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Low oxygen and life – a relationship to aid the search for habitable exoplanets?

Atmospheric oxygen around the level we experience on Earth today (21%) is commonly considered a requirement for multicellular life to develop. This idea has been applied to the search for life beyond Earth, limiting the search to planets with 'sufficient' levels of oxygen. However, this may not have to be the case – low oxygen (1–5%, or hypoxia) is common in environments on Earth, as well as *within* multicellular organisms (e.g. the bone marrow of many vertebrate groups). Higher levels of oxygen may not be optimal, or indeed necessary, for the development of large multicellular life. Perhaps the search for habitable planets beyond our own should be reconsidered to accommodate this hypothesis?

This study attempts to defend the hypothesis that hypoxia, rather than higher levels of oxygen, is required for the development of large multicellular life forms. This idea is then applied to the search for habitable exoplanets, to include those with lower levels of oxygen. An extensive literature review was undertaken, encompassing research on the history of Earth's atmospheric oxygenation correlated with the history of life, as well as the roles played by hypoxia in the development of life. An experiment was conducted to study the expansion of hypoxia within different types of sediment under an atmosphere of ~10% oxygen. Finally, the elemental abundances of white dwarfs are used to estimate the oxygen levels of exoplanets orbiting these stars.

It was found that hypoxia is essential for many aspects of multicellular life. One of the most important roles of hypoxia is the maintenance of the undifferentiated state of stem cells—these cells have the capacity to change into multiple types of cells with different functions, and their maintenance in an undifferentiated state under hypoxia allows the organism to rapidly renew a large variety of cell types, and efficiently maintain tissue function during times of stress. Hypoxia-inducible factors (HIFs) are transcription factors that control gene expression in animals under hypoxia. HIFs are 'silenced' during periods of increased oxygen, which likely developed as an adaptation to rising oxygen levels. This means their control of animal genes during hypoxia developed first, suggesting that animals were initially adapted to survive in low-oxygen conditions.

This theory can be applied to the search for habitable exoplanets. Using data from white dwarfs polluted by external material, it is possible to calculate the oxygen fugacities (fO_2) of the planets which orbited these stars. This can be used to estimate the atmospheric oxygen levels of these planets. Of the white dwarfs studied, only one had a lower initial fO_2 than the early Earth. This may indicate the developement of an hypoxic atmosphere during the lifetime of the polluting planet, and hence that it was habitable. The results of my experiment suggest that hypoxia may extend deeper within coarser sediment than finer sediment, assuming an atmosphere of ~10% oxygen and the absence of microbial life. Therefore, it may be beneficial to focus on exoplanets with atmospheres of ~10% oxygen in the search for extraterrestrial life.

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