Biological Robustness and Biological Fragility

Robustness and fragility is a ubiquitously observed property of biological systems. The definition, an example, and the influence of robustness and fragility are introduced in it. And I get the conclusion that both of them are quite important, and if we want to study the nature of organisms in depth, biological fragility and robustness must go hand in hand.

Biological Robustness

Definition and an example

The definition of biological robustness is that biological systems produce relatively invariant outputs, despite the perturbations caused by mutations and environmental fluctuations. For example, in Manchester, England, in the 18th century, there were dark and light-colored peppered moths, and we can think of this as a genetic difference between the two. Before the Industrial Revolution, this area was dominated by light-colored peppered moths. But after the Industrial Revolution, when lots of the bark became blackish-brown, the number of light-colored peppered moths rapidly decreased the dark ones increased. This shows that biological robustness allows a species to adapt to the change in environment and avoid extinction and further maintain the stability of the rest of the species in the same food chain.

Importance

Biological robustness enables the system to maintain its functionalities against external and internal perturbations. The robustness is important for the understanding of the principles of life, which has been widely observed across many species, from the level of gene transcription to the level of systemic homeostasis. Besides, robustness is a fundamental feature that enables complex systems to evolve, and evolution enhances the robustness of organisms.Properties of robust evolvable systems have direct consequences on our understanding of diseases and therapy design.[1]

Biological Fragility

Definition and an example

Compared with the definition of biological robustness, biological fragility is defined as the lack of the ability of a biological entity to maintain function in the face of mutations. For example, the research of Suzannah J. Rihn and his team shows HIV-1 CA is a genetically fragile protein. To measure the genetic robustness of HIV-1 CA, they generated a library of single amino acid substitution mutants, encompassing almost half the residues in CA. They found HIV-1 CA to be the most genetically fragile protein that has been analyzed using such an approach, with 70% of mutations yielding replication-defective viruses.[2]

Consequence

Biological robustness and biological fragility are antonyms, so I think the main consequence of biological fragility should be the opposite of biological robustness. Biological fragility will cause a change in the nature or state of an organism, which has a bad influence on the species.

However, biological fragility may also bring benefits, such as in the field of disease and therapy. As I mentioned in the example of HIV-1 CA, the extreme genetic fragility of HIV-1 CA may be one reason why cell-mediated immune responses to Gag correlate with better prognosis in HIV-1 infection, and it suggests that CA is a good target for therapy and vaccination strategies.[2]

In general, although biological fragility and robustness are opposite concepts, these two properties exist in all living things and are related to each other to some extent. The systems that have evolved to be robust against general perturbations are extremely fragile against certain types of rare perturbations.[1] To some extent, the cost of improved robustness is just fragility. So if we want to study the nature of organisms in-depth, biological fragility and robustness must go hand in hand.

[1] Kitano H. Biological robustness[J]. Nature Reviews Genetics, 2004, 5(11): 826-837.
[2] Rihn S J, Wilson S J, Loman N J, et al. Extreme genetic fragility of the HIV-1 capsid[J]. PLoS pathogens, 2013, 9(6): e1003461.