Research on Biological Robustness and Fragility

For many objects that are always in an ever-changing environment, they are able to maintain a relatively stable internal environment that allows them to survive in a variety of environments. Such kind of ability to remain stability is called robustness. Although the Boeing 747 is sturdy when faced with massive atmospheric disturbances, cargo overloads, and aging structural components, it may be doomed if tiny changes in integrated circuit chips occur, which is known as fragility. In general, robustness and fragility coexist. Something that is robust on the one hand may be fragile on the other hand.

In biology, organisms also have the characteristics of robustness, specifically called biological robustness, while fragility is also known as biological fragility.

The term “biological robustness” refers to the characteristics that the biological system maintains its structure and function stability when it is disturbed by uncertain factors such as external disturbance or internal parameter perturbation, while the term “biological fragility” refers to the ability of organisms to withstand changes in external conditions.[1] Higher fragility means that the biological system is more sensitive and susceptible to changes in response to internal conditions. Thus, biological robustness is best reflected in the adaptation of organisms to the environment.[2] For example, my hometown in northern Guangdong province is a limestone region with a very fragile ecosystem in some areas. Once affected by external natural disasters such as cold wave invasion and drought, it is difficult to recover as before or even change irreversibly. And as a kind of plant seeming fragile, mimosa is sensitive to some external interference, but relatively it is robust because when the external interference disappears, it will quickly return to its original state according to its biological robustness.

In the case of uncertainty and crisis, biological robustness has become the key to the survival of the biological system. For instance, when biological systems encounter large or small disturbances, or when the cells suffer from environmental changes or genetic variations, they can always maintain a relatively stable internal state and have a greater chance of survival in various environments. Biological organisms are also remarkably robust in the face of environmental uncertainties, even though they may be doomed by small genetic perturbations such as gene mutation or microscopic pathogens like HIV. It has been found that biological robustness exists in various biological systems, including organs, tissue, and cells. Cell signaling, cell cycle, gene mutation, and biological development are all manifestations of biological robustness. Therefore, biological robustness is an integral part of survival.

However, biological fragility sometimes is needed. In modern medical research, many researchers attempt to reduce the biological robustness of cancer cells and increase their fragility to enhance the efficacy of various treatments. The biodiversity also has the characteristic fragility. The fragility of biodiversity to climate change is reflected in changes in species behavior and richness after climate change, as well as pest infestation, resulting in changes in ecosystem structure and function. Macro fragility will have a profound impact on species types, species distribution, and lead to species extinction. Since 1992, as many as one million species have been threatened globally.

Biological adaptation is an effective way to reduce biological fragility, including natural adaptation and human adaptation, namely biological self-adaptability and human intervention adaptation. From the perspective of the biological population, adaptation is the accumulation of gene reflection formed by a population under the pressure of environmental selection, including growth, evolution, etc. Take Singapore's efforts in maintaining the ecological environment as an example. By creating hanging gardens, promoting vertical greening, and constructing ecological bridges, human intervention has successfully reduced the heat island effect, controlled PM2.5, and promoted ecological balance.

In conclusion, the biological robustness and fragility are all characteristics of biological systems. And the former has become an indispensable part of survival. These characteristics have been found to exist at many levels of biological systems including molecules, cells, tissue, organs and systems. With a better understanding of robustness and fragility especially in biological organisms, we can make more specific efforts to protect endangered species, including animals, plants and even the ecosystem. Hopefully, this research can be really applied to help preserve ecosystems and biodiversity and make the earth a more beautiful place to live.

References

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