Q1

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Biological robustness is the ability of an organism to resist and recover from environmental disturbances. It gives it the capacity to survive and prosper despite ecological changes. Fragility, on the other hand, is when a species cannot adapt to changes in the environment, leading to its eventual decline or death. For instance, bacterial chemotaxis gives bacteria a competitive survival advantage by allowing them to locate food sources and flee hazardous situations. However, because they are sensitive to variations in water temperature and pH levels and are unable to survive when those parameters differ too much, corals are thought of as fragile species.

In its most general form, robustness can be described as the maintenance of a system's characteristic behavior when subjected to perturbations or unpredictable conditions. Instead of the system remaining in homeostasis, which would mean all of its properties remained unchanged, robustness is the maintenance of a specified functionality. Both the return of the function in question to its initial state after perturbation and the transition to a new state that enables functionality to be maintained in the new conditions are examples of robustness. Therefore, biological robustness is integral to survival because it will enable an organism to adapt to changes and maintain its population in the face of a changing climate. If a species is too fragile, it won't be able to maintain itself in the face of environmental stressors, which would eventually lead to the extinction of its population. So, to some extent, I contend that resilience is a key component of complex, evolvable systems. Complex biological systems need to be resistant to genetic and environmental changes in order to be able to evolve. Evolution frequently chooses features that might increase the organism's robustness. Robustness is an inherent property of evolving, complex dynamic systems — various mechanisms incurring robustness organisms actually facilitate evolution, and evolution favours robust traits.

Depending on the species, fragility has different effects. An organism can only experience extinction if it lacks the resilience to withstand unanticipated disturbances and eventually becomes fragile. For instance, a species of the coral reef will probably succumb to illness, bleaching, and mortality if it cannot adapt to changing water temperatures. Similarly to this, if a bacteria were to be able to swim more quickly without negative feedback, this would compromise its capacity to follow a chemical gradient precisely. The usage of negative feedback enhances the bacteria's ability to follow a chemical gradient at the expense of slower swim speed. As a result, biological network robustness and fragility are related to one another. Using a more suitable illustration, a cancer cell that is resistant to a variety of chemical agents may be extremely vulnerable to certain perturbations. Since fragility is a byproduct of robustness, the system's weak point must be linked to a mechanism that results in increased robustness. When the system's frailty is revealed, robust systems, whether biological or designed, are most susceptible. For instance, diabetes mellitus can be viewed as an exposed systemic fragility that has developed robustness against near-starvation, a high energy-demand lifestyle, and a high risk of infection but is unusually upset by overnutrition and a low energy-demand lifestyle.

To avoid fragility, robustness must be increased. Making the system resilient to disturbances comes at a price, though. Enhanced complexity and fragility to unanticipated issues are the two key drawbacks of increased resilience. It is difficult to prevent fragility simply to lessen it. Since the mechanisms that ensure the robustness of a system, are system control, alternative mechanisms, modularity, and decoupling, working independently, increasing robustness can reduce some fragility.

In conclusion, biological robustness is crucial for life and plays a significant part in assisting organisms to survive in an environment that is always changing. Robustness is frequently misinterpreted as meaning that the system's structure and components, and hence its mode of operation, remain unaffected despite stimuli or mutations. Robustness is the ability of a system to maintain particular capabilities in the face of disturbances, and it frequently calls for a flexible adjustment in the system's operating mode. In other words, resilience permits the system's structure and components to alter as a result of disturbances while maintaining certain functionalities. Contrarily, fragility produces negative effects that eventually result in population reduction and extinction.