Research area in the Strategic Objective "Development of optical control technologies and elucidation of biological mechanisms"

6.2.5 Optical control of biological functions for the elucidation of biological systems

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Overview

The purpose of this research area is to develop innovative technologies for optical control of living organisms. Thus, we aim to establish new technologies for controlling biological functions through the collaboration and integration of different areas, with emphasis on the following three areas: "control of biological functions, observation of biological phenomena, and elucidation of biological systems.

In recent years, life science has begun to make rapid progress in understanding of biological phenomena through the development of various technologies for controlling biological functions utilizing properties of light. For example, optogenetics has brought about a revolutionary shift in the elucidation of biological systems for neural networks, through the expression of photosensitive protein in neurons followed by irradiation with light of a specific wavelength. In addition, new technologies for controlling biological functions have began to appear including technologies to control enzymatic activity with photosensitive proteins, intracellular signal transduction, and gene expression in combination with genome editing.

The development of these technologies may begin spreading explosively because a great number of findings, such as the identification of light-related proteins, have emerged over the past 70 years; furthermore, a basis for these proteins to be applied to the living organisms has been established. Additionally, basic findings have been further honed to overcome shortcomings of existing technologies, and the development of novel optical control of biological functions has surfaced as a globally impending issue.

Based on the background described above, we aim to promote research and development of technologies for the optical control of biological functions, together with the observation, measurement, and analysis of biological phenomena that emerge in the optical control of biological functions, as well as the elucidation of biological systems by these technologies. This research area will be managed to establish innovative optical control of biological functions by encouraging collaboration among research areas representing our country's strengths; these areas include photobiology, photonics, nanotechnology, engineering, and physiology.

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Area

In recent years, various findings have been applied for integration into new technologies, which are rapidly spreading in the area of life science. Examples include bioimaging using fluorescent proteins or small

molecules in the 1990s, and genome editing technologies in recent genetic engineering applications. New technologies are expected to be sources for innovation in science and technology, enabling applications for new product development and the subsequent creation of new markets and augmentations to basic research in the life sciences.

Optical control of biological functions, which utilizes optical properties of photosensitive proteins, may be considered a technology area with potential similar to that described above. For example, applications of photosensitive proteins (e.g., channelrhodopsin) have been spreading in life science research since the late 2000s. These technologies, represented by optogenetics, have rapidly spread to the neuroscience area because of their high spatiotemporal resolutions. Furthermore, the development of associated instruments has been activated mostly in business sectors.

Because optical control of biological functions using a photosensitive protein as a component utilizes structural changes of the photosensitive protein after absorbing light, understanding the molecular properties of the protein are essential for development and optimization of the technology. In other words, the technology linked with optical control of biological functions was built on past basic research into photosensitive proteins. It means that this technology is in the initial stage of development; therefore, it is expected that corrections for technological shortcomings and optimization will be made, ultimately leading to the creation of new innovative technologies.

Accordingly, we aim to develop innovative technologies for optical control of biological functions. Specifically, we aim to (1) develop new technologies for optical control of biological functions, (2) develop technologies for the observation, measurement, and analysis of biological phenomena emerging in optical control of biological functions, and (3) elucidate mechanisms of various biological systems by utilizing optical control of biological functions. Therefore, we solicit the participation of individuals in diverse areas for challenging research studies based on creative ideas and aimed at creating relevant sophisticated technologies. Such research should demonstrate efforts to collaborate and integrate with researchers in the fields of nanotechnology, physics, engineering, chemistry, informatics, life science, and photonics.

Although this research area is focused on optical control technologies, it does not exclude proposals concerning development of state-of-the-art control technologies for biological functions that surpass existing technologies in spatiotemporal resolutions. For example, control technologies for biological functions using electromagnetic waves and magnetic fields, which noninvasively permeate the living organisms (unlike visible light) have the potential for innovation.

We solicit research proposals that focus on the following specific topics:

(1) Development of innovative technologies for optical control of biological functions:
Technology development for light delivery; technology development for design and expression of photoreceptor proteins, enzymatic activity control, signal transduction control, gene expression

control, genome editing control, and functional control of organelles; and development of new technology for spatiotemporal control of biological functions that are superior to existing technologies in terms of performance

(2) Development of technologies for the observation, measurement, and analysis of biological phenomena emerging in optical control of biological functions:
Technology development for noninvasive observation and measurement of biological functions deep in the living organisms, simultaneous optical control and optical observation/measurement, and analysis techniques for interrelating various kinds of observation results

(3) Elucidation of diverse biological systems utilizing optical control of biological functions:
Elucidating neural network mechanisms, genesis, differentiation, regeneration, immunity, metabolism, and the like for an understanding of the network of biological systems for diverse organisms in spatiotemporal terms

The above topics are only examples. Proposals of innovative technologies other than the above would be welcomed.

Emphasis will be placed on any one of the following three points:

(a) The novelty and originality of basic elements (molecular design, technology, and the like) in the realization and innovation of optical controls

(b) The expansion of technologies in applications from topical observations to systemic observations

(c) Scientific significance of the mechanism of biological systems to be elucidated by optical control

Proposals by individuals from not only the life sciences and photonics but also physics, engineering, chemistry, and informatics would be welcomed as long as they meet these criteria. We earnestly seek proposals that are not simple extensions of past research but which courageously challenge scientific or technological difficulties that have not been overcome.

Please take into consideration the following points in proposals:

1. In a research proposal based on an innovative or original molecule or technology, please provide a concrete description about “what” can be made possible by the technology and “what kind of” biological system hitherto difficult to elucidate can be made comprehensible by the technology.
2. In a research proposal attempting to elucidate biological mechanisms that have been difficult to elucidate previously (with existing techniques) by devising optical control of biological functions, please take this opportunity to propose a more challenging research plan built on the basis of the past accumulation of research.
3. A research proposal will be more convincing if it can present preliminary data for a working hypothesis or the readiness of pertinent experimental techniques.

4. Applications of optical control of biological functions to elucidate biological systems at the organism level, and theoretical and informational researches seeking to eludicate biological mechanisms through optical control are headed for important developments in the future. We strongly encourage applications if such research can be proposed.

In managing this research area, we promote synergistic research and development by stimulating collaboration with not only CREST's " Development and application of optical technology for spatiotemporal control of biological functions" but also with PRESTO's "Ultimate control and active use of light for the creation of new era (FRONTIER)" and CREST's " Advanced core technology for creation and practical utilization of innovative properties and functions based upon optics and photonics" We also promote synergistic research and development by stimulating collaboration with associated academic societies and research organizations in Japan and overseas.

In 2016 we received fewer proposals for "observation of biological phenomena" in comparison to the other two areas: "control of biological functions" and "elucidation of biological systems". We are therefore calling for more proposals for "observation of biological phenomena".

An enormous quantity of experimental data has been accumulated with the progress of research, and theoretical and analytical studies are indispensable for the development of this research area. We therefore earnestly seek proposals for theoretical and analytical research.