【Grant-in-Aid for Transformative Research Areas（A）】

Multidimensional glocal photobiology: Shedding light on unexplored frontiers of life phenomena

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Project Information	Project Number : 26A305　Project Period (FY) : 2026-2030 Keywords : Light use, Environment, Optogenetics, Biodiversity, Evolution

Purpose and Background of the Research

●Outline of the Research

Research on biological light utilization has traditionally focused on animal vision and light-driven energy conversion in plants and microorganisms. However, recent discoveries suggest that these well-characterized processes represent only a small fraction of a much broader landscape. A key turning point has been the “opsin explosion”: opsins—once thought to be restricted to animal vision and archaeal phototrophy—have now been identified across nearly all domains of life, including viruses. As a result, (1) marine metagenomics has uncovered more than 50,000 opsins, of which ~99% remain functionally uncharacterized and their physiological roles largely unknown; (2) in animals, the number of opsin genes far exceeds what can be explained by known visual functions, and their expression in the brain and internal organs points to previously unrecognized, non-visual roles of light; and (3) opsins with diverse properties have driven the development of optogenetics, which uses light-sensitive molecules to control cellular activity—particularly in neurons—and has enabled medical applications such as vision restoration. Together, these advances indicate that biological light utilization extends to “whole-body light sensing” beyond the eye, “planet-scale light utilization” mediated by ubiquitous microorganisms, and “technology-driven light utilization” for biomedical and applied purposes (Fig. 1).

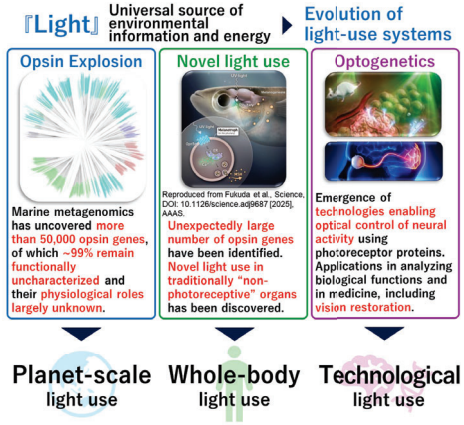
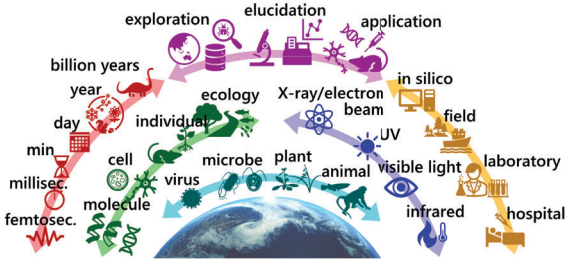


Figure 1. The true picture of how organisms use light

●Light use in organisms

Biological light utilization represents a multidimensional research domain spanning multiple axes: the organismal axis, the temporal axis, the biological scale axis, and the basic-to-translational axis (Fig. 2).



Organism | Bacteria ↔ Human, Virus
Time | Femtosecond ↔ Billion years
Wavelength | X-ray ↔ Infrared
Level | Atom ↔ Ecology
Field | *in silico* ↔ Nature/Hospital
Research | Basic ↔ Medical

Multidimensional and wide-ranging

Figure 2. Conceptual diagram of “multidimensional glocal photobiology”

●Light use in organisms（continued）

Light utilization operates not only at the local level—such as physiological processes within organisms—but also at the global level, through shared principles of planet-scale light use involving interactions among organisms and ecosystems. Optogenetics, which harnesses evolved light-utilization mechanisms to control living systems and enable medical applications, is a key field emerging from this “glocal” perspective and highlights the breadth of light utilization research. Thus, “light” is a uniquely integrative theme that connects diverse disciplines and scientific trajectories. Against this backdrop, this research area promotes interdisciplinary collaboration to advance photobiology by uncovering still-unexplored phenomena—toward a comprehensive understanding of “light and life” and “light and Earth.”

Expected Research Achievements

In this research area, we aim to clarify how organisms utilize light by addressing key questions: “Are there unknown modes of light use?”, “Do photoreceptor molecules possess such capabilities?”, and “Can these properties be harnessed?”. To achieve this, we have defined three research themes (Fig. 3), to be pursued through close collaboration among nine core project teams and publicly recruited teams.

●Local Photobiology (A01-A03):

Aims to discover and understand previously unknown uses of light in diverse organisms

●Global Photobiology (B01-B03):

Aims to elucidate unique and universal principles governing the roles and utilization of light at the planetary scale.

●Glocal Photobiology (C01-C03):

Aims to explore and expand mechanisms of biological light utilization, apply these insights to optogenetics, and achieve an integrated understanding of light signaling in relation to other environmental signals.

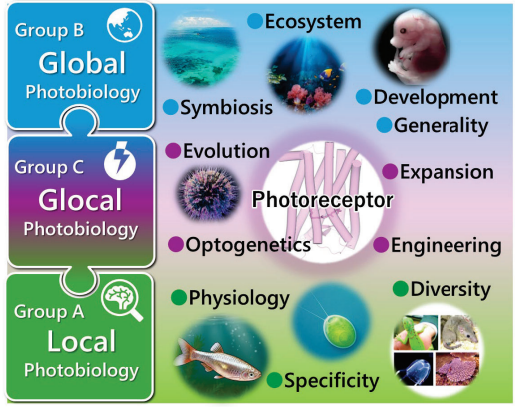


Figure 3. Local, Global and Glocal photobiology

Through interdisciplinary, multidimensional research, we will shift our paradigm on biological light utilization and drive new advances in biology, Earth science, and medicine based on the functions of light (Fig. 4).

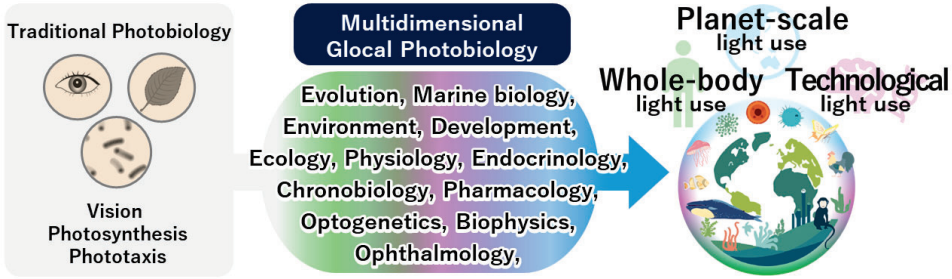


Figure 4. Shift of our paradigm on biological light use

Website(s)	https://glocal-photobiology.pharm.okayama-u.ac.jp/