BIOLOGICAL ROBUSTNESS AND FRAGILITY

Concepts and Examples of Biological Robustness

Biological robustness is a universal property of a biological system, a fundamental characteristic in a complex evolvable system to ensure that it can operate under unstable conditions. It does not refer to the ability of a biological system to keep its components, structure etc. unchanged forever, but rather to its ability to self-regulate by changing its form or workings to maintain its characteristics or to allow its specific functions to function properly under a certain degree of external or internal perturbation. One common example of this is the ability of almost all organisms in nature to survive under certain fluctuations in temperature, humidity, etc.

The Importance of Biological Robustness

The robustness of organisms is undoubtedly important because the environment in which they live is unlikely to be constant and the substances in it are not all favourable to the organism. Biological robustness not only ensures the survival of the organism in a normal environment, but also allows it to be more resilient to internal and external contingencies and to reproduce through natural selection. The means by which organisms maintain their robustness are usually in the form of enhanced capabilities for emergencies, or the use of different operating principles to solve the same thing.

Concepts and Examples of Biological Fragility and its Consequences

There is often an inherent balance involved within complex systems. Strong robustness in response to certain perturbations is also necessarily balanced with extreme vulnerability elsewhere. In the case of HIV, for example, CD4 T lymphocytes, an important part of the body's immune system that responds to external stimuli, are in fact a vulnerable link in the virus' attack on the body. The virus exposes the organism to its vulnerability by destroying the cells that maintain the organism's robustness - that is, as opposed to robustness, in the event of fluctuations in external or internal conditions (such as the external disturbance mentioned above - HIV, or due

to the organism's internal insulin secretion deficiency or impairment of its biological action causing diabetes), the system is unable to maintain its normal functioning. In other words, the organism is made to function in a manner that is not sustainable in the long term, which in turn leads to the termination of the normal working cycle of the organism, or to the collapse of the system.

Bio-fragile avoidance

To prevent such events, in terms of interventions outside the biological system, we can choose to attack vulnerability in advance, such as live attenuated or inactivated vaccines to exercise its resistance to external disturbances, or we can intervene directly in the internal dynamics of the system, such as injecting hormones that directly regulate the components of the organism; in terms of the evolution of the biological system itself, the organism can evolve immunity through exposure to a larger microbiota to reduce its range of vulnerability, e.g. humans and orangutans share a common ancestor, but in the course of evolution, the human habitat moved from the forest to the grassland to the present, and the number of microbiota to which people are exposed is far less than that of orangutans, so that immunity is not as high. Or an organism can evolve to fill its vulnerability, for example, some humans have CCR5-Δ32 on the surface of their cells, which can defend themselves against some types of HIV, or they can complicate the feedback mechanisms in the body, such as the need for two receptor tests to ensure the stability of the same hormone levels.

[PS: This essay was completed after the study of ： Hiroaki Kitano. Article in Nature Reviews Genetics · December 2004 DOI: 10.1038/nrg1471]