Biological Robustness and Vulnerability at the Individual and Ecosystem Levels

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Robustness and vulnerability are two relative concepts in biological systems. They represent the ability of biological systems to maintain their original functions despite external or internal interference. This article will introduce biological robustness and vulnerability at the individual and ecosystem levels respectively.

Kitano, in a paper published in 2004 entitled Biological Robustness, noted that "Robustness is a property that allows a system to maintain its functions despite external and internal perturbations[1]. " Besides, Stelling *et al.*, in Robustness of cellular functions published in 2004, likewise stated that "robustness, the ability to maintain performance in the face of perturbations and uncertainty, is a long-recognized key property of living systems[2]." Robustness allows a disturbed organism or ecosystem to maintain a specific function by changing the structure or components of the system. Strong robustness means the strong anti-interference ability of biological systems.

In contrast, vulnerability reflects the limitations of biological systems in responding to external or internal challenges. High vulnerability means that biological systems are likely to lose specific functions after being affected by external or internal factors. Biological vulnerability is a common feature of living organisms, and no biological system can be fully robust to all possible disturbances [1].

The robustness and vulnerability of organisms can be reflected at the individual level and the ecological level.

At the individual level, one expression of robustness is that the organism has an immune system. For example, when viruses or bacteria cause interference, the immune system

can help keep the organism healthy by recognizing and removing the pathogen. On the ecological level, species-rich ecosystems are robust and highly resistant to disturbances such as natural disasters, climate change and human activities. For example, tropical rainforest ecosystems are highly biodiverse and easily resistant to external or internal disturbances. Forests with a variety of species are better able to resist pests or diseases that target specific species than forests with lower species diversity.

One manifestation of biological vulnerability at the individual level is that some species are endangered. Pandas, for example, are sensitive to their habitat and susceptible to disease. If climate changes or bamboo production decreases, the panda's food supply will decrease, which will increase the panda's mortality rate. At the ecological level, the arctic ecosystem has extreme climatic conditions. As a result, Arctic ecosystems are vulnerable to temperature increases, which can lead to the melting of sea ice, which could affect ecosystem functioning.

Robustness is a fundamental property of biological systems. It facilitates evolvability, and evolution selects robust traits [1]. Robustness enables the organism to adapt and respond to changes in the external environment and internal challenges, and to maintain its function in the face of these challenges. For individuals, biological robustness helps them survive and reproduce better in different conditions. For ecosystems, biological robustness and ecosystem stability are related to resilience. Strong biological robustness helps them maintain stable ecosystem processes in the face of disturbances.

For individuals, biological vulnerability leads to a decline in adaptability and survival. Some endangered species are less able to withstand environmental pressures and disturbances and may become extinct if disturbed by external or internal factors. Loss or extinction of species reduces biodiversity and further decreases the resilience and function of ecosystems. Fragile ecosystems are more prone to catastrophic events, which increase the vulnerability of the ecological environment.

There are many steps we can take to avoid increased biological vulnerability. For individuals, we can use techniques such as genetic engineering to improve the robustness of a single individual. For example, developing crops that can resist drought and insects. For the ecological environment, we can take measures to protect natural habitats, and maintain biodiversity and ecosystem function. Such as reducing pollution, calling on people not to overdevelop, and affecting the ecosystem as little as possible.

In conclusion, biological robustness and vulnerability have important implications at both the individual and ecosystem levels. Kitano mentioned “It is important to realize that systems that are evolved to be robust against certain perturbations are extremely fragile to unexpected perturbations. This robust yet fragile trade-off is fundamental to complex dynamic systems [1].” Therefore, when facing problems, we need to consider robustness and vulnerability comprehensively and control the balance between them.

References

[1] Kitano, H. (2004). Biological robustness. Nature Reviews Genetics, 5(11), 826-837.

[2] Stelling, J., Sauer, U., Szallasi, Z., Doyle, F. J., & Doyle, J. (2004). Robustness of cellular functions. Cell, 118(6), 675-685.