A Discussion on Biological Robustness and Fragility

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1 Introduction

1.1 Bilogical Robustness

First of all, there must be a common understanding on what ‘robustness’ means. Defining any scientific term is a nontrivial issue, but in this paper, the following definition will be used: ‘robustness is a property that allows a system to maintain its functions against internal and external perturbations.’[1]. A similar definition with a slightly different phrasing was used by others, such as ‘robustness, the ability to maintain performance in the face of perturbations and uncertainty, is a long-recognized key property of living systems’[2].

Robustness is a ubiquitously observed property of biological systems. It is considered to be a fundamental feature of complex evolvable systems. It is attained by several underlying principles that are universal to both biological organisms and sophisticated engineering systems. Robustness facilitates evolvability and robust traits are often selected by evolution. Such a mutually beneficial process is made possible by specific architectural features observed in robust systems. But there are trade-offs between robustness, fragility, performance and resource demands, which explain system behaviour, including the patterns of failure.

1.2 Biological Fragility

Fragility may be regarded as an inherent property of an ecosystem, i.e. an ecosystem has a certain fragility whether or not it is ever exposed to any disturbances. This fragility is impossible to quantify, leaving it as a mere metaphysical term. The only observable fragility is that displayed as a result of disturbances, natural as well as human-caused, operating in the ecosystem. Therefore, relating ecosystems to the disturbances that work there can provide useful assessments, an approach closely related to environmental impact assessment.[3]

2 Related examples

2.1 Biological Robustness

Robustness is a key property of biological networks that enables to maintain their functioning against external and internal perturbations. This feature has been ubiquitously observed in various biological examples. For instance, the fate decision of a bacteriophage life cycle is robust against small perturbations at its promoter region [4]. Escherichia coli is capable of chemotaxis over a wide range of chemo-attractant concentrations[5. Drosophila establishes segmental polarity against perturbations in its initial values and rate constants of molecular interactions[6].

2.2 Biological Fragility

On the other hand, it has also been reported that biological networks are often fragile against unexpected mutations. For example, the energy control system of our body ensures robustness against common perturbations such as unstable food supply or infections, but the system is fragile against unusual mutations such as high-energy content foods or low-energy utilization lifestyle[7]. The immune system provides robustness against pathogen threats, but it is fragile against unexpected failures such as dysfunction of MyD88 which is a nonredundant core element[8]. The segment polarity gene network of Drosophila shows robustness against perturbations in its initial condition but shows fragility against a large temporal variability[9].

3 Explain about biodurability as a component of survival

Robustness is a fundamental feature of evolvable complex systems. Complex biological systems must be robust against environmental and genetic perturbations to be evolvable. Evolution often selects traits that might enhance robustness of the organism. Robustness is, therefore, ubiquitous in living organisms that have evolved.

However, systems that are robust face fragility and performance setback as an inherent trade-off. Identification of the basic architecture for a robust system and the associated trade-offs is essential for understanding their faults and countermeasures — diseases and therapies, respectively.Biological evolution is predicated on being able to survive, so biological robustness is a component of survival.

4 Consequences of vulnerability and ways to avoid it

Biological fragility can lead to specific types of organisms becoming scarce or even extinct, and biodiversity can be reduced. Various ecosystems can be affected accordingly.The complexity of fragility leads to several problems in its assessment. First, the different aspects of fragility are not necessarily interrelated. Therefore, an ecosystem might be relatively fragile in one respect and relatively stable in another[10]. To achieve a proper assessment of ecosystem fragility, using a set of definitions, it is therefore important to consider the entire set of meanings. Secondly, the various aspects of fragility are not easily quantified, and fragility as a whole even less so. Thirdly, the fragility of an ecosystem depends upon scale. Four scales are important:(i)temporal scale, (ii)spatial scale. (iii)level of taxonomic resolution, and (iv)numerical resolution,i.e. whether one analyses data about absolute abundance, abundance rankings, or presence-absence data [11]. Both human and natural factors can affect biological fragility as well.So we have to address different aspects of specific problems to avoid biological fragility consequences.

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