Biological robustness and fragility

Jingyuan Chen

Robustness and fragility are two biological manifestations of ubiquitous biological system characteristics. Those who are, to be more specific, antagonistic. For instance, biological networks are resistant to alterations like mutations, but they are frequently susceptible to unanticipated mutations [1]. These fascinating observations, as well as the underlying design idea that results in the robust but brittle properties of biological networks, are gaining increasing attention. Insights into inherent properties of robustness and fragility will provide us with a better understanding of complex diseases and a guiding principle for therapy design.

Robustness of a biological system is the persistence of a specific characteristic or trait in a system in the face of perturbations or uncertain conditions; it is a long-recognized key property of living systems that evolution has strongly favoured [2]. The yeast cell-cycle network, which is about the budding yeast's cell-cycle regulatory network, is an example of robustness. We demonstrated, using a simple dynamical model, that the cell-cycle network is extremely stable and robust for its function [3]. Robustness can be classified as mutational, environmental, or other depending on the type of perturbation involved. It is accomplished using both genetic and molecular mechanisms. Understanding cellular complexity, elucidating design principles, and fostering closer interactions between experimentation and theory may all be aided by robustness. A concept as broad as robustness will almost certainly play multiple roles in biological research. It can be regarded as an overarching evolutionary design principle or as a scientific approach. More optimistically, it may be the cure for the problems that plague large-scale dynamic modelling of biological systems.

Despite its importance in biology, there is still a lack of understanding of what robustness is and how it is achieved at the cellular or molecular level [4]. One major reason is that the robustness and apparent complexity of cellular systems are inextricably linked, making both difficult to comprehend [5][6].

Because biological robustness occurs throughout the ecosystem, it is essential for survival. It can be seen from the microscopic (cells and molecular) to the macroscopic (human and environment). The mutational robustness, for example, describes the extent to which an organism's phenotype remains constant despite mutation. Proteins studied thus far have demonstrated a tolerance to mutations of approximately 66%, and higher structural robustness improves a protein's evolvability [7]. Some organisms have developed adaptations to tolerate large changes in temperature, water availability, salinity, or food availability. Plants are unable to move when the environment changes, so they have developed a variety of mechanisms to achieve environmental robustness. [8]

When confronted with unexpected perturbations, biological fragility results in catastrophic failure. It is the cost of robustness and can be seen at various levels. For example, in biological terms, the Drosophila segment polarity gene network is robust against perturbations in its initial condition but vulnerable to large temporal variability [9]. The immune system in cells provides robustness against pathogen threats, but it is vulnerable to unexpected failures such as the dysfunction of MyD88, a nonredundant core element [10]. When fragility occurs, it is sometimes easy to recover and sometimes it is not. More specifically, robustness and fragility are symbiotic; they always coexist. In the context of treating a health problem, disease and therapy make use of fragility. For example, in cancer and HIV, we find a point of fragility that is inherent in robust systems and re-establish control of the epidemic state by introducing a counter-acting decoy or new regulatory feedback. [11]

The consequences of fragility could be harmful to the ecosystem and result in the extinction of a species. Because species are interconnected, their extinction will have an impact on the biological chain. Furthermore, biodiversity will decline. If things continue in this manner, the biological system will suffer widespread damage, and the earth will eventually face a crisis. We can reduce the occurrence of this series of phenomena by protecting the environment, such as through the United Nations taking measures to deal with the greenhouse effect, or by preserving genes to avoid the impact of species extinction.

Overall, biological robustness and fragility both provide positive and negative aspects, the most important thing is how to reduce the negative effect and maximise the positive.

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