Editorial

Evaluating the Strength of a Hypothesis on How Terrestrial Organisms Overcame the Loss of Water's Protective Shield

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In a recent article, Gale et al. [1] discussed that the adaptation of living organisms to higher levels of ionizing radiation, when they moved from water to land, may be due to the translocation of hematopoietic stem cells to the bone marrow. Gale et al. explore the possibility that this translocation occurred as an evolutionary response to increased environmental radiation exposures. The authors of this study emphasize that the first organisms to transition to a partially or fully terrestrial lifestyle faced the challenge of losing the protective effects of the water column. This transition occurred during a period when environmental radiation levels, atmospheric oxygen concentrations, and consequently, rates of radiogenic DNA damage were significantly higher compared to present times. However, certain anatomical structures played a crucial role in mitigating radiation effects.

Bone and soft tissue act as effective shields, absorbing and scatter incident photons, and thereby attenuating the radiation. With a density slightly larger than 3 $g.cm^{-3}$, bone attenuates gamma and X-ray radiations, while soft tissues provide additional attenuation of gamma and neutron radiations. It is worth noting that in adult humans, approximately half of the contents of bone marrow-bearing cavities, such as the ilium, consist of fat cells, which further attenuate gamma and neutron exposure. Gale et al. [1] believe that their hypothesis is supported by observations such as the translocation of hematopoiesis from the mesonephros to the bones in aquatic compared with terrestrial frogs.

The authors have also raised an intriguing question regarding the location of germ cells within the body, considering their sensitivity to radiation. They propose that there could be potential evolutionary benefits to housing germ cells within bone, as increased radiation-induced mutations in these cells might contribute to greater genetic variability. While it is challenging to offer definitive proof or disproof of this hypothesis, the authors encourage and welcome further discussion on the topic. The authors suggest that an increase in radiation-induced mutations in germ cells may provide a small evolutionary advantage by increasing genetic variability.

Despite the strengths of this hypothesis, there are several aspects of the hypothesis that can be critically examined. Firstly, while the authors emphasize the challenge faced by terrestrial organisms in losing the protective effects of the water column, it is important to note that the hypothesis relies on extrapolating observations from modern organisms to ancient evolutionary transitions. The environmental conditions and radiation levels during the time of this transition are not directly observable, and thus, the hypothesis relies on making assumptions about the past based on present-day knowledge.

Additionally, the hypothesis suggests that bone and soft tissue act as effective shields against radiation, which is supported by known properties of these tissues. However, it is important to consider that radiation shielding is a complex interplay of various factors, and the effectiveness of bone and soft tissue as shields significantly vary depending on the specific types of radiation and energy levels involved.

Furthermore, the hypothesis proposes that the translocation of germ cells to bone could provide an evolutionary advantage through increased radiation-induced mutations and genetic variability. Mutations play a crucial role in evolution as they contribute to the diversity of populations, allowing for evolutionary progress. Mutations can be classified into three categories based on their impact on fitness: advantageous mutations that enhance fitness, deleterious mutations that reduce it, and neutral mutations that have no significant effect on selection [2].

In this context, while the hypothesis is an intriguing idea, it is important to note that increased mutation rates can indeed lead to a higher likelihood of detrimental or neutral outcomes rather than beneficial ones. Most mutations are either neutral, meaning they have no significant effect, or deleterious, meaning they have a negative impact on an organism's fitness. The potential benefits and drawbacks of increased genetic variability through radiation-induced mutations would require further investigation and empirical evidence.

To combat the harmful effects of radiation exposure, other than the hypothesis of radiation shielding, living organisms use various defensive mechanisms, including alterations in intracellular cation levels, effective DNA repair systems, and proficient enzymatic and non-enzymatic antioxidant systems [3]. It is noteworthy that organisms with a high tolerance to radiation have been found in all three domains of life (Bacteria, Archaea, and Eukarya), despite the absence of a naturally radiation-rich environment [3].

Following the Chernobyl disaster, scientists made an intriguing discovery - fungi that were able to withstand the effects of radiation were growing in the destroyed nuclear reactor. These fungi, belonging to the Eukarya family, not only survived but also found a way to use radiation as a source of energy [4]. As a result, they are referred to as 'radiotrophic' fungi since they utilize this energy to produce food and grow. The process through which they obtain energy is called radiosynthesis and is similar to photosynthesis. Although there is still much to learn about radiotrophic fungi, it is known that they use melanin, a natural pigment, to gain energy. Approximately 200 species of radiotrophic fungi containing melanin were identified in Chernobyl [4].

Humans are considered the most complex form of life due to their unique combination of cognitive, emotional, and physical abilities. They possess advanced brain functions such as reasoning, problem-solving, and language skills, which allow them to create and innovate. Additionally, humans have complex social structures and emotional intelligence, which enable them to form strong relationships and empathize with others. Humans have also adapted to living in areas with higher levels of natural radiation, such as the Kerala region in India and the Ramsar region in Iran [5, 6]. These areas have elevated radiation levels due to naturally occurring radioactive materials in the soil and water.

Studies have shown that people who have lived in these areas for generations have developed mechanisms to better tolerate the higher levels of radiation. For example, a study conducted in Kerala found that the DNA repair mechanisms in the cells of people living in high-radiation areas were more efficient than those in low-radiation areas [7]. Humans have developed various adaptations to safeguard themselves from ionizing and non-ionizing radiations, allowing them to tolerate exposure to these radiations better, especially in areas where radiation levels are naturally higher than normal. The scientific literature has cited a paper extensively that has aided in our comprehension of the biological impacts of areas with high background radiation [6]. The authors of the paper investigated the biological effects of exposure to very high levels of natural background radiation in the city of Ramsar, Iran.

Despite receiving radiation doses much higher than the permitted dose for radiation workers, people living in high background radiation areas did not appear to have significantly higher rates of health effects compared to those in normal background areas. In fact, the study found evidence suggesting that chronic exposure to natural background radiation may induce an adaptive response that can protect against the harmful effects of radiation. Ramsar has one of the highest natural background radiation areas globally, with radiation levels in some regions higher than those on the surface of Mars [8]. This is due to radium-rich hot springs present in the area, leading to the accumulation of radionuclides in the local environment. However, radiation levels on Mars are lower than those in most natural background radiation areas on Earth, with a daily average radiation dose on the Martian surface of about 0.7 millisieverts per day [9]. It's important to note that the type of radiation on Mars is very different from that on Earth due to lack of magnetic field its thin atmosphere, allowing cosmic rays, including protons and heavier ions, to penetrate the surface more easily.

Overall, while the hypothesis introduced by Gale et al. [1] presents interesting ideas and connections between radiation exposure, anatomical structures, and evolutionary adaptations, it is necessary to approach it with caution and further explore its validity through empirical research and additional supporting evidence.

Authors' Contribution

AR. Mehdizadeh, SMJ. Mortazavi and L. Sihver concepted the idea. SMJ. Mortazavi reviewed the literature and prepared the Editorial. All authors read and approved the manuscript.

Conflict of Interest

AR. Mehdizadeh (Editor-in-Chief and Chairperson), SMJ. Mortazavi (Editorial Board Member) were not involved in the peer-review and decision-making processes for this manuscript.

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