Biological Robustness and Biological Fragility

Robustness is a property that allows a system to maintain its functions despite external and internal perturbations(Kitano 2004). Biological systems at the macro level include ecosystems of multiple organisms, and at the micro level can refer to systems of individual organisms i.e., a group of entities or organs that work together to carry out a particular task. For any biological system, it must have ability of being resistant to perturbation. For example, external perturbations in an ecosystem may come from species invasion, and internal perturbations may come from interspecific competition. For individual systems, external perturbations may come from the external environment, such as temperature and humidity, and internal perturbations may come from genetic mutations. Biological robustness can be defined as the ability of a biological system to make a series of self-adjustment or repair when it is subjected to internal or external perturbations, so as to maintain the stability of the system and keep the original structure and function from being destroyed. For instance, in a grassland ecosystem, if herbivores increase as a result of migration, plants will decrease as a result of excessive grazing, and the decrease of plants will in turn suppress the number of herbivores, thus maintaining a stable level of herbivores. This mechanism of negative feedback regulation can be considered as ecosystem robustness. Robustness is an integral part of biological systems. If a biological system is not sufficiently robust, it is highly likely to suffer devastating functional or structural damage in perturbations. The robustness for a simple ecosystem, such as a fish tank, is minimal and can withstand far less internal or external perturbations than complex ecosystems such as oceans and forests. Furthermore, complex biological systems must be robust to environmental and genetic perturbations in order to evolve. Evolution often selects for traits that enhance the robustness of organisms. Robustness is therefore ubiquitous in evolving organisms (Kitano 2004).

The mention of perturbation brings up another related concept, namely, biological fragility. It has been proposed that biological fragility is the antonym of biological robustness (Nilsson and Grelsson 1995). Biological systems are often fragile to unexpected perturbations(Kwon and Cho 2008). For example, the energy control system of human body ensures robustness to common perturbations (e.g., unstable food supply or infection), but the system is fragile to abnormal perturbations (e.g., high energy content foods or low-energy utilization lifestyles) (Kitano et al. 2004). Biological fragility can be defined as the biological system is easy to be affected by particular perturbations and difficult to effectively self-adjust or repair, resulting in the destruction of the original structure, function and stability of the system. The extinction of the dodo is an example of biological fragility. The dodo was hunted and affected to extinction 200 years after human activity on the island of Mauritius. This demonstrates the fragility of the island ecosystem to excessive human activity. In other words, the impact of human activities on the island of Mauritius had exceeded the adjustable range of the robustness of its ecosystem, resulting in unregulated damage to the ecosystem, which is species extinction. Therefore, the consequences of biological fragility are manifested as structural or functional damage to biological systems, or worse, may lead to the collapse of the entire biological system. The example is that humans are susceptible to the 2019-nCoV, infection with the coronavirus may lead to loss of taste and smell, decreased physical strength, and irreversible pulmonary fibrosis in severe cases, resulting in systemic multiple organ failure and death.

Avoiding biological fragility can make the biological system more self-adjustable when facing the perturbation, so as to maintain the stability of the system under fragile conditions. According to the definition of fragility, avoiding fragility can be done from two aspects: avoiding perturbation and enhancing robustness. For the human body, avoid biological fragility by avoiding pathogens and taking protective measures such as wearing masks to reduce exposure to perturbations caused by the 2019-nCoV. Measures such as vaccination are designed to strengthen the robustness of the system and thus avoid fragility.

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