

Biological Robustness and Fragility

Robustness is a ubiquitous feature of biological systems. It means that when a biological system is disturbed by uncertain factors such as external and internal perturbations, it will keep its structure and function stable.^[1] In short, it refers to the ability to resist or overcome adverse conditions. This ability depends on the mechanisms of system control, alternative (or fail-safe) mechanisms, modularity and decoupling.^[1] However, the robustness of biological systems doesn't mean that they will remain stable all the time. Biological fragility is common in biological systems as well. Robust systems involve intrinsic tradeoffs. Enhanced robustness against specific perturbations has to be balanced by extreme fragility elsewhere.^[1] When some unexpected mutations or perturbations happen, some problems may occur.^[2] Like a human body, if someone gets a fever and the body temperature rises, the immune system will help against the virus, and the temperature will return to normal. But if someone is living with HIV, the body's system cannot control this condition and is fragile against this kind of virus. The robustness and fragility of biological networks are correlated with each other.^[2]

There are many examples of robustness and fragility for biological. For robustness, we can take some microorganisms as examples. They have simple structures, but every part of the microorganism cooperates well. As simple organisms, their living environment is unstable and may meet the condition of high concentration solution. In addition, they may produce some intermediate product that will harm them. The robustness of microorganisms allows them to finish the function of cell wall reconstruction, reduction of cell membrane fluidity and trehalose aggregation. It can also activate the transfer system to clean up toxic substances.^[3] These abilities make the microorganism resist adverse conditions and make them robust. As for the fragility of the biological system, we can use genes as an example. If there's a gene mutation, like having one more chromosome 21, the human will become ill with down's syndrome. The body cannot maintain a stable state with this kind of mutation.

Biological robustness is an integral part of survival. First, it's crucial to maintain a stable state for the biological system and can alleviate the damage from outside under adversity factors.^[4] The environment is changing and sometimes can harm the biological system. Without the ability to keep stable when perturbations happen, the biological system is easy to break down. The robustness of biological systems can help them overcome terrible conditions and thus increase survival opportunities. From tiny organisms to complex systems, it's a necessity to have the ability to overcome minor interference from the external environment. Second, biological robustness is also essential for biological evolution.^[1] The biological system can become more suitable for the environment because of its biological robustness. Robustness facilitates the evolution process of complex dynamic systems. Evolution will select a robust trait which is tolerant against environmental perturbations, linking the

properties of robustness and evolution. Robustness is ubiquitous in biological systems that have evolved, making a great effort for a biological system to survive.

From talking above, it can be seen that biological robustness is essential. On the contrary, biological fragility can cause many consequences, from small diseases to the breakdown of the system. For example, our human body is fragile to some viruses, such as COVID-19. Then we may have the feeling of sore throat or headache. What's more, some other related problems may arise as well. If the patient had lung disease before, the symptoms might be more obvious. As for the way to avoid fragility, I think the following two are feasible. First, one needs to try to prevent dangerous external conditions. The biological system is fragile in a specific state. If these conditions are known in advance, the best way to be not influenced by the fragility is to avoid meeting these uncontrolled conditions. Second, if there are some mutations that are caused by irregular behaviors, one can take precautions against them. For example, the energy control system of our body is fragile against unusual modifications such as high-energy content foods or low-energy utilization lifestyles.^[5] One can gradually change the behaviors so that the body can adapt to the sudden change and become less fragile to the mutations.

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