

## **Defining biological robustness**

‘Biological robustness is a property that allows a system to maintain its functions against internal and external perturbations.’ (Kitano, 2004a). 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.

Biological systems can be highly robust due to the presence of redundant or alternative pathways or mechanisms that can compensate for changes or disruptions in the system. For example, a plant may be able to tolerate drought conditions by shutting down non-essential processes and using stored nutrients to survive until conditions improve. Similarly, an animal may be able to adapt to a new environment by adjusting its behavior or physiology in response to changes in its surroundings.

Overall, biological robustness is an important factor in the survival and evolution of organisms and is influenced by a variety of genetic, environmental, and ecological factors.

## **Why is biological robustness so important?**

First of all, it is a feature that is observed to be so ubiquitous in biological systems; This implies that it may be a basis for principles that are universal in biological systems.

Second, robustness is a system-level property of the system in which interactions of components give rise to this feature.

Third, Mechanisms that attain robustness against environmental perturbation may be used also for attaining robustness against mutations, developmental stability, and other features that facilitate evolvability. Its role in the survival and evolution of organisms, biological robustness is also important for maintaining the stability and functioning of ecosystems. If one species in an ecosystem becomes extinct or severely declines in numbers, it can have cascading effects on other species and the overall functioning of the ecosystem. Maintaining biological robustness can help prevent these types of disruptions and ensure the stability and sustainability of ecosystems.

Last but not least, it allows organisms and biological systems to survive and function in the face of environmental perturbations or changes. This is critical for the survival and evolution of organisms, as it allows them to adapt to new environments and changing conditions.

### **Example**

Animals: Many animals are able to adapt to changes in their environment by adjusting their behavior or physiology. For example, some animals are able to migrate to new locations when their current environment becomes inhospitable, while others are able to adjust their metabolism or behavior to better tolerate changes in temperature or the availability of food.

### **Defining biological Fragility**

Biological fragility refers to the inability of an organism or a biological system to maintain its functions and survive in the face of perturbations or changes in its environment. It is the opposite of biological robustness and indicates that an organism or system is susceptible to disruptions or changes in its environment. Biological fragility is an important factor to consider when evaluating the survival and adaptation of organisms, as well as the stability and functioning of ecosystems. In general, organisms and systems that are more biologically fragile may be more vulnerable to extinction or other types of disruption in the face of environmental changes.

### **Example**

Human health: Humans are vulnerable to various health risks, including infectious diseases, environmental toxins, and genetic predispositions to certain conditions.

### **Consequence of fragility and the way to avoid it**

The consequences of fragility can be severe and may include increased mortality, reduced reproductive success, and population declines. In some cases, fragility can even lead to extinction.

There are several ways to avoid or reduce fragility in biological systems:

- 1) Conservation and protection: Protecting and conserving vulnerable species and habitats can help reduce fragility by providing a stable environment for these organisms to thrive.
- 2) Disease prevention and management: Implementing measures to prevent the spread of disease, such as vaccination programs and quarantine measures, can help reduce fragility in human and animal populations.
- 3) Genetic diversity: Maintaining genetic diversity within a population can help reduce fragility by increasing the chances that some individuals will be able to survive and thrive in the face of negative impacts.