**Proposal (Synopsis)**

**Bacterial Sunscreens: The Microbial Intelligence for thriving in extremes**

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**Abstract**

All living organisms are detrimentally affected by ultraviolet radiation (UV). Over the last 3 billion years, cyanobacteria integrated itself into the early Earth’s geochemical cycle and escaped the lethal UV radiation. Cyanobacteria circumvented harmful UV and became the early colonizer via mitigation strategies such as the biosynthesis of sunscreen molecules, therefore adapt to the early Earth where the ozone layer was absent. While there has been enormous interest in the biotechnological applications of bacterial sunscreens, questions about the evolutionary and astrobiological influences have only received increasing attention recently. In this Review, we explain how evolution and distribution of the bacterial sunscreens can affect the Earth’s early atmosphere, drives the evolution of metabolism and branching of life. We describe the molecular, genetic, and astrobiological significance of bacterial sunscreens and postulate why bacterial sunscreens are vital for the emergence of life on early Earth and the search for extraterrestrial microbial life.

**Description of the main article sections**

**(A)** **The molecular, genetic and evolutionary significance of microbial sunscreens**

The rise of Earth’s atmosphere was originated from the oxygenic photosynthesis of ancient cyanobacteria over 2.3 billion years ago. In advance of the formation of the ozone layer, cyanobacteria tackled lethal UV while absorbing the light for photosynthesis simultaneously. As the earliest colonizers, they have adopted a few strategies to not only survive but thrive in extreme environments. Before the evolution of sunscreens against UV radiation, ancient cyanobacteria colonized in the aquatic habitat acquired water as a physical barrier against UV but not visible light for their photosynthesis. Iron and its oxidized species in water have also provided adequate protection against lethal doses of UV radiation. Biological innovation of compounds that act as sunscreen assists cyanobacteria to impede the intracellular damage caused by UV, i.e., scytonemin and mycosporine-like amino acids (MAAs). Therefore, the study of the evolution of the sunscreens via molecular and genetic approaches allow us to perceive the success story of cyanobacteria on early Earth. The comprehensive genetic and molecular studies will inspire new breakthroughs in both biotechnological applications and its evolution.

**(B) Microbial sunscreens and the diversification of life**

The high stability of cyanobacterial sunscreens does not merely protect its hosts, also acts as a useful biomarker for understanding the evolutionary history of Earth and searching for life beyond Earth. The accumulation of oxygen by cyanobacteria in early Earth facilitates the explosive diversification of metabolisms, which heavily depends on the supply of oxygen.

**(C) Distribution of microbial sunscreens and its impact on the microbial ecosystem**

The study of the oldest fossils termed stromatolites, which are the laminated organo-sedimentary structures formed by microorganisms, revealed the presence of cyanobacteria and hint us that sunscreen production was a common strategy at least 2 billion years ago. Sunscreen-producing cyanobacteria are mostly dominant on the surface layer of the modern microbial ecosystem in UV-flooded regions, i.e., Shark Bay, Australia, and this strategy offer the shield for microbial system living beneath the surface layer. Cyanobacteria also undergo positive phototaxis within the microbial mats for optimizing their daily photosynthetic efficiency.

**(D) Astrobiological aspects and future directions**

By combining the cyanobacterial fossil records, genomics, and evolutionary studies of sunscreen biosynthesis, we can track the advent of natural sunscreen. The estimation will fill the gap of the unknown history of early Earth, primarily how the emergence of cyanobacteria affects the diversification of life. As the transition is considered as the most significant event in the evolution of life, it provides a hint for the possibilities of life beyond our planet. The stability and characteristic of microbial sunscreen make it a potential biomarker for searching extraterrestrial microbial life.

**Key References**

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