What are the inherent properties of living organisms? Biological robustness and fragility might give an answer to this question. Biological robustness, which enables organisms to maintain their functions despite internal and external perturbations. In contrast, biological fragility represents the weak abilities of organisms that can lead to negative outcomes. This essay examines the definitions of biological robustness and fragility, discussing the components, the role in survival, and the need for adaptation and resilience in the face of challenges.

Biological robustness is one of the fundamental and ubiquitous attributes of living organisms that comprises three components: the system, function, and perturbations. As defined by Kitano (2004), robustness is the property that allows a system to maintain its functions despite external and internal perturbations (p. 826). (1) The term "system" encompasses a wide range of biological entities, from the level of genes to that of populations. For instance, multiple codons can code for the same amino acid, indicating that robustness operates at the level of the gene (Sanger, 1981). Furthermore, despite considerable genetic diversity, there is little variation in traits among individuals within specific populations, further illustrating the breadth of biological robustness (Kussell et al., 2005). (2) Maintaining "function" refers to the ability to sustain specific effects regardless of the dramatic shift of the system's state. This is exemplified in the work undertaken by Majercak et al. (1999), which displays that the circadian clock in Drosophila maintained relatively constant even in a wide range of temperatures. (3) The third component of biological robustness, "perturbations," refers to the diverse types and degrees of stimuli that can affect biological systems. For example, a study by Petitjean et al. (2007) investigated the effects of different types of perturbations on the function of the p53 tumor suppressor protein, a critical regulator of the cell cycle and DNA repair pathways. Overall, robustness is an essential characteristic to remain stable despite perturbations in biological organisms.

In addition to maintaining the proper functioning of the biological system, biological robustness plays a crucial role in the survival of living things. It means that robustness is essentially the consequence of modulation by different system mechanisms, such as alternative mechanisms and modularity, to ensure strong adaptation abilities coping with perturbations that probably affect lives. Various mechanisms of robustness promote biological evolution, and evolution drives biological robustness. This complex and complementary relationship helps organisms survive. On the one hand, it can mitigate the impact of dangerous factors. The tardigrades can survive in the ionizing radiation (Jönsson et al., 2008), which is an extreme instance to demonstrate this property resists the threat to lives. On the other hand, it can facilitate better survival. A study by Zimmerman et al. (1996) found that individuals with a specific genetic variant in the CCR5 gene might be more resistant to infection by the human immunodeficiency virus (HIV) and had a survival advantage compared to those without the variant.

However, biological fragility, as opposed to robustness, is another important attribute that describes the weak abilities leading to negative results while attacked by internal or external perturbations. We focus on that this property can probably result in different levels of outcomes that vary from susceptibility to certain diseases to the breakdown and death of systems. As humans, some diseases, such as colorectal (Navarro et al., 2017) and breast cancers (Hu et al., 2021), are common in specific populations due to genetics and lifestyle choices, which reflect the consequence of fragility. Another well-known example is the hard survival of polar bears because of climate warming, which threatens their habitat and food sources (Hunter et al., 2010). In a word, compared with robustness, fragility highlights the necessity for adaptation and resilience in the face of environmental and genetic challenges.

The negative consequences of biological fragility highlight the requirement to reduce external perturbations and find effective solutions, even in the presence of internal perturbations. For humans, a healthy lifestyle and staying away from harmful factors to avoid specific diseases, such as alcoholism leading to cirrhosis (Lieber, 1995), are effective actions to take. However, there is an unavoidable fact that it is hard to completely avoid this inherent property. Some researchers try to make the transformation for fragility. For example, targeted drugs and radiotherapy are utilized for cancer treatment (Begg et al., 2011), and gene phenotyping contributes to developing personalized treatment plans (Pillon et al., 2021). It is imperative to clarify the relationship between robustness and fragility, which means that there is an inherent trade-off (Kitano, 2004). Given the high stakes involved in transforming biological fragility, it is crucial to approach any measures or research with a great deal of care and consideration.

In conclusion, biological robustness and fragility are two inherent and crucial properties. The former can maintain the stability of function and is important for survival, while the latter shows the possibility of negative outcomes in the face of perturbations. As we continue to study these properties, it is important to recognize the trade-off between robustness and fragility, and to approach any measures or research aimed at transforming biological fragility with care and consideration. Ultimately, by understanding these properties, we can better appreciate the complexity and resilience of living systems.

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