BOOK REVIEW

Life and Death in an oxygen atmosphere

MANFRED K. EBERHARDT. Charleston, 2007; Booksurge LLC; 212 pages; $16.95; ISBN: 1419666932

The past twenty years has seen an explosion of interest in oxygen-derived free radicals, as their pivotal role in both chemistry and biology has come to light. The cornucopia of publications is daunting. This book, “Life and Death in an Oxygen Atmosphere”, by the accomplished physical organic chemist and former member of the faculty of the University of Puerto Rico School of Medicine Department of Pathology, Dr. Manfred K. Eberhardt, aims to capture the excitement that grips this field and share it with advanced level medical undergraduates, with particular emphasis on the importance of radical reactions in pathology. The book provides a gentle, stepwise introduction to the subject, taking the student from the basic principles of oxygen chemistry to the radical reactions and oxidative stress; and their role in biomedical and environmental processes allowing the relevance of the subject to be grasped more easily.

Three billion years ago, Earth's atmosphere was as inhospitable as that of most of the celestial bodies in the solar system or at the ever-increasing number of extra-solar planets. Two facts are known with certainty: Earth's earliest atmosphere was essentially devoid of oxygen; today's atmosphere is composed of 21% oxygen. The evolution of the Earth's atmosphere is marked by a transition from an early atmosphere with very low oxygen content to one with oxygen content within a few per cent of the present atmospheric level. With this transition, oxidative weathering became efficient, ocean chemistry was transformed by delivery of oxygen, and a large part of Earth's ecology changed from anaerobic to aerobic. Most of the events that took place between the entry of oxygen into the atmosphere and the present remain highly uncertain. Currently, a battery of geological indicators suggests a shift from an anoxic to an oxic atmosphere some time between 2.5 and 2.0 billion years ago. This shift is known as the great oxidation event. Oxygen became from the vantage point of hyperthermophilic Archaea, microorganisms that grow at temperatures of 90°C and above and considered to be the most ancient of all extant life forms, the first great atmospheric “pollutant.” Deep-sea communities comprised by members of Archea had to resort to terrestrial instead of solar energy with reduced sulfur compounds becoming the major electron donors for aerobic microbial metabolism, thus evading the corrosive effects of the newly generated “pollutant.”

The oxygen in Earth's atmosphere is almost exclusively a product of photosynthesis, thereby consigning oxygen-intolerant life forms to anoxic mud and sediment, or the lightless depths of the oceans: chemosynthesis became the form of survival in the stygian depths. The transition from an early, virtually oxygen-free world to an irreversibly oxygenated one is linked to the first appearance and proliferation of photosynthesizing cyanobacteria. But, whereas, the first notable trace of persistent atmospheric oxygen has been dated to around 2.4 billion years ago, the fingerprints of cyanobacteria seem to stretch back as much as 2.7 billion years.

It is the chemistry of this first major atmospheric “contaminant” the one Dr. Manfred K. Eberhardt addresses in this engaging and accessible book. Both terrestrial and aquatic chemistry, including that of resident organisms, was irretrievably transformed following the Mesoproterozoic. It is just this chemistry, as it applies to the life and death of organic forms, particularly human, the one Dr. Eberhardt deftly explains. Oxygen produces its damage via its reactive species. These are very clearly described in the text and their chemistry is rendered manageable for the neophyte through an understandable and cogent language free of encumbering jargon, but never skimping on the fundamentals of chemistry required to understand it. "Life and Death in an Oxygen Atmosphere" is a work to popularize a science; it is not mere popular science, and there are new insights and theories as well as a synthesis of existing material particularly pertinent to free-radical pathology. Dr. Eberhardt has a disarmingly "simple" way of expressing himself; and he proceeds linearly rather than "top down".

The evidence of a role for electronically activated oxygen species in human disease has long been prevalent. For example, Darwin repeats the well-known observation that white, blue-eyed cats are usually deaf. The human equivalent of this feline abnormality is the pigmentary abnormalities with deafness seen in Waardenberg's or Usher's syndromes in which there is an absence of the protective function of melanin against oxidate stress. Likewise, physicians have long recognized the association between radical-generating metals such as copper or iron and fibrosing processes, e.g., chronic copper toxicity as well as liver cirrhosis in Wilson's disease and hemochromatosis. The importance of the subject is further heightened by the fact that current evidence points at free radicals and excited-state species as key players in both normal biological function and in the pathogenesis of late-life human diseases. For example, generation of reactive species by inflammatory cells is a major microbiocidal mechanism and mediates important components of the inflammatory response. Dr Eberhardt deftly addresses the persistent role of oxygen and its metabolites in the genesis and progression of late-onset diseases (cancer, atherosclerosis, neurodegenerations, ageing and frailty, etc.), as well as in drug toxicity, an expression of the concept of antagonistic pleitropy.

Furthermore, reactive oxygen species are very difficult to measure under biological conditions. The evidence for their participation in biological processes -much less a human disease- is oblique and circumstantial. This often leads to needless, yet acrimonious, controversy over procedures, findings and conclusions: even less is to be expected from clinical data. Nonetheless, there is presently abundant evidence that supports reactive oxygen's role in some of the most fundamental mechanisms in the pathogenesis and progression of many human diseases.

Most 19th century chemists believed it was impossible to isolate an organic free radical: a molecule with a free electron capable of pairing with an electron of another molecule. They had learned that electrons generally travel in pairs and react quickly. The existence of organic free radicals seemed unlikely, especially since all attempts to find one had proved futile. When University of Michigan's chemist Moses Gomberg announced in 1900 that he had isolated an organic free radical, the chemistry establishment greeted the news with skepticism, and then dismissed it as a curiosity. Their potential presence in biological systems was met with incredulity and even derision. A century later, Gomberg's breakthrough has led to profound advances in biochemistry, biology and medicine; as well as the production of plastics for everything from children's toys to the space shuttle: all dependent in some way on oxygen and its derivatives. At present, oxygen-derived free radicals have come center stage in basic research. They explain why some oxidation processes support life and others cause disease. They enhance our understanding of how the cardiovascular system functions, how DNA is synthesized in the body, and other scientific phenomena, including global warming.

Most people know that the oxygen in our atmosphere comes from plants, and that we need oxygen to live. Recent science news has also spread the word that oxygen has a darker side because it causes cell damage and oxidative stress. Purveyors of health foods explain the value of green tea in terms of their anti-oxidants and their supposed ability to neutralize the harsh effects of oxygen on human bodies. But there's a mystery here; if oxygen is so reactive, why did so many life forms evolve to depend on it? Though an apparent mystery, this subject is the topic of intense research which is beginning to explain this particular tale of evolution, and is the core of Dr. Eberhardt's book.

Mrs. Jane Marcet awoke the interest for chemistry of the young Michael Faraday with her 1805 best seller "Conversations on Chemistry". Not only did Faraday turn out to be one of the greatest scientists who ever lived, but he acknowledged his debt to her influence by becoming an equally good popularizer of chemistry himself, a trend followed by Henri Poincaré in germane fields. Science popularization, so prevalent during the Scientific Revolution, has once again become a highly regarded genre. It is in this illustrious tradition that Dr. Eberhardt has cast his book. Free radical biology has become a vast research area. This text is definitely a helpful tool for students and professionals alike to grasp the fundamentals of the field. The book contains the basic concepts of metabolism, metal interactions, free radical formation, and antioxidation. It then relates these processes (that is, oxidative and nitrosative stresses) to pathological events using various disease paradigms. The text contains good illustrations and is an excellent source of references for anyone entering the field of free radical biology and medicine.

This book is what beginners in radical chemistry have been waiting for: a clear, interesting and readable introduction to the subject. The book is obviously written by an expert in free-radical chemistry, but the author also has the engaging gift of making the reader share his excitement in the subject. The early chapters lead readers gently through the basics, leaving them well equipped to understand the many and varied examples addressed, most of which have relevance in our daily life. It's a book which I was happy to read, not just to learn the details, but because I wanted to, which is mainly due to the friendly and accessible, but never patronizing manner in which the book is written. I heartily recommend it.

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