

## Biological Robustness and Fragility

Robustness and Fragility are fundamental characteristics of biological systems. Biological robustness ensures the functions of biological system are maintained against perturbations. On the contrary, the Fragility refers to the functions of biological system are damaged against perturbations.

Robustness can be observed in many biological examples. An example for biological robustness is cancer, the disease state establishes its own robustness against therapeutic interventions (H. Kitano, 2007). Cancer cells have the ability to divide and proliferate continuously without being controlled by the normal growth regulation system, as well as the ability to migrate continuously. Drug treatment can be regarded as external perturbations. However, so far no therapeutic interventions have been found worldwide that can inhibit or alter the proliferation and migration function of cancer cells. The cancer cell system is so robust that it cannot be treated with therapeutic interventions. Fragility also can be observed in biological system. For instance, volcanic eruptions are a common natural phenomenon. Volcanic ash is defined as debris and mineral particles less than 2 micron in diameter that are ejected from a volcano. During explosive volcanic activity, solid rock and molten lava are broken down into fine particles to form volcanic ash. People who live near volcanoes are likely to inhale ash. The smaller the diameter of the particles, the deeper they enter the respiratory tract. 10 micron diameter particles are usually deposited in the upper respiratory tract, 5 micron diameter can enter deeper into the respiratory tract, and less than 2 micron can penetrate 100% into the fine bronchi and alveoli. This is an external disturbance to the human lungs. When respirable particulate matter is inhaled by humans, it can accumulate in the respiratory system and cause many diseases, leading to impaired respiratory and lung function and respiratory diseases.

Physical and chemical factors in the environment, such as food and drugs, are external factors that interfere with biological systems; changes in intracellular biomolecules and the control of cellular metabolism are internal factors that interfere with biological systems. All kinds of organisms on Earth grow, develop and reproduce in a certain environment. The survival of organisms is limited by the material and energy provided by the environment. In the face of constant changes in the living environment, including temperature, air oxygenation, etc., biological systems are robust to external environmental perturbations in order for organisms to survive. For example, the body has alternative mechanisms to ensure proper body function at different temperatures. For example, in a hot environment, the skin's thermoreceptors are excited to stimulate the hypothalamus's thermoregulation center. Through regulation, skin capillaries are dilated, blood flow increases, and sweat secretion increases, thus maintaining a constant body temperature (Haen Whitmer, K.M., 2021). In a cold environment, the cold receptors in the skin receive stimulation and transmit the excitement to the thermoregulatory center in the hypothalamus. The relevant nerves are stimulated, which makes the skin blood vessels shrink and the blood flow decrease, thus reducing the heat loss of the skin. At the same time, the muscles contract and skeletal muscles shudder, increasing heat production. If the capillaries of the skin

stretch and secrete sweat when it is cold, the body temperature will be too low, and the cells will not be able to maintain their normal functions, making it impossible for people to survive in a cold environment.

The consequence of Fragility is that the function of organisms is destroyed and the survival of organisms becomes difficult. If you want to avoid fragility, you can try to avoid perturbations, but this is difficult to achieve. Organisms can avoid fragility by enhancing system control, alternative mechanisms, modularity and decoupling to enhance robustness(Hiroaki Kitano ,2004). Humans can avoid fragility to environmental change by building houses, inventing air conditioning, and heating. Animals can avoid being fragile to the environment by migrating.

Reference:

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