Question 1: Biological Robustness and Fragility

Biological robustness is a characteristic of a biological system that maintains its structural and functional stability when disturbed by uncertainties such as external perturbations or internal parameter uptake. Many biological systems have been said to as robust because they naturally possess the ability to preserve particular characteristics or functions when subjected to certain disturbances. Life can survive a range of frequency and temporal variations, both internal and external. These disturbances include, but are not limited to, genetic mutations, localized stochastic fluctuations in molecular concentrations, loss of structural integrity (due to trauma, for instance), infectious diseases, endogenous threats like cancer, temperature fluctuations, altered species interactions, and regime shifts in the physical environment.

Biological Fragility is the opposite of stability since it is the property or state of being readily broken or destroyed (Margules, 1986; Smith & Theberge, 1986).In other words, a high degree of fragility and a low degree of stability are equivalent .When a biological system is fragile, such as external disturbances or internal parameter absorption, the system is unable to maintain its structural and functional stability, which can result in illness or even death.

This characteristic has consistently been shown in several biological instances. For instance, a bacteriophage's life cycle's destiny determination is resistant to minor changes at its promoter region (Little et al., 1999). Drosophila maintains segmental polarity in the face of changes to the molecular interactions' starting values and rate constants (Ingolia, 2004).

However, it has also been shown that biological networks are frequently vulnerable to unforeseen alterations. For instance, our body's energy regulation system provides resistance to frequent disturbances like unreliable food supplies or diseases, but it is vulnerable to unexpected alterations like high-energy diets or low-energy lifestyles (Kitano, 2004a). The immune system is strong against pathogen threats, yet it is vulnerable to unanticipated failures, including malfunction of the nonredundant core element MyD88 (Kitano and Oda, 2006). The Drosophila segment polarity gene network exhibits resilience against changes to its starting state but exhibits fragility when exposed to high temporal variability (Chaves et al., 2005).

A crucial characteristic of biological networks is robustness, which permits them to continue operating in the face of internal and external disturbances.The preservation of adequate performance will determine persistence or function, according to many scientists, because proteins, cells, biochemical networks, immune systems, organisms, and natural populations exist in constantly changing and occasionally novel environments.According to recent research, mutational resilience plays a crucial role in the adaptive diversification of populations because it permits the accumulation of cryptic genetic variation (CGV) in populations, which may then be used or exapted for fast evolution in unfamiliar contexts (Hayden et al., 2011; Whitacre and Atamas, submitted).One essential characteristic of biological systems is robustness. It promotes adaptability, and evolution favors strong qualities.Therefore， due to the rapid evolution and selection, the organisms can survive longer and better.

However, when a system has certain vulnerabilities, i.e. robustness, and low stability problems, the biological system does not maintain its structural and functional stability when disturbed by uncertainties such as external perturbations or internal parameter uptake, thus not ensuring feedback, redundancy, and structural stability of the biological system, etc., and finally resulting in the inability of organisms to successfully survive, develop, adapt to the environment and control disease development.

If robustness is to be improved, then these properties can be improved by attaching human ecological control mechanisms, monitoring and maintenance. However, when controls are introduced, the uncertainty caused by the various biases and failures of the controls themselves becomes an additional disturbance to the system. How to overcome the deviations caused by this new type of disturbance becomes the so-called non-vulnerability problem of the control system.

References:

1. Whitacre James(2012), Biological Robustness: Paradigms, Mechanisms, and Systems Principles ,Frontiers in Genetics,1664-8021,doi: 10.3389/fgene.2012.00067
2. Kitano, H. (2004). Biological robustness.Nat. Rev. Genet.5, 826–837. doi: 10.1038/nrg1471
3. Nilsson, C., & Grelsson, G. (1995). The Fragility of Ecosystems: A Review. Journal of Applied Ecology, 32(4), 677–692. https://doi.org/10.2307/2404808
4. Yung-Keun Kwon, Kwang-Hyun Cho,(2008). Quantitative analysis of robustness and fragility in biological networks based on feedback dynamics, Bioinformatics, 24(7), https://doi.org/10.1093/bioinformatics/btn060