Biological Robustness and Fragility and Multilevel Effects

Robustness and fragility are reflected in multiple dimensions of biology. Whether it is basic biological macromolecules, single-celled organisms, advanced animals such as humans, populations composed of individual species, or entire ecosystems, they are delicate and complex, ingenious and fragile (Kwon and Cho, 2008). Each level involved a series of mechanisms to counter fluctuations from internal and external distribution in the natural state, maintaining its homeostasis to ensure functional integrity, which is defined as the robustness of biology (Posadas-García and Espinosa-Soto, 2022). However, according to Marta et al. (2018), complex, cascading systems simultaneously mean that any disturbances and the negative effect that cannot be eliminated or repaired will bring damage and catastrophe to either dimension, which is the fragility of biology.

In the human immune system, the process of differentiating mature B cells from lymphoid stem cells reflects biological robustness. Antibodies secreted by plasm cells can specifically recognize any antigen in the universe and induce an immune response, and achieving this ability requires a huge investment. Gene rearrangements and high-frequency mutations contribute to robustness. Su (2005) pointed out that a large number of combinations of variable antigen regions can generate antibodies to the $5\text{-}10\times10^{13}$. Eventually, 98% of immature B cells are induced into apoptosis by negative selection (Su, 2005). For a single level, robustness is achieved by functional redundancy, system regulation, and buffer settings, and the cost is a waste of resources, reduction of information degree, and improvement of cost. Excess inputs, similar functions, and flexible combinations are precise to ensure that organisms can withstand uncertainty. For the higher dimensions, the presence of defective ingredients reduces robustness, and the higher layers do not want to see immutable composition and conservatism. Therefore, vulnerability also exists in every biological dimension.

Ras is a highly conserved proto-oncogene in eukaryotes, and nearly 100% of pancreatic cancer patients carry the mutation (Song, 2010). This is because the *Ras* protein is a regulator of cell signaling, which switches between two states, opening, and closing. By comparing DNA sequences of the *Ras* gene at the base level, Hanahan and Weinberg (2011) found that in more than 6,000 base sites, mutations in just one site led to changes in their structure and loss of function. As a result, somatic cells lose their signal receivers to control division, and they lose the brakes and eventually become cancer cells that cause cancer (Song, 2010).

The reason why the robustness of organisms is ensured at such a high cost is that biological survival must ensure both survival and function. Ensure the stability of key parts and ensure their high efficiency in the form of multiple copies of functional parts. From a higher-dimensional perspective, each underlying individual is a replica of the robustness maintained by the higher level. A more complex upper-level system needs to bargain more advanced individuals from these replications, and at the same time utilize the vulnerability to remove those defective individuals to ensure the safety of higher-dimensional organisms. To have broad leeway to respond to potential crises, insurance is needed in every biological dimension. This is how robustness is delivered at each level. Robustness provides more choices for evolution while ensuring survival, and allows the exertion of specific functions to be carried out efficiently (Chen et al., 2022).

For the individual, the consequences of vulnerability manifest themselves in destruction and closure in the face of unsettled disruptions. It cannot be tolerated by the higher dimensions that uncertainties remain in their subsets and continue to be passed, which seriously affects the maintenance of their original functions. In this way, once the robustness is insufficient and the potential crises occur, molecules, organisms, individuals, populations, and ecosystems will be eliminated.

There are many ways for humans to avoid obsolescence and catastrophic consequences. By detecting pathogenic mutations that may exist in our bodies through gene sequencing, humans can prevent the corresponding diseases in advance (Umlai et al., 2022). Keeping away from mutation-causing factors such as transcription viruses, radiation, and chemical environment (carcinogens) can also avoid gene mutation (Tibbetts, 2018). In the face of immune system diseases, avoiding the harm caused by fever as a result of cytokine storms through drug means is also a means for human beings to avoid vulnerability and maintain their existence (Zhang et al., 2022).

Robustness and vulnerability are closely bound up, ensuring individual survival while contributing to the progress of the system as a whole.

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