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GROWTH OF A MAT-FORMING PHOTOTROPH IN THE PRESENCE OF UV RADIATION

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Knowledge of the survival and growth of microorganisms in the presence of ultraviolet (UV) radiation is important for understanding the potential for life to exist in environments exposed to high fluxes of UV radiation such as early Earth and other planets lacking a UV-absorbing atmosphere. The surface of early Earth was exposed to high levels of RM radiation during the period of the origin and early evolution of life.[1] Fossil evidence suggests that massive microbial mat communities developed in shallow water environments with surface exposure despite these high UV fluxes.[2] It has been suggested that various environmental factors might have protected these early organisms.[3] Results of laboratory tests on the survival of contemporary microorganisms when exposed to short bursts of UV radiation under no-growth conditions have been discouraging.[4]

We have examined the growth of a mat-forming phototrophic prokaryote, *Chloroflexus aurantiacus* in the presence of continuous high UV irradiation under otherwise optimal growth conditions. Our objective was to look for evidence of an intrinsic ability to grow in the presence of UV radiation in a carefully chosen organism known to be unusually resistant to UV radiation,[5] known to be of ancient lineage among the phototrophs,[6] known to resemble ancient microfossils from the Precambrian,[7] and known to be a ubiquitous mat-former. Previously examined microorganisms have not been selected with these criteria in mind and have been poor candidates for models of Precambrian organisms with high intrinsic UV resistance. We chose such a known UV-sensitive organism, *E. coli*, as a control in our model system. Assuming that even a high intrinsic UV resistance would be inadequate for survival and growth in the presence of very high UV fluxes, we selected one environmental factor, iron (Fe^{3+}), as a common, abundant UV-absorbing substance[8] that might protect microorganisms growing in or under iron-bearing sediments. We tested the effectiveness of Fe^{3+} as a UV-protective agent at low concentrations in thin layers.

The organisms were grown in quartz flasks containing organic media. They were grown at their optimal pH and temperature in a simulated anoxic Precambrian atmosphere of 99.5% N_2 and 0.5% CO_2. Continuous visible and near infrared radiation were provided along with a continuous exposure to UV radiation from a germicidal lamp. Some cultures were also incubated under oxic conditions. Iron was mixed in a silica gel poured to various thicknesses and inserted in the UV light path as a screen. Growth was monitored by measuring changes in turbidity.

Both *C. aurantiacus* and *E. coli* grew well in the total absence of UV irradiation in our culture system. *E. coli* did not grow under any of the experimental conditions tested, however. Even at the lowest levels of UV radiation used (0.02 Wm^{-2}) *E. coli* cells died and lysed immediately. *C. aurantiacus*, however, grew well although with lowered growth rate and depressed cell yields under oxic conditions with continuous UV exposures of 0.02 Wm^{-2}. It did not grow well under oxic conditions with 0.1 Wm^{-2} UV irradiation. Under anoxic conditions, however, *C. aurantiacus* grew reproducibly under continuous UV irradiation of 0.5 Wm^{-2}. No growth was obtained at 2.0 Wm^{-2}. Iron was an effective UV absorber. A 1.5 mm gel containing 0.02% Fe^{3+} reduced the intensity of

UV radiation measured at the surface of the culture from 2.0 to 0.5 Wm^{-2}.

We conclude that intrinsic UV resistance in some organisms may account for growth, not just survival, of these organisms when exposed to high UV fluxes under otherwise optimal growth conditions in an anoxic environment. We also conclude that Fe^{3+}-bearing sediments of 1 mm or less in thickness may provide an adequate shield against high UV fluxes permitting the growth of microorganisms just below their surface. The penetration of short wavelength visible radiation was observed to be very poor in natural sands, whereas the penetration of long wavelength visible and NIR radiation was quite good thus potentially permitting the growth of masses of phototrophic microorganisms at depths greater than 1 or 2 mm in such sediments despite high UV fluxes at the surface. As long as growth conditions were met, then the evolution and development of microorganisms would not have been hampered by high UV fluxes impinging upon the surface of iron-bearing sediments.

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