Question 1: Biological Robustness and Fragility

The property of robustness is widely recognized in biological systems. Complex systems capable of evolution are thought to have this as one of their defining characteristics. In this regard, robustness is defined as an essential characteristic of biological networks that permits them to continue functioning while being subjected to internal and external disturbances (Bianconi et al., 2019). However, recent research revealed that the robustness of biological networks is deeply connected with fragility (Kim et al., 2020). Fragility is the characteristic of biological networks that makes them susceptible to damage and destruction (Sakthivel et al., 2021). Thus, against this background, the present essay aims to discuss a detailed description in terms of biology. Thus, first, a detailed example of robustness and fragility will be discussed. Second, the importance of biological robustness in terms of survivability will be discussed. Furthermore, the fragility consequences and its avoidance will also be discussed.

Robustness in biology can be explained through the example of the robustness property of the disease of cancer. The capacity of cancer cells to preserve their functions in the face of internal and external disturbances is a key factor in the development of the disease. In this context, tumor cells continue to "function" by surviving and multiplying, which allows the tumor to maintain robust characteristics (Bianconi et al., 2015) (Fig 1). On the other hand, medical treatments could be viewed as system disturbances. Thus, cancer cells have a robust system that, through genetic variety, feedback loops, as well as the utilization of alternate mechanisms, can robustly sustain resistance to medicines (Gatenby & Brown, 2020). Thus, biological robustness can be easily explained through the example of cancer.

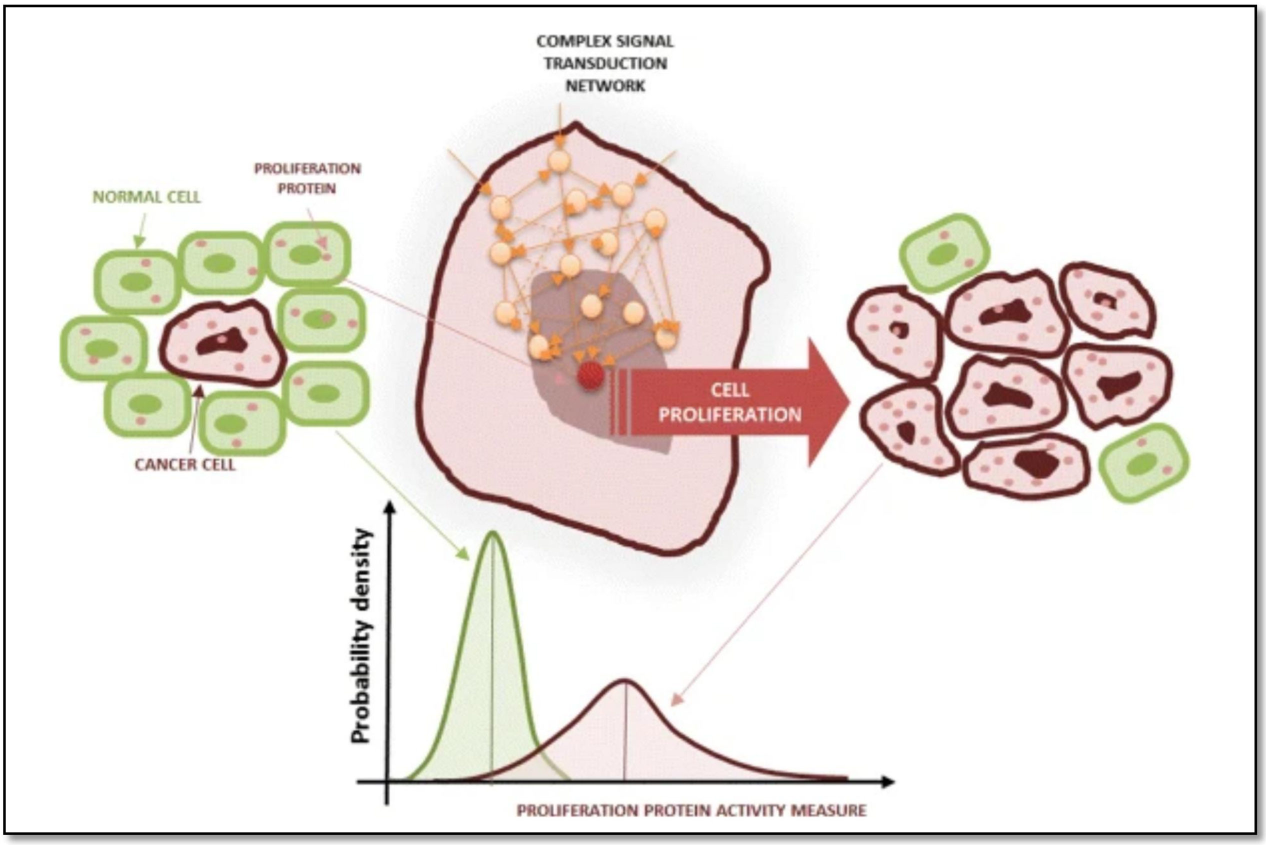

Fig 1: Cancer cell proliferation shows its robust characteristics, where green cells are normal cells, and red cells represent cancerous cells (Source: Bianconi et al., 2015).

The fragility example in the context of biology can be explained through a similar example of robustness in cancer. Certain cells have fragile components that regulate the immune system and could be used in cancer immunotherapy (Zhang et al., 2021). Thus, fragility involves the destruction of that cell proliferation to limit cancer growth, and due to this positive impact of fragility, the medical field continuously discovers different treatment options that can enhance this fragility. Therefore, fragility has a positive effect on the biological system because it can diminish the robust properties of diseased cells. Hence, preventing cancer cell proliferation acts as an example of fragility.

Biological robustness is an integral part of survival because conditions such as protein function, cellular activities, biochemical pathways, immune functions, and natural populations must adapt within the continuously changing conditions where the conservation of adequate performance will decide on survival or function. Recently, mutational robustness has interested evolutionists because it removes constraints from evolution at the molecular and systemic levels (Kaneko & Kikuchi, 2022). In addition to genetic diversity, mutational robustness has recently been shown to play a crucial role in the ability of populations to adapt to environmental change because it promotes the genetic diversity of populations, paving the way for its exploitation and quick adaptation to novel situations (Radványi & Kun, 2021). Thus, in this way, biological robustness becomes an integral part of survival.

Despite the excellent results, fragility is a notable drawback in complex networks. For example, in ecological systems, the chances of species maintaining a stable equilibrium are diminished if those systems are too fragile (Allesina & Tang, 2015). Moreover, in neural networks, fragility indicates that modifications in synaptic weights, although slight, can rapidly trigger unpredictable behaviours and even cause seizures (Pasqualetti et al., 2020). Thus, these consequences have been noticed as a result of fragility. One can avoid these negative consequences of fragility by maintaining a balance between robustness and fragility.

Therefore, from the above discussion, it became evident that robustness is a feature of cells that protects them against some perturbations. Thus, it causes some detrimental effects on the biological system. In this regard, fragility can maintain the balance. Thus, in conclusion, both the trade-off activity of robustness and fragility of a biological system can work smoothly.