Biological Robustness and Fragility

CHENGLE OUYANG

1 Definition

A biological system's ability to preserve its structure and function even when troubled by ambiguous variables like an external disturbance or an internal parameter alteration is known as biological robustness [1].

The term "fragility" describes a biodiversity's capacity to endure changes in the environment. A higher level of fragility indicates that biodiversity is more susceptible to unforeseen mutations and is quickly influenced by changes in the environment [2]. Biological networks' robustness is susceptible to unanticipated alterations.

2 Examples

Currently, it has been discovered that biological robustness is pervasive at the organ, cell, molecular, and other levels of biology, including bacterial chemotaxis, cell cycle, cell signalling, gene mutation, biological development, gene network, and other processes. Across a wide range of chemoattractant concentrations, E. coli can chemotaxis. For instance, E. coli can retain correct adaptation even when the concentration of network proteins is significantly altered [3]. This demonstrates how reliable E. coli's chemotaxis is.

The robustness and fragility of biological networks are related. However, they also put fragility at danger for malnutrition or glucose shortages. Energy control strategies offer robustness against frequent interruptions like inconsistent food supplies or illnesses. The immune system has a strong ability to protect against pathogen threats, but it is vulnerable to unanticipated malfunctions, such as the failure of MyD88, a crucial non-redundant component. Cancer cells can be very susceptible to some disturbances, despite their resistance to numerous chemical agents.

3 Necessity of biological robustness

An organism is always in a changing environment, and it also needs a relatively stable internal environment to enable it to survive in all kinds of environments. Therefore, the existence of biological robustness enables organisms to better adapt to the environment and to maintain their functions from external and internal disturbances. Biological robustness is also reflected in the slow attenuation of functional characteristics of biological systems under the condition of damage (non-catastrophic failure), so as to enhance survivability and prolong survival time [5]. Understanding biological robustness is important for the occurrence, development and treatment of cancer, AIDS, diabetes and other diseases.

4 Consequences of fragility and How to avoid

Metabolic syndrome can be brought on by glucose excess or deficiency, which might reveal fragility in the volume control system. The metabolic syndrome displays its own resilience by maintaining chronic hyperglycemia and hyperinsulinemia. Cardiovascular disease eventually confuses the syndrome's existence, albeit [4]. The Fragility of robust networks may be shown by node mutation involving a sizable number of feedback loops [2]. For instance, p53 gene or functional protein loss might make creatures more susceptible to cancer at an early age [6].

Many sophisticated networks display fragile behaviour when edge weights and connection architectures are only slightly altered. Ecosystem fragility influences the likelihood of species coexisting in a stable equilibrium, as is the case with ecosystems [7]. For instance, fragility in brain networks implies that minute variations in the weight of some synapses can abruptly cause abnormal behaviour and cause seizures [8]. The fragility of complex networks is a drawback that neither careful human design nor natural development can overcome. Existing explanations fall short in explaining this occurrence [9]. Therefore, avoiding exposure to the fragility of biological systems as much as feasible may be accomplished by increasing the robustness of complex networks and minimising perturbations, mutations, and accidents.

Biomolecular regulatory networks are robust but fragile in terms of feedback loops [2]. The number of feedback loops is an indicator of fragility, and many fatal or basic nodes involve relatively more feedback loops. Thus, less feedback loops can reduce fragility.

Reference

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