Robutness and Fragility

Whether at the level of simple macromolecular organisms or complex multicellular organisms, biological robustness and fragility have always been prevalent in organisms as a pair of characteristics with a dyadic nature. Life is able to withstand internal and external fluctuations at certain scales. Genetic mutations, local random fluctuations in molecular concentrations, loss of structural integrity (e.g. trauma), infectious diseases, endogenous threats (e.g. cancer), temperature fluctuations, altered species interactions and regime changes in the physical environment are just some examples of these perturbations. Many biological systems have an inherent capacity to maintain specific functions or characteristics when exposed to specific perturbations and are therefore described as robust. At a small number of times, certain levels of macromolecules, cells or organisms, have certain mechanisms of fragility and so are likely to be attacked and altered or destroyed, such as genetic mutations that are damaging to RNAs, or certain diseases of organisms. However, from a higher level perspective, lower levels of fragility also reflect higher levels of robustness, e.g. genetic mutations ensure species diversity, and the elimination of organisms by disease makes the surviving part of the organism more resilient.

To a certain extent, a biological system is fragile if it is unable to withstand physical, chemical or biological fluctuations that alter a property. Once a biological system is unable to cope with a fluctuation, it means that the effects of this fragility on the system will be devastating, often with irreparable damage or death as a result of the altered property. For example, mammalian T-cells, the powerful immune cells of mammals, can defend themselves against a large number of different pathogens. However, lentiviruses such as HIV, BIV and SIV can infect and destroy them, thereby damaging the immune system and leaving many mammals, including humans, fragile to opportunistic infections. In addition, the only available research on treatment is antiretroviral therapy, and only one case has been found to be self-healing but the mechanism remains unclear. The fragility of other biological systems and context is similar to that described above, i.e. it is difficult to avoid. Moreover, in a system, even when researchers are equipped with the relevant scientific techniques, a mechanism of fragility should be carefully eliminated or avoided. For its rare presence enables a balance to be created with a broad range of robustness so that biological systems can survive with changes in their environment and adapt stably to it 1. A brutal and direct alteration of a biological system's fragility mechanism may cause an imbalance that can directly or indirectly lead to new problems.

Robustness, where a property of a biological system is invariant to a physical, chemical or biological perturbation. It is widespread across biological systems; for example, because of constant genetic mutation and recombination, populations in their native habitats may have considerable genetic diversity without significant traits among individuals, i.e. the phenotype is largely robust to these specific genetic variations. This trait robustness is prevalent at all organisational levels of biology, including protein folding, gene expression, physiological homeostasis, organism survival, species persistence, etc. Robustness is ubiquitous and essential because proteins, cells, biochemical networks, immune systems, organisms and natural populations exist in changing and sometimes novel conditions in which maintaining satisfactory performance will determine persistence or function. It is in the combination of robustness and fragility that different ranges of living organisms are able to adapt stably to complex and changing external environments and that life can continue and evolve. Insights into biological robustness may also be important outside of biology, for example when applied to robotics or artificial intelligence, allowing machines to adapt to changes in their environment by adapting their behaviour or patterns to avoid the dramatic effects of disruptive perturbations.

Reference

1. Serban, M. , and S. Green . Biological robustness. 2020.