogeneity created through somatic recombination. Another way is to look for the fragility of tumors [2]. Therefore, biological robustness is an essential part of survival for both individual and future development.

When the fragility of the system is exposed, the biological system will be vulnerable. Due to the characteristics of biological robustness, the system may tolerate the removal of some components or cells. However, when the components behave inappropriately and are still remained, the system can easily be attacked [2, 4]. Furthermore, the inappropriate components and their behaviors may be robustly maintained against countermeasures [4]. The apparent consequences of fragility are diseases such as diabetes, cancer, and HIV. In order to avoid fragility, it is essential to recognize that the system evolved to be robust to some perturbations and is vulnerable to unplanned perturbations, while fragility is a side product of robustness. Meanwhile, organizing the basic mechanism of providing robustness into a coherent structure makes it to be effective at the organism level [2].

In conclusion, there is a strong correlation between biological robustness and fragility. Biological robustness is an integral part of survival. And biological fragility is a by-product of robustness, which may lead to negative consequences and should be avoided. Both robustness and fragility of biology have significance to biology and medicine.

Reference

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