

Biological Robustness and Fragility

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Biological robustness refers to the ability of an organism to maintain its functions and survive in the face of perturbations, such as changes in the environment or internal disturbances. Biological robustness makes sure that certain system operations are kept up despite disruptions from the outside and the inside. The fundamental processes that provide robustness include system control, alternate procedures, modularity, and decoupling. In addition, biological robustness is regarded as a key component of complicated, evolvable systems. It is accomplished through a number of fundamental ideas that apply to both complex biological systems and artificial species. However, there are trade-offs between performance, resource needs, robustness, and fragility that explain system behavior, including failure patterns. Systems that are robust have inherent trade-offs. Extreme fragility elsewhere must be compensated off by enhanced robustness against some disturbances.

One example of biological robustness is the human immune system, which is able to adapt and respond to a wide range of pathogens and other challenges to maintain the health of the individual. The immune system is able to recognize and eliminate many different types of invading microorganisms, and it can also adapt and learn to recognize new threats over time through processes such as immunological memory. This allows the immune system to effectively protect the body from a wide range of diseases and infections.

On the other hand, biological fragility refers to the vulnerability of an organism to perturbations. An organism that is biologically fragile may be more susceptible to changes in the environment or internal disturbances, which can affect its functions and survival.

One example of biological fragility is the human brain, which is sensitive to a range

of physical and chemical stresses that can cause damage or impair its function. For example, the brain is vulnerable to trauma, such as head injuries, which can cause damage to brain tissue and disrupt brain function. The brain is also sensitive to toxins, such as alcohol and certain drugs, which can alter its function and cause harm. Additionally, the brain is vulnerable to diseases and disorders, such as stroke, Alzheimer's disease, and Parkinson's disease, which can affect its function and structure. Overall, the complex and delicate nature of the brain makes it vulnerable to a range of stressors that can compromise its function and health.

Moreover, it has also been shown that biological networks are frequently fragile to unforeseen alterations. For instance, our body's energy regulation system guarantees resistance to typical disturbances like unreliable food supplies or diseases, but it is fragile to unexpected mutations like high-energy diets or low-energy lifestyles. The immune system is robust to pathogen assaults, but it is fragile to unanticipated failures, such as the malfunction of the nonredundant core element MyD88. The *Drosophila* segment polarity gene network exhibits resilience against changes to its starting state but exhibits fragility when exposed to high temporal variability.

As for the reasons for why biological robustness is integral part of survival, that is because robustness is pervasive in biology throughout at all organizational levels including protein folding, gene expression, metabolic flux, development, organism survival, species persistence, and ecological resilience. What's more, the preservation of adequate performance will determine persistence or function, according to many biologists, robustness is essential because proteins, cells, biochemical networks, immune systems, organisms, and natural populations exist in constantly changing and occasionally novel environments.

In addition, biological robustness is an important aspect of survival because it enables an organism to adapt to new or changing circumstances, and it helps to ensure the continuation of the species. There are many factors that contribute to biological

robustness, including genetic diversity, flexible behavior, and the ability to repair or regenerate damaged tissues. These factors allow organisms to cope with various challenges and maintain their functions despite changes in the environment.

The consequences of fragility depend on the specific system that is vulnerable, but generally, fragility can lead to dysfunction, failure, or damage. For example, if a biological system is fragile, it may be more prone to disease or injury, and it may be less able to withstand external stressors or maintain its normal functions.

To avoid fragility, it is important to identify and address the specific vulnerabilities or weaknesses of a system. This may involve implementing protective measures, such as using protective equipment or taking precautions to prevent accidents or injuries. It may also involve taking steps to improve the overall resilience of the system, such as through regular maintenance, strengthening, or rehabilitation. By doing these, it may be possible to reduce the risk of fragility and improve the overall resilience and robustness of the system.