Robustness and fragility

In biology, robustness means that a biological system maintains its structural and functional stability even when it is disturbed by uncertain factors such as external disturbances or internal parameter changes. Biological robustness can be best reflected in the adaptation of organisms to the environment, which is a ubiquitous feature in biological systems; while fragility refers to the fact that biological systems optimized for specific external disturbances inevitably show extreme fragility to unexpected disturbances. This kind of external disturbance causes the stable system to collapse. We often see alternating manifestations of status of robustness and fragility in humans and other animals.

For example, the energy control system of our body ensures robustness against common perturbations such as unstable food supply or infections, but the system is fragile against unusual mutations such as high-energy content foods or low-energy utilization lifestyle.[1] The glycogen stored in the human body guarantee temporary energy supply when food intake is insufficient which is the mechanism to maintain the body's homeostasis and provide the minimum energy. When we replenish food in time, new glycogen would be produced and stored in liver and skeletal muscle for reuse. However, if we actively consume excess food and reduce exercise, the homeostasis of the human body will be disrupted, the metabolic system will be overrun, and the excess energy will be converted into fat and stored in the organs, leading to various chronic diseases, that is, excessive food intake stimulates fragility of the energy control system, causing an unbalance between energy gain and loss.

Robustness is a universal characteristic of biological systems, leaving specific functions of the system maintained under external and internal disturbances. Besides, robustness facilitates the evolution of complex dynamical systems. Evolution, given enough time, might select for a robust trait that tolerates environmental perturbations.[2] In that case, these two properties, robustness and evolvability, would be highly linked. So we don't have to worry about our descendants growing fins as we've spent thousands of years exploring the land. Apart from that, robustness of biological systems is consistent with the heritability of species where good robustness undoubtedly ensures, under any circumstance, reproduction of species and stable transfer of genetic material to the next generation. Just imagine that your child will inherit half of your genes (probably not expressed), indicating he/she may look like you, but need to develop a brilliant brain, which is probably smarter than yours, to adapt to this ever-changing society.

At the same time, the fragility of human systems is unavoidable. We must admit, in the same biological system, robustness and fragility coexist. Diseases can be thought of in terms of the exposed fragility of robust yet fragile systems.[3] The design of effective countermeasures requires proper understanding of a system's behavioral and failure patterns. Diabetes mellitus, cancer and HIV infection represent the typical failure of such a system that requires systematic countermeasures to control robustness of an epidemic state where attack fragility play an important role. Hence, I would rather see robustness and fragility as a whole that has joint effects on human systems.

However, it doesn't mean we should ignore the potential harm from fragility. Fragility is still one of the causes of chronic disease as I have mentioned above .Taking obesity as an example, after understanding the principle of obesity, in order to bring the human body back to a steady state, we need to accelerate fat consumption through aerobic exercise, while reducing food intake, and artificially reduce the damage to the human body system caused by external disturbances. Predicting the consequences of vulnerability, understanding the principles of vulnerability, and reasonably avoiding the damage caused by vulnerability are inevitable steps to control fragility.

References

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[2] Kitano, H. Systems biology: a brief overview. Science 295, 1662–1664 (2002).

[3] Kitano, H. Computational systems biology. Nature 420, 206–210 (2002).