Microbial UV sunscreens beyond the pigment—efficient thermalization of UV light and its relevance to survival on early Earth

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Photosynthetic organisms are central to the understanding evolution of early Earth and are responsible for the great oxygen event that has directly shaped the current habitability of our planet. A characteristic of early Earth was the absence of an ozone layer to efficiently block high-energy UV-radiation, especially short wavelength UVC, that kills unprotected organisms upon short term exposure due to absorption by aromatic constituents in proteins and nucleic acids. Many hypotheses have been explored to reconcile the paradox of how surface-dwelling photosynthetic organisms survived the intense UV-radiation of early Earth and have demonstrated that cyanobacteria and related microorganisms produce sheath bound pigments that act as UV sunscreens that permit their survival at high UV exposure. Despite this well-established body of work, scientists still do not understand how these sheath-bound pigments efficiently dissipate the absorbed energy at the molecular level. Our interdisciplinary team seeks to understand how these pigmented sheaths maintain long-term photostability over the course of intense periods of UVR exposure? Such remarkable photostability requires the pigmented sheath to efficiently (1) absorb the UVR and (2) dissipate the absorbed energy. Our new results demonstrate that a lichen pigment is 14 times more stable when imbedded in polysaccharide that is like the molecular environment of the sheath vs. when the pigment is irradiated alone, demonstrating that the medium (polysaccharide) acts as a thermal sink for the absorbed UV energy. This work demonstrates a new hypothetical framework for the evolution of UV resistance on early Earth and opens new approaches to the design of photo-resistant materials, radiation countermeasures, and new biosignatures for the search for life.