Title of Project : New Photosynthesis: Re-optimization of the solar energy conversion system

Jun Minagawa
(National Institutes of Natural Sciences, National Institute for Basic Biology, Professor)

Research Project Number : 16H06552 Researcher Number : 80280725

【Purpose of the Research Project】

Photosynthesis requires solar energy, which has the potential to damage photosystems (photoinhibition). During the course of evolution, plants have developed mechanisms to dissipate such excess light to achieve an optimal balance between utilization of light energy (photosynthesis) and dissipation of light energy (photoprotection). However, this balance is not always achieved in many cultured plants, and today's science is expected to re-optimize this balance to improve photosynthetic efficiency. The goal of this project is to understand the mechanisms that regulate the proton motive force across thylakoid membranes, which is required for this re-optimization.

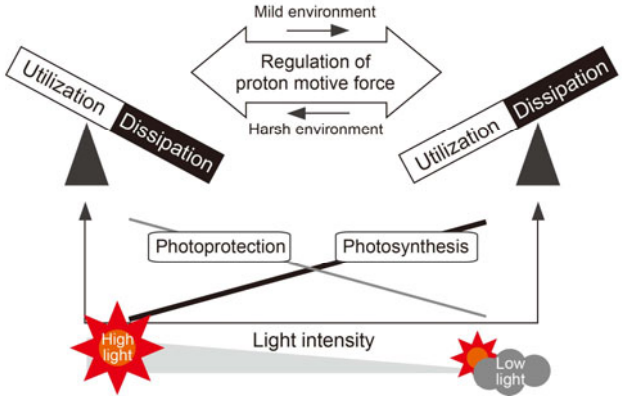

Fig. 1. To prevent photoinhibition in excess light, plants need to elevate the capacity of photoprotection, even if that involves sacrificing the efficiency of light utilization.

【Content of the Research Project】

In this proposed study, we will try to elucidate the regulatory mechanisms of photosynthesis by incorporating a new perspective, the regulation of the proton motive force. Group A01 will study the mechanisms by which the proton motive force is generated, including photochemical reactions and electron transport. The group will also study the mechanisms by which the proton motive force is regulated, including the cytochrome b_6f complex, ATP synthase, ion transporters, and the NPQ (non-photochemical quenching) mechanism that dissipates excess light energy as heat, which is activated by low pH. Group A02 will explore novel methodologies to investigate proton motive force regulation.

【Expected Research Achievements and Scientific Significance】

The proposed research will incorporate new perspectives into basic photosynthesis research with the goal of improving photosynthetic efficiency. We expect to establish strategies to re-optimize the photosynthetic performance of any organism under any environment. This could translate to a new way of converting any land to arable land for crops or any pond to culture pond for algae. This research will maximize the potential of photosynthesis in photosynthetic organisms.

【Key Words】

Proton motive force: ΔpH and membrane potential (Δψ) are generated when protons are transported across the thylakoid membranes. The sum of ΔpH and Δψ constitutes the proton motive force, which is utilized to synthesize ATP by an ATP synthase. Modulating the ratio of ΔpH and Δψ would alter the balance between light utilization and photoprotection.

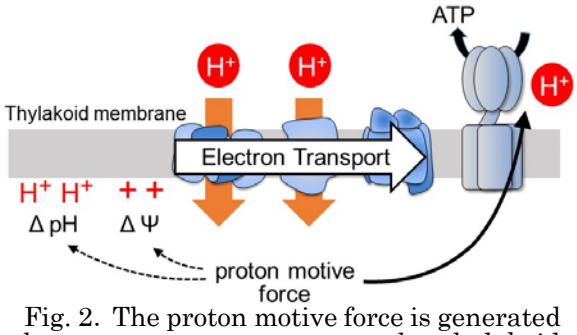

Fig. 2. The proton motive force is generated by proton transport across the thylakoid membranes, which is coupled with the photosynthetic electron transport.

【Term of Project】

FY2016-2020

【Budget Allocation】

1,057,500 Thousand Yen

【Homepage Address and Other Contact Information】

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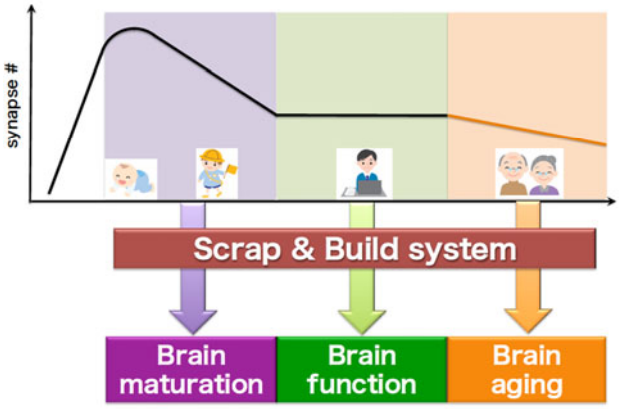
Title of Project : Dynamic regulation of brain function by Scrap & Build system

Kazuo Emoto
(The University of Tokyo, Department of Biological Sciences, Professor)

Research Project Number : 16H06455 Researcher Number : 80300953

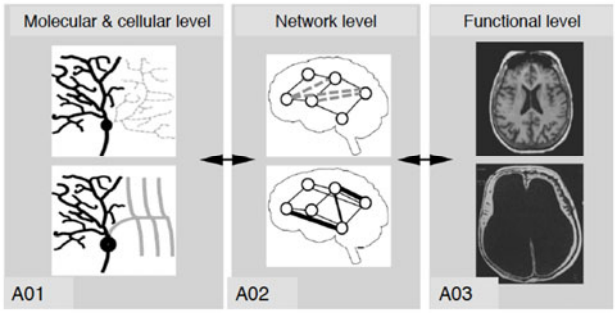
【Purpose of the Research Project】

Organisms typically achieve functional reorganization by scrapping a part of body/tissue structure with building a new structure in response to environmental changes. This scrap & build phenomenon is particularly significant in the nervous system. Neural network in the brain changes network structures in multiple different scales during distinct developmental stages: In the developing brain of infants, neurons often scrap & build whole neurites to modify connections between specific brain regions. In the matured brain, by contrast, neural circuits mainly scrap & build synapse in a few micron level. In this project, we will focus on the scrap & build phenomenon in the nervous system and clarify (1) molecular and cellular mechanisms of neural scrap & build, (2) network mechanisms of scrap & build coordination, and (3) significance of the neural scrap & build system in the brain function and disease.



【Content of the Research Project】

This inter-disciplinary research project aims to understand mechanisms of spatio-temporal regulation of the neural scrap & build system and how the neural scrap & build system regulate brain function and pathology. To this end, this project is basically composed of three subgroups: A01 will investigate molecular and cellular mechanisms underlying the scrap & build system of neural circuits. A02 will focus on the circuit mechanisms that mediate spatio-temporal coordination of the neural scrap & build processes. A03 will reveal the functional relationship between the neural scrap & build system and brain function.



【Expected Research Achievements and Scientific Significance】

The scrap & build phenomenon is recently observed in multiple tissues including vascular tissue. Scrap & build system is thus likely to be a universal mechanism responsible for the functional reorganization of multicellular organisms. We except that this project will provide impacts on a variety of research fields of biology including cell biology, developmental biology, vascular biology, and immunology. We also expect that techniques and resources to be developed for principle elucidation of the neural scrap & build can be applied to various research areas. Researches in this project are expected to provide basic information and experimental system that can contribute to clinical researches, as dysfunction of the neural scrap & build shown to be related to developmental disorder and mental disease.

【Key Words】

Spatio-temporal regulation of neuronal plasticity
Brain function and pathology

【Term of Project】 FY2016-2020

【Budget Allocation】 1,179,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.scrapandbuild.bs.s.u-tokyo.ac.jp/

Title of Project : Interplay of developmental clock and extracellular environment in brain formation

Ryoichiro Kageyama
(Kyoto University, Institute for Virus Research, Professor)

Research Project Number : 16H06479 Researcher Number : 80224369

【Purpose of the Research Project】

During development, many events such as cell proliferation and differentiation occur at predictable times. If stem cells grow for too long or too short periods, the organ size will be abnormal. If differentiated cells are born at wrong times, they cannot interact with their neighbors properly. Either case results in abnormal tissue formation.

During cortical development, neural stem cells proliferate while changing their competency over time according to the programmed schedule. They give rise to deep-layer (layers 5 and 6) neurons first and then superficial-layer (layers 2, 3, and 4) neurons (Fig. 1). After neurogenesis, neural stem cells produce glial cells (Fig. 1). Eventually, the complex structures such as layers, columns, and areas are formed. Because neural stem cells are able to change their competency autonomously, it has been suggested that an internal biological clock may control the developmental processes in these cells. On the other hand, extracellular environments, which also change over time, feedback to the clock in neural stem cells. Thus, the interplay of developmental clock in neural stem cells and extracellular environment is very important for neocortical development. In this project, we aim to elucidate the regulatory mechanism of developmental time not only for brain formation but also for other organogenesis.

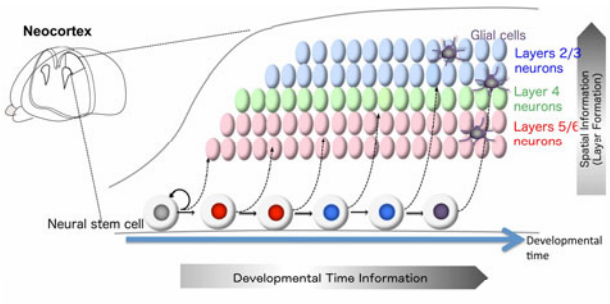


Figure 1: Neocortical development. Developmental time information programmed in stem cells is transformed into spatial information, which feedbacks to stem cells.

【Content of the Research Project】

In this project, the following three groups of researchers will collaborate with each other to elucidate the developmental timing mechanism.

Group A01 aims to understand the cellular timing mechanism, such as domino and clock factors. Group A02 aims to elucidate the interplay between cells (cellular clock) and extracellular environment. Group A03 will work together with A01 and A02 for 3D ES cell cultures, mathematical modeling, and new probe synthesis.

【Expected Research Achievements and Scientific Significance】

Spatiotemporal expression of key factors and signaling molecules will be quantified during the developmental time course, and by using such quantified data, mathematical modeling will be made. Through such analyses, our understanding of developmental timing mechanisms (domino, clock, or mixed) will be promoted, which may create a new research field, developmental chronobiology.

It is well known that the developmental time scale is different from species to species. For example, human development takes much longer than mouse development. Interestingly, this difference is reproduced in 3D ES cell cultures. Differentiation processes from human ES cells take much longer than those of mouse ES cells, suggesting that species difference in developmental time is encoded within cells. Currently, the mechanisms for such species difference are not known, but this project will promote our understanding of these mechanisms and may help shorten the time required for human ES cell-derived tissue regeneration.

【Key Words】

Developmental clock: the mechanism to induce and stop each event at predictable times during development
Stem cell: undifferentiated cell that has potential to give rise to multiple mature cell types

【Term of Project】 FY2016-2020

【Budget Allocation】 1,181,800 Thousand Yen

【Homepage Address and Other Contact Information】

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rkageyam@virus.kyoto-u.ac.jp

Title of Project : Creation, function and structure of neo-self

Mitsuru Matsumoto
(Tokushima University, Institute for Enzyme Research, Professor)

Research Project Number : 16H06495 Researcher Number : 60221595

【Purpose of the Research Project】

A classical concept of "self" vs. "non-self" has been a long belief of immune-cell recognition. However, recent findings suggested that there must be other forms of immune-cell recognition: first, a homophilic HLA (human leukocyte antigen) presents antigens to T cells. Second, an HLA in complex with misfolded protein can become the target of autoantibodies. Based on these findings, we are now proposing a novel concept of "neo-self" by which we are hoping to elucidate many immunological enigmas such as the mechanisms for the establishment of self-tolerance within the thymus, pathogenesis of allergy against metals and/or drugs, and inefficient cancer immunotherapy. Our aim is to reveal the pathogenesis of intractable immunological disorders by introducing many state-of-the-art technologies including structural biology, genomic analysis, imaging technique, bioinformatics and single-cell analysis.

【Content of the Research Project】

Many studies have been conducted with the belief that autoimmune disease and allergy are the abnormal immune responses against "self" and "non-self", respectively, with limited success. However, during the course of research project of "HLA evolution and the disease" (FY2010-2014), it turns out that complex between peptide antigen and MHC (pMHC) is not a simple structure that had been appreciated. Instead, existence of many forms of pMHC have been found, which was unexpected in an immunological concept of "self" vs. "non-self". Based on these findings, we will elucidate the exact nature of pMHC in a quantitative and qualitative way with a proposal of a novel concept of "neo-self".

【Expected Research Achievements and Scientific Significance】

By conducting the studies with the novel concept of "neo-self" from different viewpoint, we are hoping that we will be able to elucidate the mechanisms underlying many immunological disorders such as autoimmune disease and metal and/or drug allergic reactions. We are also hoping that we will be able to establish the basic knowledge for the development of a novel cancer immunotherapy.

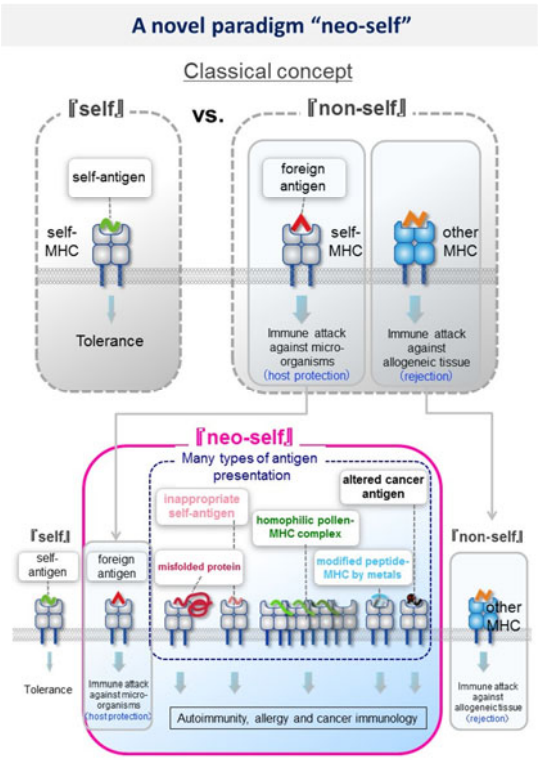


Figure: Searching for an alternative model for a classical concept of "self" vs. "non-self"

【Key Words】

Autoimmune disease: abnormal condition in which immune system attacks our own body. The exact mechanisms for this phenomenon need to be determined.

MHC: molecules expressed by immune cells, which have a huge variation among the people. Although the mechanisms have not been revealed yet, there is a strong association between the types of MHC and the susceptibility of various autoimmune diseases.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,064,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.tokyo-med.ac.jp/neoself/

Title of Project : Neo-virology: the raison d'etre of viruses

Yoshihiro Kawaoka
(The University of Tokyo, The Institute of Medical Science, Professor)

Research Project Number : 16H06429 Researcher Number : 70135838

【Purpose of the Research Project】

An ecosystem is a complex network of interactions among living organisms and the nonliving components of their environment. Generally, a living organism is defined as belonging to one of the three domains of life, the archaea, bacteria, and eukaryote domains, and therefore viruses are not considered living components of the global ecosystem. Given that approximately 10^{31} viruses exist on Earth and all of them are parasitic in living organisms, it is not hard to imagine how virus infection might affect the physiological functions of hosts and the ecosystem. However, since traditional virology tends to focus on viral pathogenicity research, the significance of viruses and viral-mediated processes in the global ecosystem are poorly understood. Therefore, to identify previously unrecognized roles of the virus per se in nature, here we propose to establish a new academic field designated as 'Neo-virology'. In this research field, we define a virus as a component of the global ecosystem and aim to elucidate its key roles in host organisms and the global ecosystem.

【Content of the Research Project】

Our project consists of three research units: A01 "Coevolution", A02 "Symbiosis", and A03 "Diversity". In the A01 "Coevolution" unit, we propose to conduct comprehensive screens to identify endogenous virus-like elements in various hosts by using a deep sequence approach. We will elucidate the effects of identified endogenous virus-like elements on the biological functions and/or evolution of the hosts. Further, the mechanisms of coevolution of the virus and host will be analyzed.

In the A02 "Symbiosis" unit, we propose to elucidate the effects of symbiosis with the virus on the physiological functions and immune responses of the hosts, as well as their functional mechanisms, which will lead to an understanding of the essential roles of the virus in the regulatory biological processes of the host organisms.

In the A03 "Diversity" unit, we propose to conduct comprehensive screens to identify viruses that are yet-to-be discovered, in particular, in protoctista and prokaryotes. We will also identify the mechanisms of the life cycles of the newly identified viruses, which will lead to an understanding of the novel roles of these viruses in the global ecosystem.

In this project, we will analyze data sets collected from various living organisms and environments by utilizing system-biology approaches to understand the mechanism of the virus-regulatory ecosystem.

【Expected Research Achievements and Scientific Significance】

This research project is expected to lead to the establishment of a new research field to understand the roles of viruses in host living organisms and in the global ecosystem. It has the potential to generate new uses for virus as tools to regulate ecosystems, and may lead to solutions for serious environmental problems, such as global warming, CO_2-induced climate change, and desertification. This research project is expected to develop into an important scientific field that examines the interactions between the global ecosystem and viruses.

【Key Words】

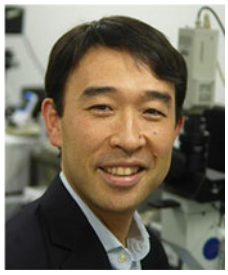
Virus-regulatory ecosystem studies: Elucidation of the key roles of viruses in host organisms and the global ecosystem.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,061,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.neo-virology.org/
kawaoka@ims.u-tokyo.ac.jp



Title of Project : Determining the principles of the birth of new plant species: molecular elucidation of the lock-and-key systems in sexual reproduction

Tetsuya Higashiyama
(Nagoya University, Institute of Transformative Bio-molecules, Professor)

Research Project Number : 16H06464 Researcher Number : 00313205

【Purpose of the Research Project】

In plant reproductive process, the system that "maintains its own genome without intercrossing with other species" prevents intercross of species with different genome. This is rarely overwritten by a system that "flexibly incorporates other genome to produce a new species", which results in a new species that includes different sets of genomes. The birth of new species with combined genome makes a critical event that achieves rapid evolution, and its molecular mechanism can be considered as an recognition of multiple sets of "lock-and-key" in the reproductive process. In this project, we aim to clarify primary mechanism in the birth of new species by revealing a whole picture of molecule-leveled understanding of "lock-and-keys" in plant reproduction through active interdisciplinary collaborative research

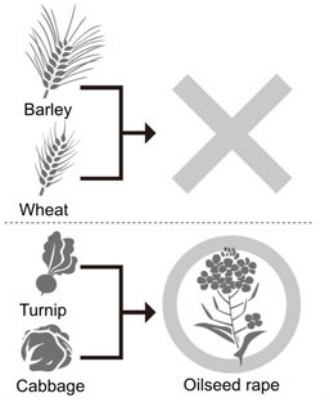


Figure 1. Examples of intercrossing results between different genome

【Content of the Research Project】

In this project, a basic research to clarify the principle mechanisms that enable "intercross between different plant species and survival of the resulted new species" is conducted, especially to aim for full understanding of "the system which maintains its own genome without intercrossing with other species". The system is being clarified that it consits of a strict authentication mechanism of self and non-self, and we defined this mechanism as "lock -and-key".

Plant reproduction research in our country has been leading the world and continuously revealing the molecular entity of "lock-and-key". The entity of "lock-and-key" has been considered in the past as "ligand receptor", but it is now extended to include "transcription complex composed of multiple transcription factors and its target genes" and "group of small RNAs and its target regions of genome". For in-depth understanding of the molecular structure and dynamics in this area, cutting-edge technology of our country is actively used, such as live cell imaging, synthetic organic chemistry and structural biology.

【Expected Research Achievements and Scientific Significance】

The research on plant reproduction to date has focused on genetics and biochemistry. In this research area, Dr. Higashiyama, the director of this project, will conduct a cross-field collaborative research, by taking advantage of technologies and facilities of live cell imaging, synthetic organic chemistry, and structural biology in Nagoya University. This project will further lead the global cutting edge field.

When this "lock-and-key" system in the plant reproduction process is clarified with advancement of the research in this area, controlling reproduction process will become possible through the control of "lock-and-key" systems by organic chemical synthesis of its inhibitor and accelerator, thus an innovative methodology in producing new plant species with adaptability to drastically changing environment can be constructed.

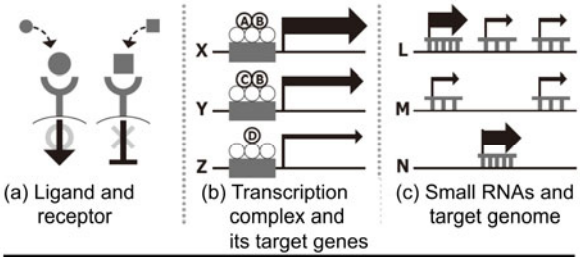


Figure 2. Examples of "lock-and-key" defined in this research

【Key Words】

lock-and-key in reproduction process: strict authentication mechanism of self and non-self without intercrossing with other species

【Term of Project】 FY2016-2020

【Budget Allocation】 1,208,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ige.tohoku.ac.jp/prg/plant