Biological Robustness and Fragility

Zihang Yu

1. Definitions

Biological robustness is a quality that enables a system to continue functioning normally in spite of internal and external disturbances. It is a basic and frequently seen systems-level phenomenon that cannot be comprehended by examining the individual components (Kitano 2004).

On the contrary, biological fragility means that biological networks are often fragile against unexpected mutations (Kwon and Cho 2008).

2. Examples

An example of biological robustness is the robustness of a gene regulatory circuit. Previous research found that the functioning of the phage λ gene regulatory circuitry is highly robust to minor changes at its promoter region (Little, Shepley et al. 1999).

An example of biological fragility is the energy control system of the human body. Our body's energy regulation system guarantees robustness to frequent disturbances like unreliable food supplies or illnesses. However, it is vulnerable to unexpected mutations which are exploited to cause chronic disorders, such as high-energy diets or low-energy lifestyles (Kitano, Oda et al. 2004).

3. Biological robustness is integral part of survival

Biological systems are exposed to a wide range of mutations, including genetic mutations, localised stochastic fluctuations in molecular concentrations, infectious illnesses, life-threatening diseases like cancer, temperature variations, and changing species interactions (Whitacre 2012). Biology robustness is crucial for biological systems to be able to deal with these mutations. The robustness of phenotypes can be observed at various levels of biological organization, such as gene expression, metabolic flux, protein folding, physiological homeostasis and organismal survival (De Visser, Hermisson et al. 2003).

Therefore, biological robustness is important not only for the survival of individuals in the biological systems, but also for the survival of whole ecosystems. That’s the reason why biological robustness is an integral part of survival.

4. Consequences of fragility and how to avoid it

The consequences of fragility can be catastrophic, as the biology systems cannot trade off the unexpected mutations by their robustness. Native species may decline due to invasive species, for instance, the unexpected change in the relative significance of competitive ability and stochastic colonisation success in disturbed environments caused native Mytilaster-dominated mussel populations in the Mediterranean Sea to suddenly shift to becoming dominated by invading Brachidontes (Didham, Tylianakis et al. 2007). In exceptionally rare circumstances, fragility can provide insights into the history of evolution (Whitacre 2012).

Since the stability and productivity of ecosystems could be enhanced by species diversity, therefore, preserving species diversity in nature might be a good approach to avoid fragility (Johnson, Vogt et al. 1996).
Finally, human activities have a huge impact on the biological systems in the modern world. To maintain food production and advance technology, it is crucial for humans to alter biogeochemical cycles. However, releasing chemicals for purposes other than those for which they were originally intended can have detrimental effects on human health, ecosystem function, and the earth's climate system (Sobota, Compton et al. 2015). Therefore, humans should reduce the damage to the environment, thus could help the ecosystems to avoid fragility.

5. Reference

De Visser, J. A. G., et al. (2003). "Perspective: evolution and detection of genetic robustness." Evolution **57**(9): 1959-1972.

Didham, R. K., et al. (2007). "Interactive effects of habitat modification and species invasion on native species decline." Trends in Ecology & Evolution **22**(9): 489-496.

Johnson, K. H., et al. (1996). "Biodiversity and the productivity and stability of ecosystems." Trends in Ecology & Evolution **11**(9): 372-377.

Kitano, H. (2004). "Biological robustness." Nature Reviews Genetics **5**(11): 826-837.

Kitano, H., et al. (2004). "Metabolic syndrome and robustness tradeoffs." Diabetes **53**(suppl_3): S6-S15.

Kwon, Y.-K. and K.-H. Cho (2008). "Quantitative analysis of robustness and fragility in biological networks based on feedback dynamics." Bioinformatics **24**(7): 987-994.

Little, J. W., et al. (1999). "Robustness of a gene regulatory circuit." The EMBO journal **18**(15): 4299-4307.

Sobota, D. J., et al. (2015). "Cost of reactive nitrogen release from human activities to the environment in the United States." Environmental Research Letters **10**(2): 025006.

Whitacre, J. M. (2012). "Biological robustness: paradigms, mechanisms, and systems principles." Frontiers in genetics **3**: 67.