

The impact of solar UV radiation on the early biosphere

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Stratospheric ozone, photochemically produced from atmospheric oxygen, is a protective filter of the Earth's atmosphere by absorbing most of the biologically harmful UV radiation of our sun in the UV-C (190-280 nm) and short wavelength-region of the UV-B (280-315 nm). Numerous lines of isotopic and geologic evidence suggest that the Archean atmosphere was essentially anoxic. As a result the column abundance of ozone would have been insufficient to affect the surface UV radiation environment. Thus, as well as UV-B radiation, UV-C radiation would have penetrated to the Earth's surface with its associated biological consequences. The history of this ultraviolet stress for the early Earth has been determined from theoretical data and data obtained in Earth orbit on the inactivation of *Bacillus subtilis* spores under a simulated ozone layer of different thicknesses. Although the UV-C and UV-B regions contribute only 2 % of the entire solar extraterrestrial irradiance, photobiological experiments in space have demonstrated a high mutagenicity and lethality of this UV range to living organisms. The reason for these severe effects of extraterrestrial solar UV radiation - compared to conditions on present-day Earth - lies in the absorption characteristics of the DNA, which is the decisive target for inactivation and mutation induction at this UV range. Being a strong mutagen, UV-radiation is considered as a powerful promoter of biological evolution on the one hand, on the other hand, it may have deleterious consequences to individual cells and organisms, e.g. by causing inactivation, mutations or cancer induction. In response to potential harmful effects of environmental UV radiation, life on Earth has developed several strategies of survival, either avoiding exposure to UV radiation or restoring UV damage. Mechanisms of avoidance of exposure to UV radiation include (i) moving away from the UV radiation into shadowed areas, which requires the development of UV radiation sensing mechanisms; (ii) application of external shielding, such as covering by mud, sand or rock material; (iii)

development of intrinsic UV screening pigments, such as tanning, inductive flavonoid production of plants, intracellular mycosporin production in cyanobacteria, (iv) accumulation of antioxidants and quenching substances. However, if UV damage has been induced - in spite of all avoidance efforts, organisms may restore their functionality by numerous repair processes. Repair pathways of a rich diversity and functional universality include (i) direct repair with the reversal of photochemical abnormalities, e.g. in the DNA; (ii) recombination repair removing the UV-induced abnormality by homologous recombination; and (iii) excision repair, where the section of the DNA strand containing the abnormality is removed and a repair patch is synthesized using the intact strand as a template. In addition to efficient repair systems for radiation-induced DNA injury, life has developed a variety of defense mechanisms, such as the increase in the production of stress proteins and the activation of the immune defence system. Some of these capacities have certainly already been evolved in the early biosphere, when it was exposed to the extended UV-spectrum of the sun. Only since the early Proterozoic, due to a rapid rise in the atmospheric oxygen concentration and consequently a photochemical built up of the stratospheric ozone layer, a more moderate UV radiation climate prevailed with wavelengths shorter than 295 nm being effectively cut off.