Biological robustness and fragility

The concept of robustness has been studied in various fields of science, but in the context of biology, it takes on a new dimension. Living organisms are incredibly complex systems that have evolved over millions of years to adapt to changing environmental conditions. Thus, it is interesting and meaningful to discuss biological robustness. In this essay, I will give the definitions and examples of biological robustness and fragility, explain why biological robustness is an integral part of survival, and discuss the consequence of fragility and how to avoid it.

The word robustness refers to: 'A property that allows a system to maintain its functions against internal and external perturbations.'[1] Similarly, biological robustness can be defined as the ability of organisms to maintain their physiological functions despite perturbations or variations in the internal and external environment. For instance, we can see biological robustness in the ability of an organism to maintain body temperature within a narrow range despite external environmental temperature, and the ability of cells to maintain their physical and chemical properties against the variant internal environment. These examples are categorized as homeostasis, which enables organisms to survive stressors in their environment. Besides, the robustness in the nervous system offers organisms the ability to adapt to different environments. For example, in the visual system, the neural activity pattern in response to the same object is consistent regardless of the view from which you see the object. Similarly, organisms form robust and consistent neural activity patterns for the auditory sense, olfactory sense, tactile sense, and even the temperature sense. Such robustness ensures organisms are not confused by the variant and multivariate physical worlds.

From the above words, we can draw the conclusion that first, biological robustness is fundamental for organisms to handle a wide range of conditions and stresses. Second, in the perspective of evolution, during natural selection, only species with relatively

high robustness to the present environment would be chosen. In other words, the species we can see today are already highly robust and complex systems. I think these two points illustrate that biological robustness is an integral part of survival.

However, the highly optimized tolerance (HOT) model argues that systems that have evolved to have a higher level of complexity are optimized for specific perturbations but, at the same time, are also inevitably extremely fragile against unexpected perturbation.[2] [3] Here, we introduce biological fragility as the opposite of biological robustness, which refers to organisms having a low tolerance to changes in the environment. In many cases, organisms have constructed optimal strategies to face a specific environment. However, once the environment intensively changes, such as climate change and continental drift, the organisms become vulnerable to the new environment. For example, rhinoceroses were prevalent in ancient China. But unexpected climate change and human activity in the central part of China resulted in the extinction of at least one species of rhinoceros. Nowadays, we can only find rhinoceroses in the southern part of China. Actually, there are trade-offs between robustness and fragility. When an organism becomes robust to a certain environment, the degree of freedom of this organism's system decreases. This therefore makes the system fragile to unexpected perturbation.

Normally, biological fragility can lead to severe consequences. In the physiological aspect, loss of homeostasis causes irreversible damage to the body's tissues and organs, which ultimately leads to sickness, loss of function, and even death. Besides, fragility in the nervous system may cause several types of cognitive disorders, such as Alzheimer's disease, prosopagnosia, and dyslexia. In genetics, organisms' gene expression is generally robust to slight mutations. However, due to carcinogenic chemicals, radiation, and aging, gene mutations may go beyond the limitation of cells' robustness and cause cancer or other severe genetic disorder.

To avoid biological fragility, one could maintain a healthy lifestyle, keep away from

toxic chemicals, and not push your body out of homeostasis. These suggestions can make you not get into a situation of biological fragility. And one should have physical examinations regularly to detect potential health problems. Also, if one has been detected to have health problems, he should have treatment as soon as possible to recover his body's robustness. Finally, one could engage in mental and cognitive activities to avoid biological fragility in the nervous system.

References

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