

Biological Robustness and Fragility

Robustness and fragility are the common properties of the complex system. Undoubtedly, biological system is an extremely complex system.

Biological robustness refers to the ability of an organism to maintain its functional integrity and stability in the face of internal and external perturbations. At the cellular level, it can be seen as the ability of cells to maintain a stable internal environment in the face of changes in temperature, PH, or other factors. At the organismal level, it can be seen as the ability to maintain the physiological functions in the face of challenges such as injury, infection or stress. There are several factors that contribute to biological robustness, which is the crucial part for survival. First of all, the redundancy refers to a situation in which several identical, or similar components can replace each other, when another component fails. It ensures that even if one component fails, the biological system can still function normally. For example, the human immune system has multiple types of white blood cells that can recognize and attack pathogens, ensuring the body have the immune response even if one type of cell is compromised. Second, modularity provides an effective way to minimize the influence of damage or perturbation on the whole system. It means that all the modules are hierarchically organized and operate independently, if one module damaged, it would not influence other module's function. For example, the human brain consists of distinct regions that are specialized for different functions, such as movement, cognition, sensation and so on. Third, the feedback mechanisms allow the system to monitor and adjust their behavior in response of the changing situation. It ensures that the body can maintain a stable internal environment even face with the environmental fluctuation. For example, the body temperature can maintain a steady level even the environment temperature changes rapidly.

Fragility is also an inherent property of biological system, because of its complexity. It refers to the susceptibility of an organism to dysfunction or failure in response to perturbations. Limited resources and constant threat of environmental changes are two important factors contribute to the biological fragility. The living organism should make a balance between the demands of maintain the internal stabilization and the needs that

can acquire from the environment. The balance can be disrupted by environmental perturbations such as food shortages and exposure to toxins. The constant threat such as temperature, humidity, which may overwhelm the body's ability to maintain its functions and integrity. The system can resist against general perturbations, but not the rare perturbations. It tells us that if we want to avoid the biological fragility, we should keep a balance and nutritious diet to supply enough energy to the organisms, and avoid these extreme environments.

Moreover, biological robustness and fragility have significant implications for health and disease. It can inform our approach to treating complex diseases. For example, the cancer or HIV infection are maintained and promoted through the robustness mechanism of host system rather than attack the fragile part. The possible clinical strategies that could be used against cancer are the control of the robustness of tumour and finding out the fragility. Therapy should be directed to induce tumour dormancy by selectively inducing cell-cycle arrest, rather than aiming at tumour eradication.

In conclusion, biological robustness and fragility are the fundamental property of biological system. It promotes the biological evolvability, and the evolution chooses the robustness at the same time. And it is also important to realize that systems that are evolved to be robust against general perturbations and fragile to the unexpected perturbations. At the same time, the relationship between biological robustness and internal or external factors is difficult to be identify. It is important to combine the traditional biological engineer with the data science to explore the nature of the biological world. And it will bring a lot guidance for us to understand the biological phenomena, and for therapy design.