Answer to question 1:

Biological robustness generally refers to biological networks maintaining their basic functioning against external and internal perturbations. Fragility refers to when biological networks are fragile against unexpected mutations. Although there are often trade-offs between robustness and fragility in a system, they are correlated. Both biological robustness and biological fragility are critical properties in a biological system.

Robustness and fragility happen all the time in our bodies. For example, the immune system will provide robustness against pathogen threats when a person gets sick. The nose and mouth secrete mucus, and the body sweats as a specific symptom. An example of biological fragility is starvation or thirst, which may result in serious health problems if we stop consuming food and water because there is no nutrient trade into our bodies. Besides, the robustness and fragility of biological networks can, of course, be defined in various ways according to their cellular context and functions.

Biological robustness has been studied as an integral part of survival, which helps our body withstand internal and external fluctuation at various frequencies and timescales. Some disturbances can be, to some extent, genetic mutation, loss of structural integrity, infectious diseases, endogenous threats such as cancer, temperature fluctuations, regime shift in the physical environment, and so on. Robustness supports our health by providing associative functions, such as protein folding, gene expression, metabolic flux, physiologic homeostasis, development, organism survival, and ecological resilience. All these functions are required to maintain health, and biological robustness is ubiquitous and essential.

"Complex systems evolved to be robust against general perturbations can extremely be fragile against certain types of rare perturbations." (Carlson and Doyle, 2022) There are always changes that exist in proteins, cells, biochemical networks, immune systems, and organisms, the maintenance of

satisfactory performance will determine persistence. However, robustness has limitations within a biological system; fragility is a significant issue in this case. In fact, besides illness, fragility can also be caused by bad habits, including dietary, no exercise, smoking, or excessive drinking. If a person has these bad habits for an extended period, it may result in risks of high blood pressure, cholesterols, or diabetes. If an individual has the following symptom, he/she could be considered to have a risk of fragility:

1. An individual always feels weak; there is trouble standing without assistance.
2. An individual always feels exhausted. Everything he/she does may consume most of his/her energy.
3. An individual has a low activity level, including formal exercise, household chores, or entertainment.

"If we understand the underlying biomedical processes that create fragility, we can develop better interventions —- from medications to lifestyle changes," says Samuel Durso, M.D., the director of geriatric medicine and gerontology at Johns Hopkins. *"And fortunately, research already shows that some lifestyle steps can help."* There are a couple of ways that help us avoid fragility. First, one can stay active most of the week and exercise healthily. Some research has determined that easy strength-exercising will improve strength and reduce weakness, which is helpful to any age group of people. In addition, eating well is very important. We can conduct meals that provide fruit, vegetables, proteins, good fat, and low-fat dairy products, which guarantees the necessary nutrients we consume per day. Also, it is helpful that keeping an active mind and attitude of optimistic, positive feelings always translates into a low risk of fragility across most studies. *"Staying socially connected with others and continuing to learn may also help,"* Durso says, *"Johns Hopkins research has found that those factors may explain why older volunteers who tutor in elementary schools sharpen their own thinking skills and improve their physical functioning too."*

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