**Question 1**

**Using your own understanding write a 700-word essay on Biological Robustness and Fragility**

Organisms are constantly subject to a wide range of disturbances from internal and external factors. Biological robustness refers to the fact that biological systems can withstand these disturbances (e.g., genetic mutations, infectious diseases, loss of structural integrity, and more) via mechanisms and maintain their normal operation in general [(Whitacre, 2012)](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3350086). Being robust means organisms are insensitive against such changes.

Here, homeostasis will be taken as an example to illustrate robustness in a simplified way. Human body, when subjected to the influence of external environment (e.g., temperature fluctuations and water availability) tends to maintain its internal environment constant so that cells can function properly, such as maintaining a balance between water input and output or maintaining a body temperature at about 37 °C by getting rid of excess body heat when people are hot but retaining heat when the environment is cold. In this case, the system remains unchanged in its properties. However, biological robustness does not really mean the system remains unchanged but means to maintain specific functionality by either returning the function to its original state or transitioning to a new state but still allowing proper functionality following disturbances [(Quinton-Tulloch, 2012)](https://research.manchester.ac.uk/en/studentTheses/fragile-robustness-principles-and-practice).

Taking the COVID-19 as an example, some patients suffer from temporary loss of smell at an early infection stage. [(Jiang, 2020)](https://hms.harvard.edu/news/how-covid-19-causes-loss-smell) suggested that SARS-CoV-2 affects the cells that support olfactory nerves but does not directly damage olfactory nerves. Therefore, COVID-19 patients typically recover their sense of smell within a short period of time after rebuilding nerve support cells. This is the case which organisms get benefits from biological robustness, in which organism can recover and maintain their normal functionality despite suffering from COVID-19 disease. However, in case where there is a breakdown of robustness, organisms are prone to be attacked by disturbances and suffer from diseases. Therefore, robustness to disturbances is thought to be vital to the fitness of organisms [(Quinton-Tulloch, 2012)](https://research.manchester.ac.uk/en/studentTheses/fragile-robustness-principles-and-practice) and is integral part of survival.

Biological systems are not only robust against perturbations but are also known to be fragile against certain disturbances. As opposed to robustness, biological fragility refers to organisms responding sensitively to certain genetic and environmental disturbances and, therefore, causing failure of certain functions. HIV infection, which can lead to acquired immunodeficiency syndrome (AIDS), is an example of biological fragility. Human immune systems are compromised after the virus attacks immune cells and cause the depletion of numbers of immune cells. This makes the immune system highly vulnerable to other opportunistic infections [(Whitacre, 2012)](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3350086/). Eventually, it leads to organ failure and loss of vital function.

In view of this, biological fragility is an annoying but inherent attribute of biological organisms. The best way to avoid it is to understand the underlying mechanisms of robustness and fragility and therefore facilitate the understanding of complex diseases[(MC;, 2017)](https://pubmed.ncbi.nlm.nih.gov/28859407/). This may lead to drug development and possible therapy for certain incurable diseases such as cancer and HIV/AIDS Phenotypic plasticity is one of the mechanisms of robustness that has been revealed. This mechanism uncovers the ability of organisms to alter their phenotype to suit their environmental changes via control of rates of transcription and translation [(MC;, 2017)](https://pubmed.ncbi.nlm.nih.gov/28859407/). In the past, evaluation the robustness may only be done *in situ*. Thanks to advent of high-throughput technologies, the evaluation of robustness can now be performed in silico, where the research is carried out by means of computer modelling [(Whitacre, 2012)](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3350086/). This facilitates the progress of research and allow researchers to introduce specific perturbations that are difficult to be done in biological experiment(Whitacre, 2012).Mathematical modelling techniques are also used to make quantitative predictions about system behaviour [(Kitano, 2004)](https://www.nature.com/articles/nrg1471#Abs2) to better understand the complex biological systems.

Since the 1950s, biomedical research has advanced from molecular biology, genomics to current system biology. As a result, our understanding of disease has expanded from a single molecular level to more comprehensive understanding of complex biological systems. Despite these advancements, the biggest challenge that biomedical researchers currently face is to extracting disease-related information from vast amounts of biomedical data. Nevertheless, this step is crucial and indispensable for identify the root cause of diseases and developing effective strategies for early diagnosis and accurate treatment.

In conclusion, advancing our understanding of complex biological systems and developing new approaches to mitigate their negative effects is essential for avoiding biological fragility and improving human health, ultimately benefiting all of mankind.

Reference:

1.Whitacre, J. M. (2012). Biological Robustness: Paradigms, Mechanisms, and Systems Principles. *Frontiers in Genetics*, *3*. https://doi.org/10.3389/fgene.2012.00067

2. Quinton-Tulloch, M. J. (2012, August 1). *Fragile robustness: principles and practice*. Research Explorer the University of Manchester. https://research.manchester.ac.uk/en/studentTheses/fragile-robustness-principles-and-practice.

3.Kitano, H. (2004). Biological robustness. *Nature Reviews Genetics*, *5*(11), 826–837. https://doi.org/10.1038/nrg1471

4.Nijhout, H. F., Sadre-Marandi, F., Best, J., & Reed, M. C. (2017). Systems Biology of Phenotypic Robustness and Plasticity. *Integrative and Comparative Biology*, *57*(2), 171–184. https://doi.org/10.1093/icb/icx076

5.Jiang, K. (2020, July 24). *How COVID-19 Causes Loss of Smell*. Hms.harvard.edu. https://hms.harvard.edu/news/how-covid-19-causes-loss-smell