科研費
KAKENHI

Frontline Scientific Research Projects Advanced in JAPAN

— Newly Selected Large-scale Research Projects under FY2019 —
Grant-in-Aid for Scientific Research

December, 2019

Ministry of Education, Culture, Sports, Science & Technology (MEXT)
Japan Society for the Promotion of Science (JSPS)

Foreword

Grants-in-Aid for Scientific Research (KAKENHI) are competitive funds disbursed for the purpose of making leapfrog advances in scientific research carried out based on the free ideas of researchers themselves—research in all fields of the humanities, social sciences and natural sciences, spanning the spectrum from basic to applied science. Grants-in-Aid are awarded through a peer-review selection process, and they support pioneering, cutting-edge research that provides the underpinnings for building a bountiful society.

Within the program, various grant categories are established to coincide with the objective, content and scale of research projects. Applications are solicited and screened under the terms of each of category. This booklet introduces research projects newly selected in FY 2019, namely under the categories Specially Promoted Research and Scientific Research (S), carried out by a single researcher or a relatively small number of researchers, and Scientific Research on Innovative Areas (Research in a proposed research area), carried out by multiple researches or a research group.

We will be pleased if the information provided this booklet is helpful in understanding the research activities being carried out in Japanese universities and other research institutions.

Research Promotion Bureau, Ministry of Education, Culture, Sports, Science & Technology (MEXT)
(https://www.mext.go.jp/a_menu/shinkou/hojyo/main5_a5.htm)

Japan Society for the Promotion of Science (JSPS)
(https://www.jsps.go.jp/english/index.html)

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Grant-in-Aid for Specially Promoted Research

☐ Distribution by Research Area of the Newly Adopted Projects

Purpose and Description of Grant-in-Aid for Specially Promoted Research (excerpt from the "Application Procedures for Grants-in-Aid for Scientific Research-KAKENHI-"):

1) **Funding target**:
Outstanding and distinctive research plan, conducted by a single or a relatively small number of researchers, is expected to yield excellent research results and to open up a new scientific field

2) **Range of total budget (total budget throughout the research period)**:
200 milion to 500 million yen
The upper limit of the total budget per research project is set at 500 million yen. If truly needed, however, application exceeding this upper limit is not excluded.
※ Handling of research projects with a total budget exceeding 500 million yen
The reason why such a budget is needed should be stated in detail in the appropriate column of the research proposal document. The necessity of the budget will be scrutinized.

3) **Research period**: 3 to 5 years
※ If it is truly needed, application with a longer research period (up to 7 years) is possible.

4) **Number of research projects to be adopted**: Around 10 in total

【 New Projects 】

	Number of Applications			Total Grant Disbursements※ (FY2019)	Per-project Grants※ (FY2019)	
	Received	Adopted	Ratio		Average	Largest
			(%)	(Thousands of Yen)	(Thousands of Yen)	(Thousands of Yen)
Humanities and Social Sciences	7	1	14.3	77,400	77,400	77,400
Science and Engineering	74	8	10.8	734,900	91,863	150,900
Biological Sciences	25	3	12	310,700	103,567	120,300
Total	106	12	11.3	1,123,000	93,583	150,900

【 New and Ongoing Projects 】

	Number of Applications	Total Grant Disbursements※ (FY2019)	Per-project Grants※ (FY2019)	
			Average	Largest
		(Thousands of Yen)	(Thousands of Yen)	(Thousands of Yen)
Humanities and Social Sciences	5	338,700	67,740	77,400
Science and Engineering	43	3,524,600	81,967	178,200
Biological Sciences	16	1,304,700	81,544	120,300
Total	64	5,168,000	80,750	178,200

※ Direct expense only

List of the Newly Adopted Projects for Grant-in-Aid for Specially Promoted Research of KAKENHI, FY2019

（1）Humanities and Social Sciences（1 Project）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05457	OKUMURA Hiroshi 60185551	Kobe University, Graduate School of Humanities, Professor	From Local Historical Material Studies to Regional Historical Culture: Creation of a New Research Field for Resilient Local Communities in a Country of Natural Disasters	FY2019-2025	77,400	316,300

（2）Science and Engineering（8 Projects）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05458	NAGASAKI Yukio 90198309	University of Tsukuba, Faculty of Pure and Applied Sciences, Professor	Molecular design of innovative drugs based on molecular assembly	FY2019-2025	119,200	481,700
19H05459	NAKAMURA Eiichi 00134809	The University of Tokyo, Graduate School of Science, Project Professor	Molecular electron microscopy for dynamic studies on molecules and their assemblies	FY2019-2025	47,100	475,200
19H05460	NISHIHARA Hiroshi 70156090	The University of Tokyo, Graduate School of Science, Professor	Creation of two-dimensional conjugated polymer, coordination nanosheet, and manifestation of higher-order functions using high quality and hetero-structured nanosheets	FY2019-2025	67,400	418,700
19H05461	FUJITA Makoto 90209065	The University of Tokyo, Graduate School of Engineering, University Distinguished Professor	Protein Encapsulation by Synthetic Cages for Functional Control and Structure Determination	FY2019-2025	100,000	480,000
19H05462	HORI Masaru 80242824	Nagoya University, Center for Low-temperature Plasma Sciences, Professor	Development of “super-bio-functions” by plasma-activated biological substances"	FY2019-2025	117,400	464,100
19H05463	ITAMI Kenichiro 80311728	Nagoya University, Institute of Transformative Bio-Molecules (ITbM), Professor and Director	Creation of unexplored molecular nanocarbons	FY2019-2025	84,500	491,500
19H05464	KASAHARA Jiro 60312435	Nagoya University, Institute of Materials and Systems for Sustainability, Professor	Study on Self-compression Type Detonation Propulsion: Evolutionary Space-Flight Demonstration Study Using Sounding Rockets	FY2019-2025	150,900	480,900
19H05465	KANEMITSU Yoshihiko 30185954	Kyoto University, Institute for Chemical Research, Professor	Fusing nanomaterials and strong electric field nonlinear optics for new advances in photonics	FY2019-2025	48,400	429,300

（3）Biological Sciences（3 Projects）　　（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05466	SIOMI Mikiko 20322745	The University of Tokyo, Graduate School of Science, Professor	Comprehensive understanding of mechanisms underlying the piRNA pathway	FY2019-2025	104,000 417,300
19H05467	TAKADA Masahiko 00236233	Kyoto University, Primate Research Institute, Professor	Elucidating the primate basis of neurobiological mechanisms underlying developmental disorders	FY2019-2025	86,400 391,400
19H05468	TSUKITA Sachiko 00188517	Osaka University, Graduate School of Frontier Biosciences, Specially Appointed Professor	Novel approach focusing on the tight junction-based paracellular barrier combined with the apical barrier toward understanding and manipulating epithelial barriers	FY2019-2025	120,300 431,000

【Grant-in-Aid for Specially Promoted Research】

Humanities and Social Sciences

Title of Project：From Local Historical Material Studies to Regional Historical Culture: Creation of a New Research Field for Resilient Local Communities in a Country of Natural Disasters

OKUMURA Hiroshi
(Kobe University, Graduate School of Humanities, Professor)

Research Project Number：19H05457　Researcher Number：60185551
Keyword：Local historical material studies , Regional historical culture

【Purpose and Background of the Research】

After the Great Hanshin Awaji Earthquake in 1995, various activities were conducted all over Japan to save, conserve, and employ the damaged historical and cultural materials as well as materials recording the risks of the natural disasters. Our project in 2009, 'Creation of Local Historical Document Studies based on theory of Historical Materials Preservation at the time of large-scale natural disasters' [Grant-in-aid for Scientific Research (S)], collected and analyzed the numerous cases of such activities. Its research findings produced a new research field called the 'Local Historical Material Studies,' which was to provide researchers of humanities, social science and technology with a huge platform of public engagement.

Based on the 2009 project and the experience of the 3.11 catastrophe, we have been conducting the KAKENHI project since 2014,'Establishment of Local History Materials Science: Forming Disaster Subculture in the Post-3・11 World.'This acclaimed project found that it is necessary to make 'cultures resilient to the natural disasters' (hereinafter, 'disaster resilient cultures') in local communities in Japan, and the Local Historical Material Studies successfully found some practical knowledge and methodology to develop disaster resilient cultures.

However, these 2 projects have clarified that local communities in Japan faces not only the risk of natural disasters, but also serious problems derived from the current population drop and globalisation. All these problems make it increasingly difficult to inherit rich regional historical culture in Japan to the future generation. The loss of regional historical materials and culture would give a devastating blow to vast range of academic fields depending on them (e.g. History, Studies on Cultural Heritages, and Seismology) and furthermore, even endanger local communities themselves. Our project team, who have been engaged in research focusing on times of disaster, found it necessary to immediately start a new research focusing on ordinary times, employing our knowledge and methodology of the Local Historical Material Studies developed in times of disasters.

【Research Methods】

This project consists of three research fields on national and international scale: (1) Study for Inheritance of Regional Historical Materials to the Future, (2) Study for Creation of Digital Data Infrastructure to Inherit Regional Historical Materials, (3) Study for Making a New Local History of Japan Including Disaster Resilient Culture. These three different fields will be synthesized in the final phase of the project. Through the whole process of our project, the needs and opinions of people in the local communities have priority

【Expected Research Achievements and Scientific Significance】

Our studies will give 4 national/international impacts on research fields of Humanities, Science and Technology, as well as on Japanese/foreign society: (1) Studies for Memory Inheritance Culture this project deepens will be an indispensable part of various research fields of Humanities, (2) A new academic research field, 'Regional Historical Culture Studies,' can make a practical contribution to empower and revive local communities on the verge of extinction, (3) By presenting a unprecedented regional history of Japan including history of natural disasters from a long-term perspective, and by building a national data infrastructure model for inheritance of historical materials, this project can improve the level of academic research about local communities. Furthermore, these results will lead to reduce damages by future natural disasters, (4) This new academic research field 'Regional Historical Culture Studies' is such an academic breakthrough that can realize international platform of academic research on the initiative of our project team in Japan.

【Publications Relevant to the Project】

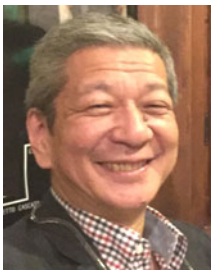
Hiroshi Okumura (ed.), Protection of Historical Cultures from Natural Disaster: The Construction of the Local Historical Materials Studies (University of Tokyo Press: Tokyo, 2014).
Hiroshi Okumura, The Great Earthquakes and the Conservation of Historical Materials (Yoshikawa Ko-Bunkan: Tokyo, 2012).

【Term of Project】FY2019-2023

【Budget Allocation】316,300 Thousand Yen

【Homepage Address and Other Contact Information】

tokusui-core＠lit.kobe-u.ac.jp



Title of Project：Molecular design of innovative drugs based on molecular assembly

NAGASAKI Yukio
(University of Tsukuba, Faculty of Pure and Applied Sciences, Professor)

Research Project Number：19H05458　Researcher Number：90198309
Keyword：Molecular assembling drug, Antioxidant, Parkinson disease, Oligo-nucleic acid, Cancer

【Purpose and Background of the Research】

Administration of conventional antioxidants such as vitamins and N-acetyl cysteine distribute nonspecifically and a serious disadvantage of destroying redox reactions in normal cells because of small molecules. We found that covalent attachment of antioxidants to macromolecules with self-assembling property suppresses uptake into normal cells and accumulates at inflammatory sites to effectively eliminate reactive oxygen species (ROS). This result indicates the possibility that the self-assembly of small molecules can realize pharmacological functions and therapeutic effects that cannot be obtained by small molecules alone. In this research, we develop a new drug discovery principle that exerts drug effects by self-molecular organization as a third drug modality, next to a conventional low molecular weight drugs and protein drugs. The results of this research are expected to be the foundation of innovative pharmaceutical industry and lead to the creation of patient-friendly medical technology.

【Research Methods】

This project is aimed at establishment of the concept for the molecular-assembling-drugs. Although amino acids and peptides show various physiological activities, and thus they are useful, they are water-soluble and rapid to metabolize and are difficult to carry and use to the target site. We have recently designed polypeptide based nano-assembles, which are stable under physiological conditions. After accumulation of the polypeptide in target site, it is metabolized to original amino acid by endogenic enzymes and functions as peptide drug. In addition to our original antioxidant self-assembling drugs, we will investigate versatile self-assembling drugs such as amino acids, fatty acids. Other types of molecular-assembling drugs such as the smart oligonucleotides incorporating a non-reactive molecule into the oligonucleotide, which can be activated by forming the hybridized complex with the target DNA or RNA. Self-assembling peptide derivatives that cause gelation at an extremely low concentration in a cancer cell, lead to selective cancer cell death. These new concepts will also be constructed.

【Expected Research Achievements and Scientific Significance】

Numerous numbers of synthetic drugs have been synthesized by organic synthesis for over 100 years. With the development of biotechnology in recent years, drug discovery is shifting from organic synthesis to biopharmaceutical synthesis. Based on such a paradigm shift, drug discovery technology has dramatically advanced and an extremely large market is anticipated, but due to protein engineering the cost of drug development is abnormally rising.

Unlike organic synthesis and biopharmaceuticals, the development of molecular assembling drugs is expected as a new drug discovery field (Fig.). As Japan is pioneering in the materials nanotechnology field, it is extremely important for us to develop a future academic field and create a new drug discovery field that does not follow the other countries. To discover new drugs and develop new medicine fields, it is important to take our own methods and way.

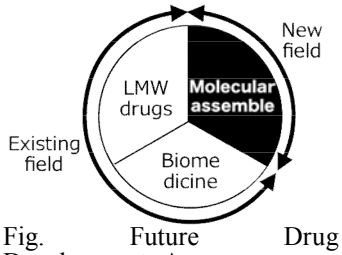


Fig. Future Drug Developments Area

【Publications Relevant to the Project】

・Yukio Nagasaki, Design and Application of Redox Polymers for Nanomedicine, ***Polymer Journal, (Review),*** Volume 50, No. 9, 821-836(2018). (10.1038/s41428-018-0054-6)
・Long Binh Vong, Shinya Kimura, Yukio Nagasaki, Newly designed silica-containing redox nanoparticles for oral delivery of novel TOP2 catalytic inhibitor for treating colon cancer, ***Advanced Healthcare Materials,*** Vol.6,1700428(2017) (0.1002/adhm.201700428)

【Term of Project】FY2019-2023

【Budget Allocation】481,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ims.tsukuba.ac.jp/~nagasaki_lab/index.htm
happyhusband@nagalabo.jp

Title of Project：Molecular electron microscopy for dynamic studies on molecules and their assemblies

NAKAMURA Eiichi
(The University of Tokyo, Graduate School of Science, Project Professor)

Research Project Number：19H05459　Researcher Number：00134809
Keyword：Structural analysis, Electron microscopy, Microanalysis, Organic chemistry

【Purpose and Background of the Research】

Video imaging of the dynamic behavior of a single organic molecule captured by high-resolution electron microscopy was reported first in 2007 (Single Molecule Atomic-resolution Real-Time Electron Microscopy, SMART-EM), linking organic chemistry to EM that had then focused largely on analysis of periodic structures and solid samples in biological and materials research. With a recently acquired state-of-the-art EM equipped with an ultrafast camera, we will capture high-speed two-dimensional videos at millisecond, and also acquire nano level three-dimensional information. Our purpose is to establish a new experimental method to be called "molecular electron microscopy" for studying the dynamic behavior of molecules and molecular assemblies.

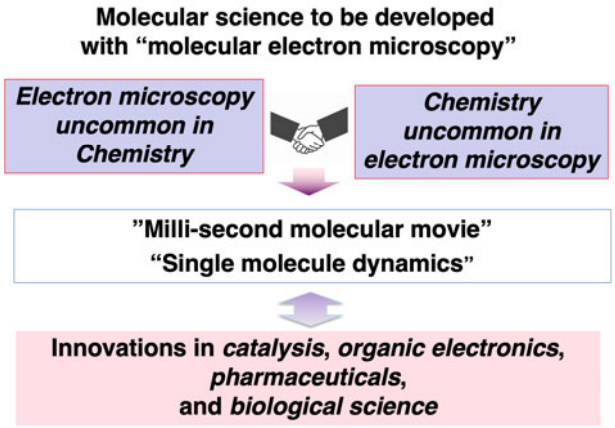


Figure. Research overview

【Research Methods】

SMART-EM is an imaging method fundamentally different from "cryo-EM" and "micro electron diffraction (ED)" in that it provides real time images of the dynamic behavior of a single molecule, enabling video imaging of single molecules and linking them to the understanding of macroscopic physicochemical properties and reactivities. The method will open up an experimental approach previously considered impossible, such as isolation and structure determination of a single molecule in a reaction mixture, and in situ observation of the time course of chemical reaction events.

It has been a chemists' dream to see in situ and at atomic resolution a molecule that changes its shape and reacts. The most advanced camera can capture 1,600 electron microscopic images per second. Through software development such as denoising and automatic video analysis, high-speed imaging of molecular motions and reactions will be achieved, providing hitherto unavailable basic knowledges in molecular science.

【Expected Research Achievements and Scientific Significance】

This research aims for the development of a variety of electron microscopic techniques centering on the SMART-EM method and solving problems in catalysis, organic electronics, pharmaceuticals, and life sciences. Elucidation of the dynamic behavior of molecular species, which cannot be studied by previously known methods, will be made possible by capturing and identifying a molecular amount of reaction intermediates and analyzing amorphous organic aggregates.

This study will realize a dream of people since Dalton's atomic theory in the 19th century, that is, seeing in situ the motions and reactions of the single molecules as they happen. By sharing such experience with young people, we will be able to make the world of atoms and molecules more familiar to people at large.

【Publications Relevant to the Project】

・M. Koshino, T. Tanaka, N. Solin, K. Suenaga, H. Isobe, E. Nakamura, Imaging of Single Organic Molecules in Motion, *Science*, **316**, 853, (2007).
・E. Nakamura, K. Harano, Chemical Kinetics Study through Observation of Individual Reaction Events with Atomic-Resolution Electron Microscopy, *Proc. Jpn. Acad., Ser. B*, **94**, 428-440, (2018).

【Term of Project】

FY2019-2023

【Budget Allocation】

475,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.chem.s.u-tokyo.ac.jp/~common/NakamuraLab.html
nakamura@chem.s.u-tokyo.ac.jp

Title of Project：Creation of two-dimensional conjugated polymer, coordination nanosheet, and manifestation of higher-order functions using high quality and hetero-structured nanosheets

NISHIHARA Hiroshi
(The University of Tokyo, Graduate School of Science, Professor)

Research Project Number：19H05460　Researcher Number：70156090
Keyword：two-dimensional material, metal complex, crystal, hetero-structure, energy storage

【Purpose and Background of the Research】

The coordination nanosheet (CONASH) refers to ultra-thin film of a two-dimensional (2D) conjugated polymers composed of metal ions and planar bridging organic π-ligands. We reported the nickelladithiolene (NiDT) CONASH, the first example to show metallic properties, in 2013. Contrarily to inorganic nanosheets such as graphene, CONASH can be synthesized at the liquid-liquid and gas-liquid interface. There are numerous combinations of metals and ligands, such that various chemical structures can be obtained. Also, most coordination reactions proceed under ambient conditions, such that easy and cheap bottom-up synthetic method can be employed. The purpose of this project is to open up new areas of CONASH research in fundamental science and engineering leading to further applications that will contribute to the advancement of our society.

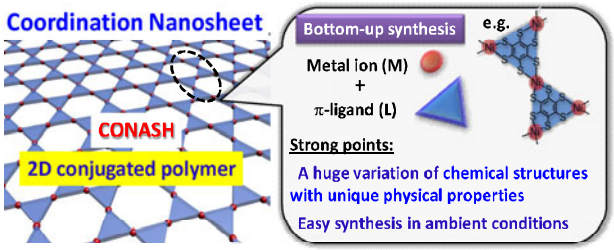


Fig. 1. Concept of CONASH.

【Research Methods】

In this research, the following four issues will be tackled; 1) to create new functional CONASHs by combining with a theoretical calculation, 2) to synthesize single crystalline CONASHs of high purity and large area (100 μm^2) for understanding the essential structure-property correlations, 3) to uncover ultimate physical and chemical functions based on the features of both metal complexes and 2D conjugated structures, and 4) to fabricate hetero-structures (van der Waals-layers and lateral hetero-junction) of CONASHs and discover their unique properties and functions. These issues will be investigated using our past research method and our collaborative research network with physicists and electronic engineers, but a giant leap is necessary in order to synthesize high quality CONASHs. We will achieve this leap by introducing our original new techniques and methods, and will find unprecedented functions and phenomena of CONASH. In particular, we will study on the electrochemical energy storage/conversion functions of CONASH in collaboration with Dr. Ken Sakaushi (NIMS).

【Expected Research Achievements and Scientific Significance】

It has been demonstrated that CONASH is a promising material group utilizable for various applications by the extensive researches since our report of the electronically conducting NiDT CONASH. However, there is still challenge for CONASH to install it in practical applications, *i.e.* a general synthetic approach to prepare high quality nanosheet samples in large scale. One of the aims of this project is to develop a method to obtain the high-quality sample of CONASHs, which directly leads to revealing intrinsic parameters of their physical and chemical properties important for basic science and manifesting high performance important for applications.

Other aims of this project are to design new functional CONASH to investigate ultimate physical and chemical functions, and to fabricate hetero-structures of CONASHs. The progresses of researches on these issues using high quality CONASHs will expand the field of basic and applied research on materials science, chemistry, physics, and electronic engineering etc.

【Publications Relevant to the Project】

・π-Conjugated Nickel Bisdithiolene Complex Nanosheet. T. Kambe, R. Sakamoto, K. Hoshiko, K. Takada, M. Miyachi, J. Ryu, S. Sasaki, J. Kim, K. Nakazato, M. Takata, H. Nishihara, *J. Am. Chem. Soc.* **2013**, *135*, 2462-2465.
・Coordination nanosheets (CONASHs): strategies, structures and functions. R. Sakamoto, K. Takada, T. Pal, H. Maeda, T. Kambe, H. Nishihara, *Chem. Commun.* (Feature article) **2017**, *53*, 5781-5801.

【Term of Project】FY2019-2023

【Budget Allocation】418,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.chem.s.u-tokyo.ac.jp/~inorg/
nisihara@chem.s.u-tokyo.ac.jp

Title of Project：Protein Encapsulation by Synthetic Cages for Functional Control and Structure Determination

FUJITA Makoto
(The University of Tokyo, Graduate School of Engineering, University Distinguished Professor)

Research Project Number：19H05461　Researcher Number：90209065
Keyword：Protein encapsulation, NMR structure analysis, X-ray structure analysis, self-assembly, cage compounds

【Purpose and Background of the Research】

The principal investigator (PI) has pioneered a variety of self-assembled hollowed complexes and created a number of new scientific concepts related to the functions of their inner nanocavities since 1990. In this project, we aim to explore the potential of proteins encapsulated within precisely designed molecular capsules. More accurately, we will develop our technology based on the following perspectives: 1) control the property of protein (e.g., stability, ligand affinity or selectivity), 2) control enzymatic reactivity (e.g., activity or new function) and furthermore 3) develop new analytical methodology (coupled with NMR, X-ray, MS or cryoEM etc.). We envision to contribute to the field of life science by providing them the preceding fundamental technologies.

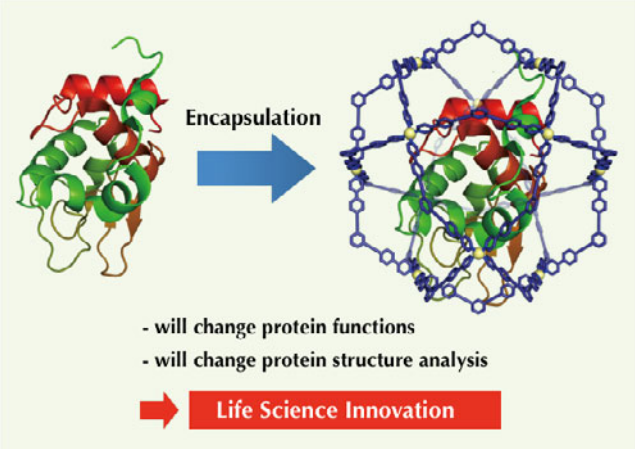


Figure 1. The basic concept of the project

【Research Methods】

We have already developed a mathematical design theory for the self-assembly of gigantic cage without critical upper size limits. Based on this theory, we further scale the size of synthetic molecular capsules. Basic methods for protein encapsulation in the cages have been also established. We are particularly interested in applications of the protein encapsulation that aids protein structural analysis. There still be many limitations in conventional protein structural analysis. Protein encapsulation in this study has the potential to solve some of the problems. As specific research projects, we will work on a) NMR data acquisition under non-biological conditions, b) Structural analysis of agglutinative proteins/peptides stabilized by encapsulation, c) Dynamic structural change analysis of proteins as typified by the folding process and d) New methodologies for facile X-ray or CryoEM structural analysis.

【Expected Research Achievements and Scientific Significance】

Taking the privilege to be the first one to explore this area of protein spatial modification, we are confident to unveil many fruitful results benefit multiple fields that handle protein molecules either in academic or industry. The true importance and necessity should accompany the following points: 1) the research stands on applicant's original science, 2) the research is not on the simple extension of the past, 3) no other groups has the similar research direction and 4) massive academic impact to be expected when it gets materialized.

【Publications Relevant to the Project】

・Self-Assembly of Tetravalent Goldberg Polyhedra from 144 Small Components, D. Fujita, Y. Ueda, S. Sato, N. Mizuno, T. Kumasaka, M. Fujit, Nature 2016, 540, 563-566.
・Protein encapsulation within synthetic molecular hosts, D. Fujita, K. Suzuki, S. Sato, M. Yagi-Utsumi, Y. Yamaguchi, N. Mizuno, T. Kumasaka, M. Takata, M. Noda, S. Uchiyama, K. Kato, and M. Fujita, Nature Commun. 2012, 3, 1093.

【Term of Project】FY2019-2023

【Budget Allocation】480,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://fujitalab.t.u-tokyo.ac.jp
mfujita@appchem.t.u-tokyo.ac.jp

Title of Project：Development of "super-bio-functions" by plasma-activated biological substances

HORI Masaru
(Nagoya University, Center for Low-temperature Plasma Sciences, Professor)

Research Project Number：19H05462　Researcher Number：80242824
Keyword：plasma, Low-temperature Atmospheric Pressure Plasma, Plasma Medicine, Plasma Agriculture

【Purpose and Background of the Research】

We found that biological liquids irradiated with plasma (aggregate of active particles [radicals, ions, electrons, light]) exhibit highly selective anti-tumor effects against various cancers. We also found that plasma propagates central nerve cells that could not be conventionally reproduced and surprisingly promotes plant growth. We have also systematically analyzed effects of plasma-activated liquids on biological systems (gene expression, metabolism, immunity, and signal transduction) by developing plasma science within the fields of medical science and molecular biology. In this project, we plan to investigate the molecular structures and physical properties of plasma-activated biological substances and to integrally understand interactions among the substances and biological system to elucidate the expression of “super bio-functions” by plasma as a universal molecular mechanism in eukaryotes for processes such as cell death, proliferation, and differentiation. Based on the findings, we expect to provide an academic foundation for “Plasma Life Science” as a compass for pioneering new industries such as plasma medicine and agriculture, and will produce innovations to resolve problems with intractable and food shortages.

【Research Methods】

The primary objective is to focus on elucidating the molecular structure and physical properties of bioactive substances resulting from the interactions between plasma and biological fluids.

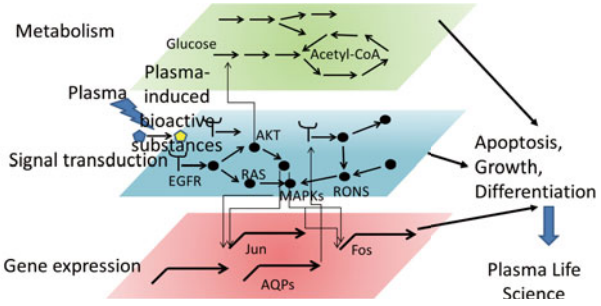


Figure 1 M olecular reactions between plasm -induced bioactive substances and living bodies.

Next, we will systematically investigate molecular reactions (signal transduction, gene expression, metabolism, immunity, hormones) between plasma-induced bioactive substance and the living body at the cellular level with respect to selective death and regeneration/proliferation phenomena caused by interactions between each substance and animal and plant cells (Figure 1). The second objective is to clarify the mechanisms of death, regeneration and growth from the transcriptome (exhaustive gene expression) and metabolomic analysis in animal models (mouse, rat) and plant models (model plants, strawberry, rice). Finally, the third objective is to open up studies of plasma as a life science by clarifying the essence of the phenomenon.

【Expected Research Achievements and Scientific Significance】

Our researches focusing on cell death and regeneration among phenomena caused by combined exposure to bioactive substances result in a comprehensive understanding of these phenomena and opening up the field (plasma life science) to clarify the "essence of living body" responses to plasma. These results will be a compass to approach to the Plasma Life Science producing the incredible academic impact.

【Publications Relevant to the Project】

・F. Utsumi, H. Kajiyama, K. Nakamura, H. Tanaka, M. Mizuno, K. Ishikawa, H. Kondo, H. Kano, M. Hori, F. Kikkawa, Effect of Indirect Nonequilibrium Atmospheric Pressure Plasma on Anti-Proliferative Activity against Chronic Chemo-Resistant Ovarian Cancer Cells In Vitro and In Vivo, Plos One, 8 (2013) e81576/1-10.
・H. Tanaka, K. Nakamura, M. Mizuno, K. Ishikawa, K. Takeda, H. Kajiyama, F. Utsumi, F. Kikkawa, M. Hori, Non-thermal atmospheric pressure plasma activates lactate in Ringer's solution for anti-tumor effects, Sci Rep, 6 (2016) 36282/1-11.

【Term of Project】

FY2019-2023

【Budget Allocation】

464,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://horilab.nuee.nagoya-u.ac.jp/
hori@nuee.nagoya-u.ac.jp

Title of Project：Creation of unexplored molecular nanocarbons

ITAMI Kenichiro
(Nagoya University, Institute of Transformative Bio-Molecules (ITbM), Professor and Director)

Research Project Number：19H05463　Researcher Number：80311728
Keyword：π-extended compounds, organic materials, selective synthesis, supramolecular chemistry, chemical biology

【Purpose and Background of the Research】

Nanocarbons, nanometer-sized carbon materials, conduct electricity, absorb and emit light, and exhibit interesting magnetic properties. In addition to well-known nanocarbons such as spherical fullerenes, cylindrical carbon nanotubes, and sheet-shaped graphenes, theoretical simulations have predicted a number of exotic three-dimensional nanocarbon structures that have yet to be synthesized. At present, however, synthetic routes to nanocarbons almost invariably lead to mixtures of compounds displaying a range of different structures and properties; these mixtures cannot be easily separated into pure forms. The "*mixture problem*" that arises during the synthesis of nanocarbons represents one of the most significant challenges in the science and technology of nanocarbons.

The objectives of this project are (1) to design and synthesize novel nanocarbons as single structures, individually distinguishable and identifiable, and (2) to create highly advanced functional materials based on these single-molecule materials. We combine chemical and physical methods for the controlled synthesis of single-molecule nanocarbons, and conduct interdisciplinary research that encompasses the control of molecular arrangement and orientation, structural and functional analysis, and applications in devices and biology. Through this project bringing molecular science and materials science together, we aim to establish the new field of *molecular nanocarbon science*.

【Research Methods】

1. Carbon nanotubes

Carbon nanobelt is the molecule that represents the fully fused cylindrical aromatic hydrocarbon (e.g. *Science* 2017). In this project, we establish the synthetic methods of carbon nanobelts having various lengths, diameters, and structures. As a further challenge, we perform the CNT growth using carbon nanobelt as a seed to provide CNTs with uniform physical properties.

2. Graphene nanoribbons

We have synthesized graphene nanoribbons (GNRs) with various widths, edge structures, lengths, and periodic defects by using APEX reactions (e.g. *Science* 2018) developed by our group. Here we challenge to create APEX polymerization reactions to control the length of GNR precisely. Sequential oxidative annulation reaction can proceed to the formation of adjacent carbon-carbon bonds to form planar GNRs. By utilizing this technique, we synthesize various GNRs (fjord-type GNRs and armchair-type GNRs) having different width and edge structures by using precisely designed silole monomers.

3. Three-dimensional nanocarbon network

In this subject, we work on the creation of three-dimensional carbon networks that enables condensed conjugation with only carbon atoms. Three-dimensional carbon networks consisting solely of sp^2 carbon atoms are substance groups of dreams considering the theoretical prediction of outstanding physical properties. In this research, we apply molecular nanocarbon synthesis technology such as APEX reaction of aromatic compounds.

【Expected Research Achievements and Scientific Significance】

The concept of "molecularity and molecular materials" will lend new values and creativity to nanocarbon science, which is already starting to create a social ripple effect, and the creation of innovative molecular nanocarbon materials will have a huge impact on industry. Furthermore, many new methodologies and techniques for molecular synthesis and structural analysis will be developed throughout this project. Synthesis and analysis techniques are not particular to a single type of molecule or substance. Therefore, these methodologies will bring breakthroughs to many chemical, physical, or biological fields as molecular sciences.

【Publications Relevant to the Project】

・Segawa, Y.; Itami, K. *et al.,* Synthesis of a carbon nanobelt, *Science* **2017**, *356*, 172–175.
・Murakami, K.; Itami, K. *et al.,* Synthesis of partially and fully fused polyaromatics by annulative chlorophenylene dimerization, *Science* **2018**, *359*, 435–439.

【Term of Project】 FY2019-2023

【Budget Allocation】 491,500 Thousand Yen

【Homepage Address and Other Contact Information 】

http://synth.chem.nagoya-u.ac.jp

Title of Project：Study on Self-compression Type Detonation Propulsion: Evolutionary Space-Flight Demonstration Study Using Sounding Rockets

KASAHARA Jiro
(Nagoya University, Institute of Materials and Systems for Sustainability, Professor)

Research Project Number：19H05464　Researcher Number：60312435
Keyword：Propulsion, Thermo-fluid dynamics, Detonation, Aerospace Engineering, Sounding Rocket

【Purpose and Background of the Research】

The detonation (hypersonic combustion) propulsion mechanism is now causing a revolution in the field of aerospace engineering. In the present research, we study a revolutionary self-compression-process disc-shaped rotating detonation engine with porous injectors and a detonation combustion actuator in the effort to realize an integrated propulsion device with an airplane body. We investigate the principles of advanced high performance and light weight for an aerospace system.

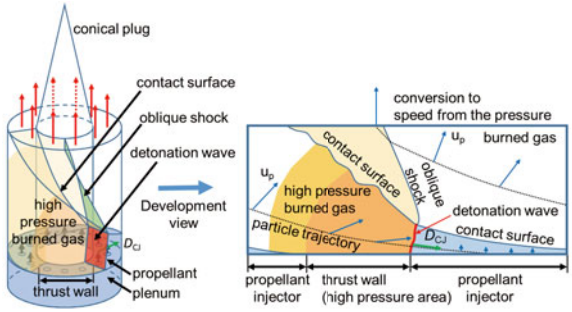


Figure 1　Detonation Engine

【Research Methods】

In the present research, we perform experimental and numerical studies in which we vary the inner diameter of the disc-shaped rotating detonation engine, in addition to the injection condition and mixture condition. We also clarify the most fundamental combustion phenomena in this engine, and the mechanism of pressure gain. We verify the limitation of the pressure gain using a multi-staged disc-shaped rotating detonation engine. We fabricated a porous cooling wall injector-type rotating detonation engine. On the fuel-oxidizer injector wall of this engine, detonation wave propagation was maintained stably. We experimentally and numerically clarify the detonation structure and heat flux into the wall, and the heat transfer coefficient from the gas flow to the wall.

We fabricate the small detonation actuator using the state-of-the-art nanometer-order machining technique, and clarify the high-speed-flow thrust characteristics of the actuator and performance of the ejector effect. We also clarify the thrust and aerodynamic characteristics (lift and drag force and rolling torque coefficients) when the engine and body are integrated by these small actuators.

【Expected Research Achievements and Scientific Significance】

We will also demonstrate the principles investigated to achieve objectives with a rocket system in a low-earth-orbit flight test using the third stage of the sounding rocket system in 2025. The present research will allow us to realize innovative propulsion performance and body structure, and will create a completely new area in the aerospace engineering field.

【Publications Relevant to the Project】

・K. Goto, J. Nishimura, A. Kawasaki, K. Matsuoka, J. Kasahara, A. Matsuo, I. Funaki, D. Nakata, M. Uchiumi, K. Higashino, Experimental Propulsive Performance and Heating Environment of Rotating Detonation Engine with Various Throat Geometries, Journal of Propulsion and Power, Vol. 35, No. 1, 2019, pp.213-223.
・Kawasaki, T. Inakawa, J. Kasahara, K. Goto, K. Matsuoka, A. Matsuo, I. Funaki, Critical Condition of Inner Cylinder Radius for Sustaining Rotating Detonation Waves in Rotating Detonation Engine Thruster, Proceedings of the Combustion Institute, Vol. 37, No. 3, 2019, pp. 3461-3469.

【Term of Project】FY2019-2023

【Budget Allocation】480,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.prop.nuae.nagoya-u.ac.jp/
kasahara@nuae.nagoya-u.ac.jp

Title of Project：Fusing nanomaterials and strong electric field nonlinear optics for new advances in photonics

KANEMITSU Yoshihiko
(Kyoto University, Institute for Chemical Research, Professor)

Research Project Number：19H05465　Researcher Number：30185954
Keyword：Optical properties of materials, nanomaterials, strong electric field nonlinear optics, high harmonic generation, terahertz spectroscopy

【Purpose and Background of the Research】

Sophisticated high-power laser techniques are becoming a fundamental part of new photonics research, with recent advances in high intensity and ultrashort pulse laser technology opening up new avenues of optical science. Irradiating solids with strong laser pulses can introduce new nonlinear optical phenomena, such as high harmonic generation, which produces multiple frequencies of the incident laser's frequency. Ultrashort (attosecond) pulsed light sources covering a wide range of wavelengths from the infrared to X-ray have many potential technological applications. Strong optical pulses dramatically change the electronic states of solids, inducing phenomena such as Zener tunneling. In this research, we study the nonlinear optical properties of solids with novel electronic states and nanoscale structures by means of advanced laser techniques. We promote the development of new high-field photonics and foster future applications into material phase control, optical switching, and spectroscopic analysis.

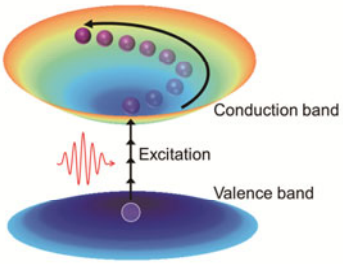


Fig. 1 Strong field-induced optical phenomena caused by accelerated carriers in the band.

【Research Methods】

Our investigations into the optical response of new solid materials draw on our strong research background in nanomaterials science. Using ultrafast coherent spectroscopy, we aim to discover new optical phenomena of nanomaterials generated under high fields. Electronic motions and states in solids and nanomaterials are altered using high electric field optical and terahertz pulses. Modern high-field science and photonics are furthered through the precise control of the phase and polarization of these pulses.

【Expected Research Achievements and Scientific Significance】

Advanced laser technologies are expected to revolutionize current research and open up new disciplines of study. While initially developed for atomic and molecular systems, we will extend the study of strong-field nonlinear phenomena to include nanomaterials. Examining the fundamental physics of nanomaterials is expected to lead to new spectroscopic technologies, new material control technologies, light processing technologies, and light energy conversion technologies, etc., which will dramatically advance optical science research and impact on a wide range of research fields.

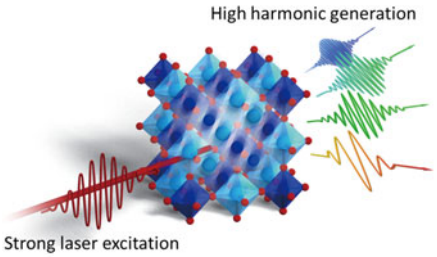


Fig. 2 Schematic of high harmonic generation from electrons driven by strong laser excitation.

【Publications Relevant to the Project】

・H. Tahara, Y. Kanemitsu *et al.*, "Harmonic quantum coherence of multiple excitons in PbS/CdS core-shell nanocrystals", *Phys. Rev. Lett.* **119**, 247401 (2017).
・Y. Sanari, Y. Kanemitsu, H. Hirori *et al.*, "Zener tunneling breakdown in phase-change materials revealed by intense terahertz pulses", *Phys. Rev. Lett.* **121**, 165702 (2018).

【Term of Project】

FY2019-2023

【Budget Allocation】

429,300 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.scl.kyoto-u.ac.jp/~opt-nano/index-e.html

Title of Project：Comprehensive understanding of mechanisms underlying the piRNA pathway

SIOMI Mikiko
(The University of Tokyo, Graduate School of Science, Professor)

Research Project Number：19H05466　Researcher Number：20322745
Keyword：piRNA, Transposon, PIWI, RNA silencing, gonad

【Purpose and Background of the Research】

piRNAs are small RNAs enriched in animal gonads where they arms race with transposons to maintain germline genome integrity. Although transposons are powerful agents contributing to evolution, they are also regarded as selfish DNA parasites. Indeed, loss of piRNAs causes derepression of transposons, leading to DNA damage and failure in gonadal development and fertility. Thus, piRNA-mediated transposon silencing is indispensable for animals that undergo obligate sexual production. The piRNA studies have intensively been conducted worldwide from which fundamental scheme of the pathway have emerged. However, the molecular mechanism is not yet fully understood. In this proposal, we aim to gain insights into the molecular mechanisms underlying the piRNA-mediated transposon silencing pathway to reach our goal: Comprehensive understanding of the pathway.

【Research Methods】

To reach our final goal, we will pursue five research plans, RP-1 to RP-5, which are indicated below.
[RP-1] Understanding of the mechanism underlying piRNA biogenesis in OSCs
[RP-2] Understanding the molecular mechanism underlying piRNA biogenesis in germ cells
[RP-3] Understanding the mechanism underlying piRNA-driven transcriptional silencing in OSCs
[RP-4] Solving the 3D structures of piRNA factors
[RP-5] Understanding the mechanism underlying dynamics of local heterochromatin in mouse gonocytes

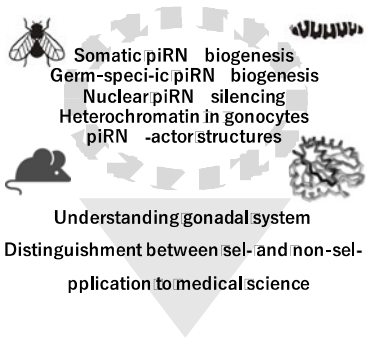


Figure 1. Comprehensive understanding of the piRNA pathway

【Expected Research Achievements and Scientific Significance】

Genetic studies identified maternal effect genes with an involvement in the piRNA pathway. Our expertise and use of cultured OSCs allow us to biochemically analyze their functions, and gain new insights into the molecular functions in piRNA biogenesis and piRNA-mediated silencing mechanism. Our continued studies will further contribute to understanding of the natural biological functions of the germline. This is unique, important and necessary, as the *in vivo* engineering of the piRNA-mediated gene silencing or related pathways may result in biotechnological and biomedical applications such as the development of antiviral and cancer therapies, and methods to treat diseases related to functional defects in the ovaries and testes, including infertility.

【Publications Relevant to the Project】

・Ishizu H, Kinoshita T, Hirakata S, Komatsuzaki C and *Siomi MC. Distinct and collaborative functions of Yb and Armitage in transposon-targeting piRNA biogenesis. ***Cell Reports*** 27:1-14. 2019
・Nishida KM, Sakakibara K, Iwasaki Y, Yamada H, heteroMurakami R, Murota Y, Kawamura T, Kodama T, Siomi H and *Siomi MC. Hierarchical roles of mitochondrial PAPI and Zucchini in *Bombyx* germline piRNA biogenesis. ***Nature*** 555:260-264. 2018
・Matsumoto N, Nishimasu H, Sakakibara K, Nishida KM, Hirano T, Ishitani R, Siomi H, *Siomi MC and *Nureki O. Crystal structure of silkworm PIWI-clade Argonaute Siwi bound to piRNA. ***Cell*** 167:484-497. 2016
・Sumiyoshi T, Sato K, Yamamoto H, Iwasaki YW, Siomi H and *Siomi MC. Loss of l(3)mbt leads to acquisition of the ping-pong cycle in *Drosophila* ovarian somatic cells. ***Genes & Development*** 30:1617-1622. 2016

【Term of Project】

FY2019-2023

【Budget Allocation】

417,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www-siomilab.biochem.s.u-tokyo.ac.jp/publications.html

Title of Project：Elucidating the primate basis of neurobiological mechanisms underlying developmental disorders

TAKADA Masahiko
(Kyoto University, Primate Research Institute, Professor)

Research Project Number：19H05467　Researcher Number：00236233
Keyword：Developmental disorders, Social behavior, Neural networks, Cognitive genome, Primates

【Purpose and Background of the Research】

Social mind is crucial to live our social life adaptively and create our society itself. Nurturing the social mind is indispensable to keep good relationships between the self and others for our comfortable daily life through social/collective behaviors. Therefore, it is a critical issue for us to consider how a group or individuals within the group should behave. However, individuals suffering from developmental disorders, such as autism spectrum disorder and schizophrenia, cannot take social/collective behaviors in a proper fashion. Exploration of the neural mechanisms underlying the social mind and developmental disorders caused by its disruption is of high necessity and emergency not only for understanding ourselves and our society, but also for proposing effective intervention/therapy programs against the issue that the contemporary society faces, based on the scientific evidence. The present research project aims at elucidating the primate basis of neurobiological mechanisms underlying the social mind and developmental disorders caused by its disruption, by employing monkeys (macaques, marmosets) as primate models and attempting a paradigm shift from previous “individual-level life science” to novel “society/group-level life science”. The major objective of this project is to clarify the fundamental mechanisms underlying the linkage of a biological triangle that comprises social behavior (collective behavior, inter-individual interaction) executed by a group or individuals within the group, neural network activity regulating the social behavior, and cognitive gene expression governing the network activity, through identifications and functional analyses of genes and neural networks involved in generation and control of the social mind.

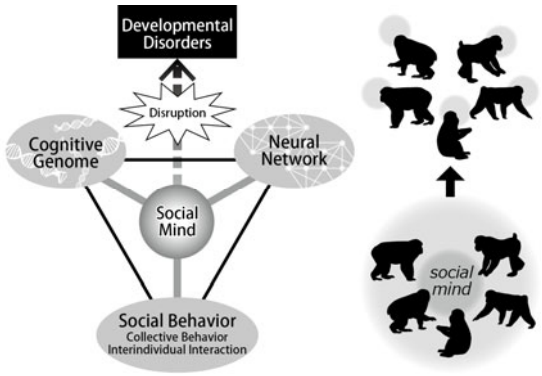


Figure 1　Social mind and developmental disorders

【Research Methods】

In the present research project, we employ a wide variety of innovative technologies as well as the excellent research environment at the PRI (collective cages, open enclosures): comprehensive search and functional analysis of risk genes for developmental disorders, neuronal activity manipulation by intracranial gene transfer with viral vector systems, multi-individual behavior simultaneous tracing, and dual neuronal activity measuring on two monkeys. Six research plans are conducted comprehensively to establish pathway-selective optogenetic/chemogenetic manipulation and whole-brain level gene transfer, product primate disorder models by these techniques, and analyze collective behaviors with multi-individual behavior simultaneous tracing.

【Expected Research Achievements and Scientific Significance】

The outcome issued by the present research project will lead to understanding not only the behavioral properties of developmental disorders from a collective viewpoint, but also the behavioral features of developmental disorder patients within a group or in the society, and may also expand into early detection of serious social problems in adolescence (i.e., bullying and suicide) and development of novel approaches to intervention/therapy against them.

【Publications Relevant to the Project】

Nagai Y, Inoue K, Takada M, Minamimoto T et al. (2016) PET imaging-guided chemogenetic silencing reveals a critical role of primate rostromedial caudate in reward evaluation. Nature Communications 7:13605.

Inoue K, Takada M, Matsumoto M (2015) Neuronal and behavioral modulations by pathway-selective optogenetic stimulation of the primate oculomotor system. Nature Communications 6:8378.

【Term of Project】

FY2019-2023

【Budget Allocation】

391,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.pri.kyoto-u.ac.jp/sections/systems_neuroscience/index.html
takada.masahiko.7x@kyoto-u.ac.jp

Title of Project : Novel approach focusing on the tight junction-based paracellular barrier combined with the apical barrier toward understanding and manipulating epithelial barriers

TSUKITA Sachiko
(Osaka University, Graduate School of Frontier Biosciences,
Specially Appointed Professor)

Research Project Number: 19H05468 Researcher Number: 00188517
Keywords: Epithelial barrier, Tight junction, Apical membrane, Cell adhesion, Cytoskeleton

【Purpose and Background of the Research】

Epithelial cell sheets that form barriers between two biological compartments are a basic feature of metazoans. The cells in these sheets are adjoined by a specialized cell-cell adhesion apparatus called the Tight Junction (TJ) to form paracellular barriers in vertebrates. Although the TJ molecular composition is well studied, questions remain about the organization and function of the TJ-paracellular barrier and its relationship to the apical barrier, which forms at the apical side of epithelial cells. Based on our previous achievements in TJ research, our current project comprises two subjects. One aim is to resolve the *in vivo* TJ molecular structure at the amino acid level using a highly advanced technique, single particle cryoelectron microscopy (CryoEM). The other aim is to establish how the TJ-paracellular barrier is integrated with the apical barrier by the "TJ-Apical Complex," a system consisting of TJs, the apical cytoskeleton, and apical membranes, to organize the epithelial barrier. These analyses will be performed at the molecular, cellular, tissue/organ, and animal levels. Our project explores broader roles of the TJ-paracellular and apical barriers in forming the total epithelial barrier, which plays critical roles in biological systems.

【Research Methods】

(1) Establishment of the hypothetical "Antiparallel double row model" for TJs *in vivo*. How claudins polymerize to form TJs *in vivo* remains unknown. We seek to resolve the *in vivo* TJ structure by high-resolution cryoEM using various TJ preparations.

(2) TJ-Apical Complex analysis at the molecular~animal level. We unbiasedly screened the TJ fractions to identify four novel factors that bridge the TJ and apical cytoskeleton termed TJ microtubule (MT)-associating proteins (TJMAPs). These proteins localize to the TJ and bind to MTs and actin filaments (AFs) (and possibly intermediate filaments) to organize apical functions. We seek to clarify how TJs are integrated with apical functions to organize the epithelial barrier.

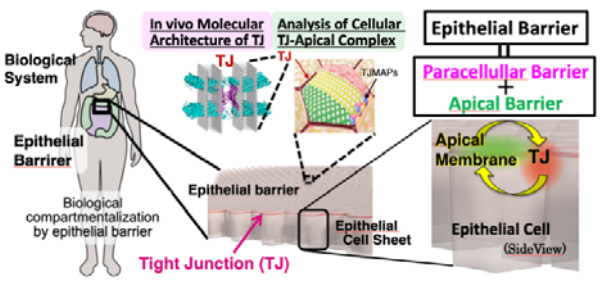


Figure 1 Epithelial barrier-based biological systems and projects in this study

【Expected Research Achievements and Scientific Significance】

We will pursue two major lines of study. One is a structural physiological study using the highly advanced cryoEM to obtain a detailed molecular model for the organization and function of the TJ-paracellular barrier. The other is a cell biological study in which we establish our proposed concept, "The TJ-Apical Complex," a functional cytoskeletal-signaling system that integrates the structure and function of the TJ and apical components. The data obtained will lead to a systematic understanding of biological functions governed by the TJ and TJ-Apical Complex in normal and disease states, which may provide a conceptual platform for new health management strategies, therapeutic approaches, and bioengineered tissues.

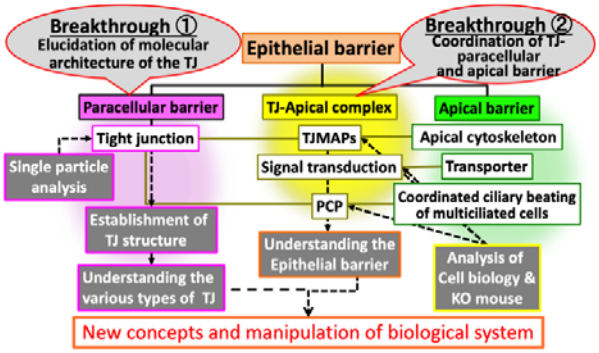


Figure 2 Molecular~mouse level analyses on epithelial barrier-based biological systems

【Publications Relevant to the Project】

・Kunimoto,K., …… , and Tsukita,S. Coordinated ciliary beating requires *Odf2*-mediated polarization of basal bodies via basal feet. *Cell* 148, 189-200 (2012).
・Saitoh,Y., Suzuki, S., Tani,K., ……, Tsukita,S., and Fujiyoshi,Y. Structural insight into tight junction disassembly by *Clostridium perfringens* enterotoxin. *Science* 347, 775-778 (2015).
・Tsukita,S., Tanaka,H., and Tamura,A. The claudins: from tight junctions to biological systems. *Trends in Biochem. Sci.* 44, 141-152 (2019).

【Term of Project】 FY2019-2023

【Budget Allocation】 431,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.fbs.osaka-u.ac.jp/labs/tsukita/
tsukiweb@biosci.med.osaka-u.ac.jp

List of the Continuing Projects for Grant-in-Aid for Specially Promoted Research of KAKENHI

Humanities and Social Sciences（ 4 Projects ）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05692	ICHIMURA Hidehiko 50401196	The University of Tokyo, Graduate School of Economics, Professor	Construction of Policy-Evaluation-Oriented and Heterogeneity-Sensitive National Transfer Accounts and their Application to Policies for Coping with Declining Fertility and Population Aging	FY2015-2019	417,100
16H06283	MATSUZAWA Tetsuro 60111986	Kyoto University, Institute for Advanced Study, Distinguished Professor	Primate foundation of language and altruism	FY2016-2020	361,200
17H06086	HIGUCHI Yoshio 20119001	Keio University, Fucultyl of Business and Commerce, Project Professor	Economic disparity and intergenerational transfer in the longevity society: Policy evaluation analysis using panel data	FY2017-2021	428,700
18H05204	ISHIDA Hiroshi 40272504	The University of Tokyo, Institute of Social Science, Professor	A Comprehensive Study of Life Course and Inequality Using the Framework of Cumulative Advantages and Disadvantages	FY2018-2024	470,800

Science and Engineering（ 35 Projects ）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05693	SAGAWA Hiroyuki 80178590	The University of Tokyo, Institute for Cosmic Ray Research, Professor	Extended Telescope Array Experiment-Nearby Extreme Universe Elucidated by Highest-energy Cosmic Rays	FY2015-2019	447,100
15H05694	FUKUI Yasuo 30135298	Nagoya University, Graduate School of Science, Designated Professor	Innovation of the “interstellar medium” by accurate measurements of the interstellar hydrogen	FY2015-2019	424,200
15H05695	TSUCHIYAMA Akira 90180017	Ritsumeikan University, Research Organization of Science and Technology, Professor	A model for formation and evolution of solid materials in space based on 3D structures of solar primitive materials	FY2015-2019	394,900
15H05696	YAMANOUCHI Kaoru 40182597	The University of Tokyo, Graduate School of Science, Professor	Sub-femtosecond molecular imaging	FY2015-2019	399,600
15H05697	OHKOSHI Shin-ichi 10280801	The University of Tokyo, Graduate School of Science, Professor	Design of light- or electromagnetic-wave-correlating phase transition materials and research of their advanced functionalities	FY2015-2019	374,700
15H05698	KOBAYASHI Shu 50195781	The University of Tokyo, Graduate School of Science, Professor	Revolutionizing organic chemistry by utilizing water as solvent	FY2015-2019	421,200
15H05699	NITTA Junsaku 00393778	Tohoku University, Graduate School of Engineering, Professor	Spin-orbit Engineering	FY2015-2019	445,800
15H05700	ARAKAWA Yasuhiko 30134638	The University of Tokyo, Institute for Nano Quantum Information Electronics, Director	Solid-state Quantum Electrodynamics in Quantum Dot-Nanocavity Multiply-Coupled Quantum Systems and Its Application to Novel Light Sources	FY2015-2019	399,500
15H05701	YAMADA Atsuo 30359690	The University of Tokyo, Graduate School of Engineering, Professor	Development of advanced energy storage system based on overall strategies on new materials and new interface	FY2015-2019	437,100
15H05702	ONO Teruo 90296749	Kyoto University, Institute for Chemical Research, Professor	Spin-orbitronics and device application	FY2015-2019	432,500

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
16H06284	KATORI Hidetoshi 30233836	The University of Tokyo, Graduate School of Engineering, Professor	Investigation of novel engineering and scientific applications of ultra-precise optical lattice clocks	FY2016-2020	452,600
16H06285	HIROSE Kei 50270921	The University of Tokyo, Graduate School of Science, Professor	Behaviour of liquids under high pressure and the early evolution of the Earth	FY2016-2020	387,500
16H06286	SHIOKAWA Kazuo 80226092	Nagoya University, Institute for Space-Earth Environmental Research, Professor	Study of dynamical variation of particles and waves in the inner magnetosphere using ground-based network observations	FY2016-2020	376,100
16H06287	SUMI Takahiro 30432214	Osaka University, Graduate School of Science, Professor	Search for cold exoplanets and free-floating planets by near infrared gravitational microlensing observation	FY2016-2020	450,400
16H06288	KOBAYASHI Takashi 70291317	High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Professor	Measurement of CP symmetry of neutrino by upgrading T2K experiment	FY2016-2020	418,600
16H06289	OHMORI Kenji 10241580	National Institutes of Natural Sciences, Institute for Molecular Science, Professor	Addressing Quantum Many-Body Dynamics by Ultrafast Coherent Control with Attosecond Precision	FY2016-2020	426,400
16H06290	ITO Yukishige 80168385	RIKEN, Synthetic Cellular Chemistry Laboratory, Chief Scientist	Chemical Biology of ER Related Glycan Modifications	FY2016-2020	319,400
16H06291	OKI Taikan 50221148	The University of Tokyo, Institute of Industrial Science, Professor	New frontiers in global hydrology	FY2016-2020	340,700
16H06292	ASADA Masahiro 30167887	Tokyo Institute of Technology, Institute of Innovative Research, Professor	High-performance semiconductor terahertz devices unifying quantum transition and traveling of electrons	FY2016-2020	413,700
16H06293	ISHIHARA Tatsumi 80184555	Kyushu University, Graduate School of Engineering, Professor	Creation of Novel High Performance Catalyst Tailored by Chemo-mechanical Effects	FY2016-2020	380,700
17H06087	WATANABE Naoki 50271531	Hokkaido University, Institute of Low Temperature Science, Professor	Chemical evolution on cosmic dust: approach from elementary processes	FY2017-2021	433,900
17H06088	SHIGEKAWA Hidemi 20134489	University of Tsukuba, Faculty of Pure and Applied Sciences, Professor	Development of sub-cycle time-resolved STM and its applications	FY2017-2021	453,600
17H06089	FUJISAWA Akihide 60222262	Kyushu University, Research Institute for Applied Mechanics, Professor	Plasma Turbulence Observation System (PLATOS) for puzzling out the principles of structural formation and functional expression in turbulent plasmas	FY2017-2021	448,600
17H06090	WADA Michiharu 50240560	High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Professor	Study of the origin of heavy elements using an innovative mass spectrograph	FY2017-2021	427,100
17H06091	CHATANI Naoto 30171953	Osaka University, Graduate School of Engineering, Professor	Development of Next-Generation Transformation Involving Molecular Activation as a Key Step	FY2017-2021	427,300
17H06092	MIURA Masahiro 20183626	Osaka University, Graduate School of Engineering, Professor	Revolution of Synthetic Technologies by Deeping C-H Activation Chemistry	FY2017-2021	388,800
17H06094	IKUHARA Yuichi 70192474	The University of Tokyo, School of Engineering, Professor	Atom-by-atom imaging of ion dynamics in nano-structures for materials innovation	FY2017-2021	454,000
18H05205	MISAWA Hiroaki 30253230	Hokkaido University, Research Institute for Electronic Science, Professor	Development and elucidation of highly efficient photoreaction systems using a strong coupling between nanocavity and plasmon	FY2018-2022	477,700

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
18H05206	YOSHIDA Shigeru 00272518	Chiba University, Graduate School of Science, Professor	High Energy Neutrino Universe explored by IceCube-Gen2	FY2018-2022	411,400
18H05207	FURUSAWA Akira 90332569	The University of Tokyo, Graduate School of Engineering, Professor	Study on time-domain-multiplexed 2D continuous-variable cluster states and its application to large-scale quantum information processing	FY2018-2022	489,200
18H05208	KOSHIHARA Shinya 10192056	Tokyo Institute of Technology, School of Science, Professor	Development of novel photo-induced phase conversion materials based on quantum dynamics control of Charge-Structure-Spin-Photon coupled systems	FY2018-2022	484,700
18H05209	YASHIMA Eiji 50191101	Nagoya University, Graduate School of Engineering, Professor	Development of Ultimate Functions Based on Helical Polymers with Helicity Memory	FY2018-2022	457,300
18H05210	NAKAMURA Mitsuhiro 90183889	Nagoya University, Institute of Materials and Systems for Sustainability, Professor	Nuclear Emulsion – New deployments for fundamental and interdisciplinary researches in the 21st century –	FY2018-2022	455,400
18H05211	FUJIMAKI Akira 20183931	Nagoya University, Graduate School of Engineering, Professor	Research on ultra-low power sub-terahertz superconducting quantum digital systems based on pulse-driven circuits	FY2018-2022	473,400
18H05212	FUJIWARA Yasufumi 10181421	Osaka University, Graduate School of Engineering, Professor	Development of semiconductor intra-center photonics	FY2018-2022	490,300

Biological Sciences（13 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05703	TAKAYANAGI Hiroshi 20334229	The University of Tokyo, Graduate School of Medicine, Professor	Promotion of osteoimmunology for understanding the new regulatory systems of vertebrate	FY2015-2019	398,300
15H05704	AKIRA Shizuo 50192919	Osaka University, Immunology Frontier Research Center, Specially Appointed Professor	Comprehensive analysis of innate immunity	FY2015-2019	433,800
15H05705	ENDO Toshiya 70152014	Kyoto Sangyo University, Faculty of Life Sciences, Professor	Elucidation of the integrated cellular network for mitochondrial biogenesis	FY2015-2019	349,300
16H06294	NUREKI Osamu 10272460	The University of Tokyo, Graduate School of Science, Professor	Molecular mechanism of membrane proteins regulated by physical stimuli	FY2016-2020	433,300
16H06295	SAKAGUCHI Shimon 30280770	Osaka University, Immunology Frontier Research Center, Specially Appointed Professor	Study of the function and development of regulatory T cells	FY2016-2020	411,500
16H06296	Jian Feng Ma 80260389	Okayama University, Institute of Plant Science and Resources, Professor	Integrated analysis of mineral transport system in crops	FY2016-2020	412,500
17H06095	YANAGISAWA Masashi 20202369	University of Tsukuba, International Institute for Integrative Sleep Medicine, Director and Professor	Elucidation of sleep/wakefulness regulation using forward genetic approach	FY2017-2021	423,000
17H06096	FUKADA Yoshitaka 80165258	The University of Tokyo, Graduate School of Science, Professor	Molecular dissection of robust and flexible circadian clock and its control of animal physiology	FY2017-2021	435,800
17H06097	SHIMADA Ichio 70196476	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	In situ functional analyses of membrane proteins by NMR	FY2017-2021	354,100

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
17H06098	SAITOU Mitinori 80373306	Kyoto University, Graduate School of Medicine, Professor	Mechanism and Reconstitution In Vitro of Human Germ Cell Development	FY2017-2021	435,300
18H05213	INOKUCHI Kaoru 20318827	University of Toyama, Graduate School of Medicine and Pharmaceutical Sciences, Professor	Mechanisms underlying Information processing in idling brain	FY2018-2022	427,200
18H05214	SASAKI Hiroyuki 30183825	Kyushu University, Medical Institute of Bioregulation, Professor	Omics approaches towards the elucidation of the molecular network regulating the developmental capacity of the mammalian oocyte	FY2018-2022	391,200
18H05215	NAKAYAMA Keiichi 80291508	Kyushu University, Medical Institute of Bioregulation, Distinguished Professor	Investigation for mechanisms underlying cell cycle regulation and metabolism in stem cells	FY2018-2022	394,400

Grant-in-Aid for Scientific Research on Innovative Areas
(Research in a proposed research area)

☐ Distribution by Research Area of the Newly Adopted Projects

Purpose and Description of Grant-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area) (excerpt from the "Application Procedures for Grants-in-Aid for Scientific Research"):

1) **Purpose**:
Research aimed at developing a new research area proposed by a researcher or a researcher group that can lead to improvement or strengthening of the scientific level of Japan, through efforts such promotion of joint research and cultivation of research personnel and joint use of facilities.

2) **Total budget provided**:
The budget provided per research area is set at around 10 to 300 million yen per fiscal year

3) **Research period**:
5 years (application for research period other than the left is not subject to screening)

4) **Number of research projects scheduled to be selected**:
Around 10 (subject to strict selection)

【 New Projects】

	Number of Applications			Total Grant Disbursements※ (FY2019)	Per-project Grants※ (FY2019)	
	Received	Adopted	Ratio		Average	Largest
			(%)	(Thousands of yen)	(Thousands of yen)	(Thousands of yen)
Humanities and Social Sciences	9	1	11.1	222,200	222,200	222,200
Science and Engineering	69	7	10.1	1,656,100	236,586	257,700
Biological Sciences	42	4	9.5	893,800	223,450	237,100
Interdisciplinary Area	61	6	9.8	1,328,900	221,483	237,300
Total	181	18	9.9	4,101,000	227,833	257,700

※ Direct expense only

【 New and Ongoing Projects】

	Number of Applications
Humanities and Social Sciences	7
Science and Engineering	36
Biological Sciences	24
Interdisciplinary Area	30
Total	97

List of the Newly Adopted Projects for Grant-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area) of KAKENHI, FY2019

（1）Humanities and Social Sciences（1 Project）

(Thousands of Yen)

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05731	MATSUMOTO Naoko 30314660	Okayama University, Graduate School of Humanities and Social Sciences, Professor	Integrative Human Historical Science of “Out of Eurasia”: Exploring the Mechanisms of the Development of Civilization	FY2019-2023	222,200	1,069,000

（2）Science and Engineering（7 Projects）

(Thousands of Yen)

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05822	SHIBAUCHI Takasada 00251356	The University of Tokyo, Graduate School of Frontier Sciences, Professor	Physical Properties of Quantum Liquid Crystals	FY2019-2023	257,700	1,134,000
19H05695	NONAKA Masami 90358771	Japan Agency for Marine-Earth Science and Technology, Application Laboratory, Group leader	Mid-latitude ocean-atmosphere interaction hotspots under the changing climate	FY2019-2023	231,900	1,138,000
19H05785	MATSUNAGA Katsuyuki 20334310	Nagoya University, Graduate School of Engineering, Professor	New Materials Science on Nanoscale Structures and Functions of Crystal Defect Cores	FY2019-2023	234,200	1,098,000
19H05714	KATO Takashi 70214377	The University of Tokyo, Graduate School of Engineering, Professor	Aquatic Functional Materials: Creation of New Materials Science for Environment-Friendly and Active Functions	FY2019-2023	237,200	1,185,200
19H05802	INOUE Kunio 10242166	Tohoku University, Research Center for Neutrino Science, Professor	Unraveling the History of the Universe and Matter Evolution with Underground Physics	FY2019-2023	237,300	1,129,500
19H05817	TAMURA Ryuji 50307708	Tokyo University of Science, Department of Materials Science and Technology, Professor	Hypermaterials: Innovation of materials science in hyper space	FY2019-2023	238,500	791,200
19H05812	IRIYAMA Yasutoshi 30335195	Nagoya University, Graduate School of Engineering, Professor	Science on Interfacial Ion Dynamics for Solid State Ionics Devices	FY2019-2023	219,300	1,127,800

（3）Biological Sciences（4 Projects）

(Thousands of Yen)

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05705	KOMATSU Masaaki 90356254	Juntendo University, Graduate School of Medicine, Professor	Multimode autophagy: Diverse pathways and selectivity	FY2019-2023	191,500 / 1,199,600
19H05749	OGURA Atsuo 20194524	RIKEN, BioResource Research Center, Division Head	Program of totipotency: From decoding to designing	FY2019-2023	228,100 / 1,139,100
19H05739	NAKANISHI Makoto 40217774	The University of Tokyo, Institute of Medical Science, Professor	Mechanisms underlying replication of non-genomic codes that mediate plasticity and robustness for cellular inheritance	FY2019-2023	237,100 / 1,168,000
19H05670	NAKAJIMA Keiji 80273853	Nara Institute of Science and Technology, Graduate School of Science and Technology, Professor	Intrinsic periodicity of cellular systems and its modulation as the driving force behind plant development	FY2019-2023	237,100 / 1,159,900

（4）Interdisciplinary Area（6 Projects）

(Thousands of Yen)

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05776	IWATA So 60452330	Kyoto University, Graduate School of Medicine, Professor	Non-equilibrium-state molecular movies and their applications	FY2019-2023	218,100 / 1,064,000
19H05722	OTA Jun 50233127	The University of Tokyo, School of Engineering, Research into Artifacts, Center for Engineering (RACE), Professor	Hyper-adaptability for overcoming body-brain dysfunction: Integrated empirical and system theoretical approaches	FY2019-2023	237,100 / 1,165,800
19H05760	TSUMOTO Kouhei 90271866	The University of Tokyo, School of Engineering, Professor	Integrated Biometal Science: Research to Explore Dynamics of Metals in Cellular System	FY2019-2023	236,800 / 1,166,600
19H05794	OKADA Yasushi 50272430	The University of Tokyo, Graduate School of Science, Professor	Information physics of living matters	FY2019-2023	237,300 / 1,150,100
19H05690	ISHIGURO Hiroshi 10232282	Department of Systems Innovation, Osaka University, Professor	Studies on intelligent systems for dialogue toward the human-machine symbiotic society	FY2019-2023	162,500 / 1,088,500
19H05679	TAKAYA Naoki 50282322	University of Tsukuba, Faculty of Life and Environmental Sciences, Professor	Post-Koch Ecology: The next-era microbial ecology that elucidates the super-terrestrial organism system	FY2019-2023	237,100 / 1,154,300

Title of Project：Integrative Human Historical Science of "Out of Eurasia": Exploring the Mechanisms of the Development of Civilization

MATSUMOTO Naoko
(Okayama University, Graduate School of Humanities and Social Sciences, Professor)

Research Project Number：19H05731　Researcher Number：30314660

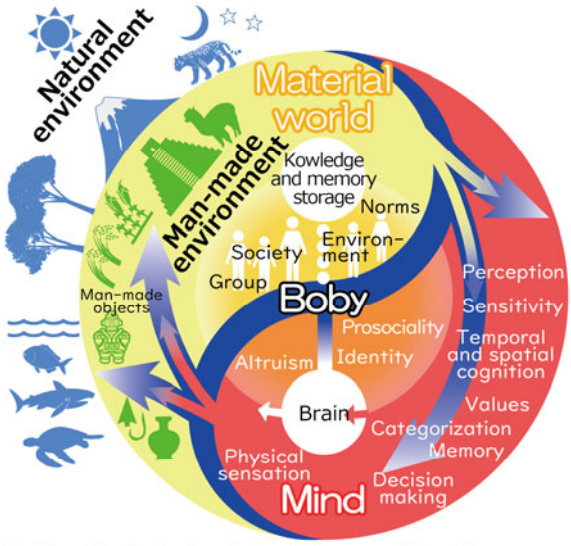
【Purpose of the Research Project】

It was in the period of the development of civilization that the specific characteristics which greatly separate human from other animal behaviors, such as a large-scale and complex social structure, a high level of scientific technology, and a variety of religious beliefs including massive world religions, made their appearance. The developmental period of civilization may be assessed as the time when the nomadic hunting-and-gathering lifestyle, which had continued through 2 million years of evolution of the genus *Homo*, made a massive change in direction. Accordingly, in order to understand how mankind has reached its present state, it is necessary to clarify how the formation and development of civilization occurred.

In this regard, the current research area focuses on the human being itself which links nature and culture, mind and matter, and on human action and cognition, and advances an unprecedented theory of the development of civilization. Based on the three vantage points of the material realm physically produced by humans, the human body, and the mind which lies at the nucleus of the interaction of these two and produces culture, and focusing on the material culture of the period of the development of civilization, we construct an integrative history of humankind that will clarify how the specifically human niche construction has been formed.

【Content of the Research Project】

We place a model of the mutual permeation of matter and mind as mediated by the body as the basis of our research strategy. Based on this model, as a theoretical framework for considering temporal change, we adopt the theory of niche construction which holds that organisms change their environments on their own, and such changes influence the evolution of succeeding generations. The Americas, the Japanese archipelago, and Oceania, the regions of final destination for *Homo sapiens* who left Eurasia and dispersed by overcoming bottlenecks and extreme conditions, are strategically selected as research objects. We will systematically compare the unique developments of civilization under different circumstances in a transdisciplinary framework including archaeology, bioarchaeology, anthropology, cognitive science, brain and neuroscience, social psychology and molecular anthropology. The results will be integrated and shared for discussion, mathematical analysis and modelling.



Mediated by the body, mind and the material world permeate one another. Through the process of mutual creation between humans and the material world, the body also changes.

【Expected Research Achievements and Scientific Significance】

Establishing a new research field of Integrative Human Historical Science is the core accomplishment that can be anticipated. More specifically, the actual state of affairs concerning how culture as a system of knowledge surpassing the abilities of individuals as biological creatures came to be formed, will be made clear for various places in the Japanese archipelago, Mesoamerica, the Andes, and Oceania. Thus the historical process by which unique social realities are formed will be clarified, providing new understandings of man and culture.

As a ripple effect of this research, as the peculiarities of modern warfare and international relationships are thrown into relief, new insights for relieving social stress and violent behaviors, and the formation of a sustainable society will be obtained. A basis can be obtained for considering, as globalization progresses, how the body and culture will change, and the significance of maintaining diversity.

【Key Words】

Niche construction: The process by which an organism alters its own local environment through actions and selections.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,069,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://out-of-eurasia.jp
contact@out-of-eurasia.jp

Title of Project：Physical Properties of Quantum Liquid Crystals

SHIBAUCHI Takasada
(The University of Tokyo, Graduate School of Frontier Sciences, Professor)

Research Project Number：19H05822　Researcher Number：00251356

【Purpose of the Research Project】

In rod- or disk-shaped molecular systems, a state called "liquid crystal" appears in addition to the three states of matter; gas, liquid, and solid. Recently, electronic states that have similarities to liquid crystals have been observed in a variety of solid materials. These electronic states have been studied independently in the fields of quantum spins, strongly-correlated metals, and superconductivity, but here we define these states respectively as "spin liquid crystals", "charge liquid crystals" and "pair liquid crystals". In this innovative area research, we introduce a new concept "quantum liquid crystals" (QLCs) to unify these novel electronic states.

Within this, we will promote new collaborations between researchers from different fields, to clarify and control the physical properties of QLCs. We aim to understand the ground states of different QLCs; to establish the universal features common to all QLCs; and to understand the diversity of phenomena seen in experiment. In addition, by using state-of-the-art technologies, we will elucidate and control the elementary excitations of QLCs. This will lay the foundation for future QLC-based technologies exploiting the flexible characteristics of liquid crystals, and the large and fast responses of quantum systems.

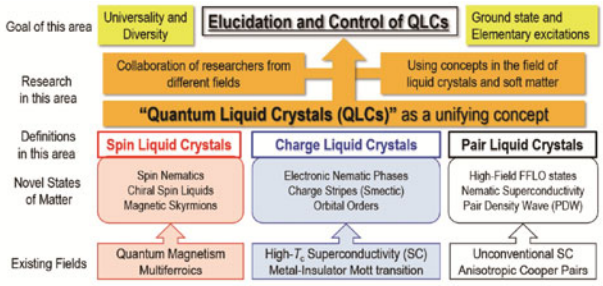


Figure1. Outline of the research project

【Content of the Research Project】

Within this innovative research area, we have identified four different themes, based on methodology, which will be used to promote new collaborations.

-A01: Development of QLC materials

To develop and characterize new materials in which novel QLC states emerge, using a broad range of established and original synthesis techniques.

-B01: Advanced measurements of QLCs

To elucidate QLC electronic states in experiment, by using a combination of established high-precision measurement techniques and through the development of new techniques, in combination with different technologies.

-C01: Theory of QLCs

To describe the order parameters of QLCs and effects of their quantum fluctuations, as well as to design QLC materials and their functionality.

-D01: Control and functionality of QLCs

To control QLC states and search for useful QLC functions, by utilizing micromachining-based nanoscience and ultrafast optics.

Research in this area will be interdisciplinary, and aims to establish the basics of new quantum technologies.

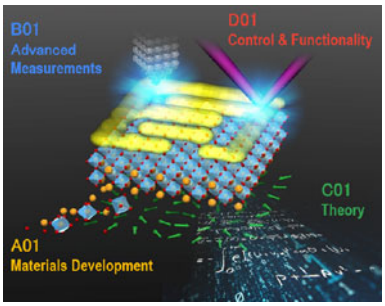


Figure2. Four themes to study QLCs

【Expected Research Achievements and Scientific Significance】

The advances in the field of "liquid crystals and soft matter" beyond the three states of matter have successfully led to many technological applications. Our QLC area can be considered as its quantum version, which can potentially generate novel phenomena and concepts. It will also pave a pathway to new QLC technology that has some useful functions in the quantum information.

【Key Words】

Quantum liquid crystals (QLCs): New electronic states similar to liquid crystals emerging from quantum effects. In liquid crystals molecules have anisotropy, but in QLCs quantum-mechanical degrees of freedom lead to anisotropic states with peculiar physical properties.

【Term of Project】 FY2019-2023

【Budget Allocation】 1,134,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://qlc.jp
office@qlc.jp

Title of Project：Mid-latitude ocean-atmosphere interaction hotspots under the changing climate

NONAKA Masami
(Japan Agency for Marine-Earth Science and Technology, Application Laboratory, Group leader)

Research Project Number：19H05695　Researcher Number：90358771

【Purpose of the Research Project】

Frequency of extreme rainfalls and snowfalls has been increasing these years, and those events severely affect human lives and properties.

It has been considered that tropical ocean and atmosphere variability such as El Niño, as well as the warming climate, remotely influences mid-latitude extreme weather/climate, while the mid-latitude ocean is passive to atmospheric variability. Current operational seasonal climate predictions are conducted based on this climate "assumption."

Recent high-resolution ocean/atmospheric data analyses, however, have revealed that mid-latitude ocean also influences atmospheric circulations and their variability. Rediscovering strong warm current (e.g., the Kuroshio and the Gulf Stream) and associated strong ocean frontal zones as "*climate hotspot*", we have elucidated mechanisms of ocean-atmosphere interactions and established a new paradigm of active roles of mid-latitude oceans in the climate system, replacing the conventional "assumption."

The research progress has prompted a new crucial task: application of such new knowledge to predictions of extreme rainfalls/snowfalls and climate variability. In the present project, I) we will further our understandings of mid-latitude ocean-atmosphere interaction processes that span multiple spatio-temporal scales and interplay among them through tight collaborations of latest observational and numerical modeling tools. Also, based on the improved understandings, II) we investigate predictability of extreme weather (such as typhoons and bomb cyclones), of persistent atmospheric circulation anomalies that induce those extremes, projection of climate changes, and active roles of mid-latitude oceans in those phenomena. The purposes of the present project are then deepening of the previously established paradigm and showing its scientific and societal importance and validity.

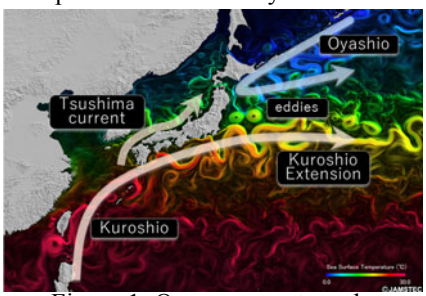


Figure 1. Ocean currents and temperature around Japan

【Content of the Research Project】

For I), we conduct an intensive observational campaign of both atmosphere and ocean in the Tsushima warm current region located upwind of Japan with directly impacts on its climate, utilizing state-of-the-art observational equipment. We further expand our understanding of ocean-atmosphere interactions with their linkage to atmospheric substances through investigations of impacts of heat and aerosols exchanges between ocean and atmosphere on low-level clouds and marine ecosystems.

For II), our studies will extend to evaluations of potential improvements of prediction and/or uncertainty of disaster inducing atmospheric circulation anomalies and extreme rainfall/snowfall, by considering active influences from mid-latitude oceans. Also, we will try to obtain general understandings of roles of *climate hotspot* under the changing climate and its impacts on uncertainty of climate change projection.

【Expected Research Achievements and Scientific Significance】

Three achievements are expected: 1. Further deepening of our understandings of multi-scale ocean-atmosphere interactions and their mechanisms. 2. Evaluations of possible contributions of ocean-atmosphere interactions in *climate hotspot* and especially ocean's active roles onto improvements of predictability of extreme rainfall/snowfall, extreme weather events such as typhoon and bomb cyclones, and persistent atmospheric circulation anomalies associated with extreme climate. Also, estimations of predictability of ocean currents and eddies, which induce ocean temperature variability. 3. Basic and general knowledge on overlooked roles of mid-latitude air-sea interactions for the warming climate. This will make the first estimation of uncertainty of climate change projection caused by mid-latitude ocean-atmosphere interactions in climate projection models. Through these developments in the fields of *predictability* and *global warming*, wide societal impacts are expected from the present project.

【Key Words】

mid-latitude air-sea interactions (ocean and atmospheric affect each other to induce their structure and variability)
extreme weather/climate (unusual state such as extreme rainfalls and snowfalls with several days scale, and such as cool summer and warm winter with seasonal scale)

【Term of Project】

FY2019-2023

【Budget Allocation】

1,138,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.jamstec.go.jp/apl/hotspot2/
nona@jamstec.go.jp

Title of Project：New Materials Science on Nanoscale Structures and Functions of Crystal Defect Cores

MATSUNAGA Katsuyuki
(Nagoya University, Graduate School of Engineering, Professor)

Research Project Number：19H05785　Researcher Number：20334310

【Purpose of the Research Project】

In this project, specific electronic and atomic structures of grain boundaries, interfaces and dislocations that can realize novel and distinct materials properties are defined and referred to as “crystal defect cores”. Researchers specializing in theoretical calculations, nanoscale characterization and advanced materials processing conduct collaborative studies, aiming at creating a new area in materials science named “crystal defect core”. Through establishing new scientific principles based on the concepts of “crystal defect core”, we will further explore novel properties and materials due to crystal defects.

Conventional studies have focused on average bulk structures and macroscopic properties of materials in general, and thus understanding of crystal defects is often limited to their static and averaged atomic pictures. Recent technological progresses in methods and approaches of nanoscale characterization and computational science are so remarkable that we have been enabled to acquire quantitative information on nanoscale structures of crystal defects. These advanced approaches and methods have facilitated our more in-depth understanding about the crucial roles that the crystal defects play for realizing various materials properties. For future materials design and development, it is essential to reveal relationships between nanoscale structures of crystal defects and materials properties. Thus, in this project, we aim at discovering or creating new materials functions and new exploratory materials based on “crystal defect cores”, including those emerging under external stimulus including thermal, electric, magnetic, optical or stress fields.

【Content of the Research Project】

This research project has three major Research items as follows:

A01: Modeling and design of crystal defect cores
A02: Nanoscale characterization of crystal defect cores
A03: Materials development based on crystal defect cores

In Research items A01 and A02, we focus on basic science of crystal defects. We do collaborative and systematic researches of grain boundaries, interfaces and dislocations so as to establish new scientific principles based on in-depth understanding of a structure-property relationship of the crystal defects, by means of theoretical calculations, materials informatics and nanoscale characterization at the world-class highest level. Researches in the Research item A03 of materials processing come from diverse materials fields, and try to develop novel materials and their properties by controlling crystal defects at the nanometer scale. Throughout the research area, it is expected for our intensive and extensive collaborations to prove that “crystal defect core” is a universal concept to realize novel materials development in the next generation.

【Expected Research Achievements and Scientific Significance】

■ To establish new scientific principles to make it possible to explore novel and distinct materials properties originating from crystal defects
■ To discover or create new materials with remarkable properties in diverse fields of materials science
■ To facilitate considerable technical development of theoretical calculations, nanoscale characterization, and materials processing.

Our concept of “crystal defect core” will provide a scientific impact when we succeed in developing materials and their properties through precisely controlling crystal defect cores. This is because crystal defects have been thought to play a negative role for materials properties. This research area can find out a new strategy for controlling crystal defect cores so that they play positive roles for better properties, paving a new avenue for future materials developments.

【Key Words】

Crystal defects: Irregular atomic arrangements in crystalline materials.
Crystal defect cores: Specific electronic and atomic structures that can realize novel and distinct materials properties

【Term of Project】 FY2019-2023

【Budget Allocation】 1,098,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.core.mp.pse.nagoya-u.ac.jp
kmatsunaga@nagoya-u.jp

Title of Project：Aquatic Functional Materials: Creation of New Materials Science for Environment-Friendly and Active Functions

KATO Takashi
(The University of Tokyo, Graduate School of Engineering, Professor)

Research Project Number：19H05714　Researcher Number：70214377

【Purpose of the Research Project】

In this project, Aquatic Functional Materials is defined as materials that harmonize and interact with environment and bio-systems in the existence of water. The objective of this project is to create and establish materials science on Aquatic Functional Materials and to develop innovative materials by fusion of materials science and basic science of water. Water is essential for the sustainable development of human civilization as described in the SDG6 of the United Nations. It is our emergent issues to develop Aquatic Functional Materials serving in a wide range of the fields including environment, energy, healthcare and agriculture.

【Content of the Research Project】

The specific feature of our project is to understand the interactions between water and materials in the level of molecules and molecular nano-assemblies based on fundamental science of structure-function relationship between water and materials for the creative development of Aquatic Functional Materials. We study on Aquatic Functional Materials from a wide range of standpoint of views including organic chemistry, polymer chemistry, experimental physics, computational science, and engineering.

As bio-system and global environment do not function without water, we focus on behavior of water as molecules for materials science. In this project, we define aquatic environments as living and industrial regions where water exists, and bio-system as well as hydrosphere because there are common features that interactions of water molecules with molecules and materials play key roles.

New principles of materials design are required to develop materials that exhibit high function in aquatic environments. We need to establish unified materials science based on understanding of structure-function relationship between water and substance. In conventional water science, structures and properties of water as single components have been mainly studied. In conventional materials science, for example, electronic materials and polymer materials to be used in non-aquatic circumstances have been intensively focused. It is our intention that we unify science of water and materials science together and further develop to establish science of Aquatic Functional Materials.

Figure 1. Fusion of sciences and engineering for the achievement of research in this project.

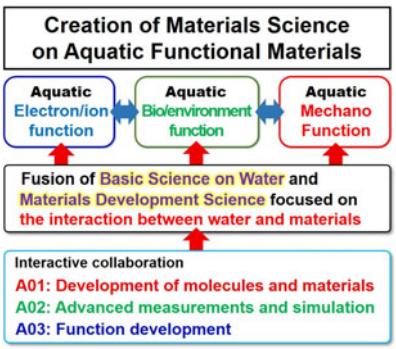


Figure 2. Scheme of research in this project.

【Expected Research Achievements and Scientific Significance】

1. Creative development of innovative materials that function in aquatic environments

The development of highly functional materials in the coexistence with water, which were not well studied, is expected. For example, we expect the fabrication of aquatic electron/ion functional materials

2. Creation of Science of Aquatic Functional Materials

New science that gives design principles for materials that exhibit high functions in aquatic environments will be established by fusion of basic science of water and materials science.

【Key Words】

Aquatic Functional Materials: In this project, materials that function in the living and industrial regions where water co-exists, and bio-system as well as hydro-regions of ocean and river of sphere are defined as Aquatic Functional Materials. It is because that when we examine behavior of water and interactions of water in molecular level, there are common issues in science.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,185,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.aquatic-functional-materials.org/
kato@chiral.t.u-tokyo.ac.jp

Title of Project：Unraveling the History of the Universe and Matter Evolution with Underground Physics

INOUE Kunio
(Tohoku University, Research Center for Neutrino Science, Professor)

Research Project Number：19H05802　Researcher Number：10242166

【Purpose of the Research Project】

We aim at unraveling the history of the universe and matter evolution to answer "How is matter created?", "How are galaxies/stars formed?", "How are elements created?" and "How do they end up with the earth?", by concentrating all efforts of underground astroparticle experiments covering neutrino-less double beta decay (0ν2β), dark matter (DM), supernova (SN) and geo-neutrino (ν). The vigorous cooperation at "Kamioka" will expands to world-wide, and newly involved subjects (low temp. sensors, nuclear matrix element, DM distribution, SN explosion and matter evolution theory) will further deepen each research field and enhance the synergy among them. It will sustain the competitiveness and superiority in the world and contribute to nurture young talents.

【Content of the Research Project】

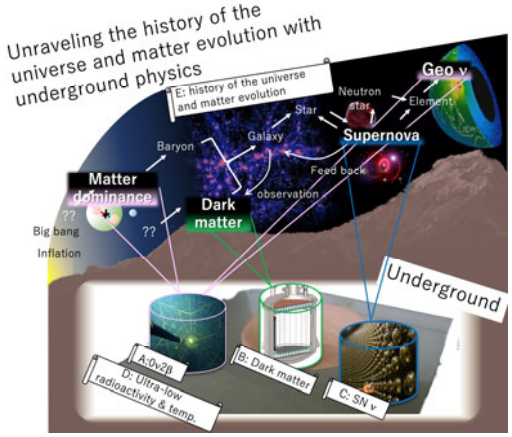


Figure1. Research projects and relevant subjects

KamLAND-Zen is leading the search for 0ν2β in the world. XENON has been leading the direct search of DM and is evolving to XENONnT. Super-Kamiokande has the world best sensitivity on SN-ν detection and is upgrading to SK-Gd. KamLAND is the pioneer of and leading geo-ν observation. We develop the cooperation among these top-runners and challenging projects for future on the common technologies. As challenging projects, a 0ν2β experiment involves isotopic enrichment and scintillating bolometer aiming at an ultimate sensitivity, and directional detection of DM develops under the world cooperation to overcome the limit of neutrino floor. The ultra-low radioactivity technology as the common base will pursue the world-best performance and raise the technological floor of the whole field sharing and internationalizing the low-BG database. We also incorporate low-temp. sensors as novel techniques to improve energy resolution and to achieve lower threshold for new science frontiers, and sustain the competitiveness. Moreover, we aim at a seamless connection of particle cosmology and matter evolution picture as a theoretical flamework that spans the history of the universe from the beginning to the present. It will largely enhance the synergy of research in this area and the connection to diverse fields.

【Expected Research Achievements and Scientific Significance】

We propel researches on the most important subjects in underground astroparticle physics, search for 0ν2β and direct detection of DM, and also SN relic ν and geo-ν detection those provide important information of matter evolution in the universe. These top-runners are closest to world's first big discoveries. Developing the common novel technologies and theoretical flamework of the whole history of the universe will inspire surrounding fields, therefore, this area continues to be a core of the field of underground astroparticle physics. The international cooperative environment we realize will largely contribute to nurture young active talents in the world.

【Key Words】

Underground astroparticle physics: experimental researches of rare phenomena connected with particle, nuclear, cosmological, astronomical and geo- science run at underground ultra-low radioactivity environment
Neutrino-less double beta decay (0ν2β): unique realistic phenomenon to verify the ν/anti-ν identity as a key to explain the matter dominance in the universe
Dark matter (DM): Yet undiscovered elementary particle indispensable for the structure formation of the universe, with the halo density around the earth at ~0.3GeV/cm^3
Supernova relic ν: ν cumulatively arriving from past SN explosions that provide information on star formation history, SN explosion mechanism and matter evolution

【Term of Project】

FY2019-2023

【Budget Allocation】

1,129,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.lowbg.org/ugap/
inoue@awa.tohoku.ac.jp

Title of Project：Hypermaterials: Innovation of materials science in hyper space

TAMURA Ryuji
(Tokyo University of Science, Department of Materials Science and Technology, Professor)

Research Project Number：19H05817　Researcher Number：50307708

【Purpose of the Research Project】

The discovery of quasicrystals, with high symmetry impossible for three-dimensional periodic crystals, has brought about a paradigm shift in crystallography and has overturned the definition of crystals that have been accepted for hundreds of years. The quasicrystal has a cross-sectional structure of a high-dimensional periodic crystal, and another extra space called "complementary space" is required to describe the atomic structure. This project aims at establishing a new concept of substances, "hypermaterial", which is a high-level concept that includes the existing concept for substances, and also at creating a new theory that incorporates the concept of hypermaterial.

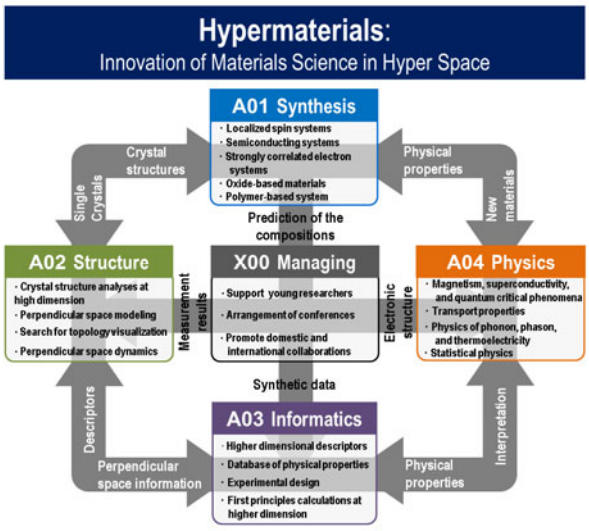
【Content of the Research Project】

In order to achieve the above purpose, this project will be conducted with four research groups (Figure).

[A01] Synthesis of Hypermaterials
[A02] Structure of Hypermaterials
[A03] Hypermaterials Informatics and the Search for Hidden Orders
[A04] Physics of Hypermaterials and the Search for Hidden Orders

The A01 group challenges to synthesize new metallic, semiconducting, ceramic, and polymer hypermaterials, partly based on the material compositions provided by the A03 group. In the A02 group, the static and dynamic structure of the newly synthesized hypermaterials are investigated by using X-ray, neutron beam, etc. In the A03 group, a database of hypermaterials is constructed, and the descriptors related to the stability of hypermaterials will be identified. Also, the descriptors related to the structure and physical properties of hypermaterials are searched in the real space as well as in the complementary space, and predictions of the compositions and physical properties of hypermaterials are performed. In the A04 group, the physical properties of the newly synthesized hypermaterials are measured, and the states of electrons, spins, phonons, etc. are investigated. Also, in cooperation with the A02 group, the physical quantities are mapped to the complementary space in order to elucidate the hidden orders, and their interpretation is performed.

Through active collaborative research among the four research groups, we will search for new physical properties and new phenomena, which cannot be obtained with conventional crystals, and will create new materials science based on the complementary space.



Organization of the Project

【Expected Research Achievements and Scientific Significance】

1. Hidden orders behind the complex behaviors of hypermaterials will be elucidated, and a new theory that incorporates the hidden orders will be developed.
2. The hypermaterial is a high-level concept of substances including existing periodic crystals, and this project will bring us a new material view, that is, leading us to view the structural information in the complementary space.
3. The world of hypermaterials will expand not only in metals, but also to semiconductors, ceramics, polymers.

【Key Words】

Hypermaterial: Abbreviation of "material" in "hyper space (high-dimensional space)". Quasicrystals and approximant crystals can be described as cross-sectional structures of high-dimensional periodic crystals. Hypermaterials refer to the substances described in a high-dimensional space in a unified way, and are characterized by having structural information not only in the real space but also in the "complementary space".

【Term of Project】FY2019-2023

【Budget Allocation】791,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.rs.tus.ac.jp/hypermaterials/html

Title of Project：Science on Interfacial Ion Dynamics for Solid State Ionics Devices

IRIYAMA Yasutoshi
(Nagoya University, Graduate School of Engineering, Professor)

Research Project Number：19H05812　Researcher Number：30335195

【Purpose of the Research Project】

Solid-solid interfaces generate entirely new functions different from the intrinsic nature of each solid material. In this project, unique interfacial ion dynamics around the hetero/homo interfaces of solid state ionics materials (SSIM) are systematically investigated so as to establish design principles for fast ion transport and concentrated ion storage around interfaces, that is, "*Interface Ionics*".

【Content of the Research Project】

There are two kinds of SSIM; i) insertion electrode material (electrode), where electrons or holes move faster than ions. ii) solid electrolyte, where ions moves faster than electrons or holes. When these two SSIMs are combined, an equilibrium state is formed through the rearrangement of all the charged carriers (electron, hole, and ion) and then their electrochemical potentials become equal. As a consequence, the electrode/solid electrolyte interface obtains different properties with each intrinsic SSIM due to space charge layer formation, mechanical relaxation (strain distribution), etc., which provide unique interfacial ion dynamics (Fig. 1). The aim of this project is to investigate these physical and chemical modulations around the interface in detail and establish the interface design principle which makes it possible to generate novel functions around the interfaces. This project integrates chemistry, physics, advanced measurement, theory and data science, and material science and consists of the four research groups (Fig. 2).

Gp-A01 fabricates model interfaces using single crystalline substrates, epitaxial thin films, etc. and investigates their interfacial ion dynamics. Gp-A02 analyzes modulation and distribution of voltage, ion concentration, chemical potential, local structure, etc. around the interface using advanced measurements. Gp-A03 clarifies ions and electrons distribution and their dynamics around the interface using multi-scale theoretical calculation and informatics analyses. Gp-A04 develops advanced materials especially focusing on metastable phases with lattice defects and lattice strains by combining crystalline and amorphous SSIMs.

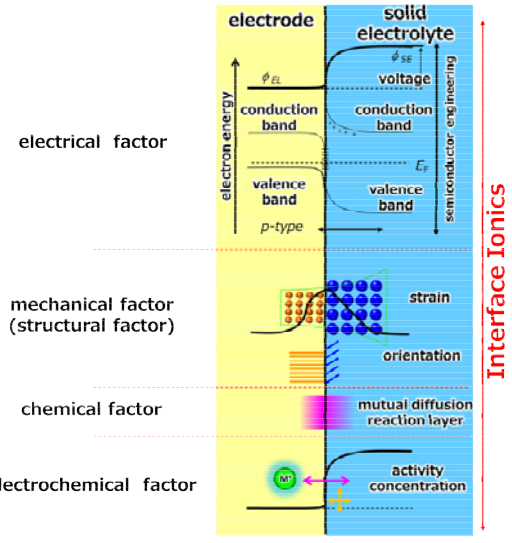


Fig.1 Schematic image of various factors affecting "*Interface Ionics*".

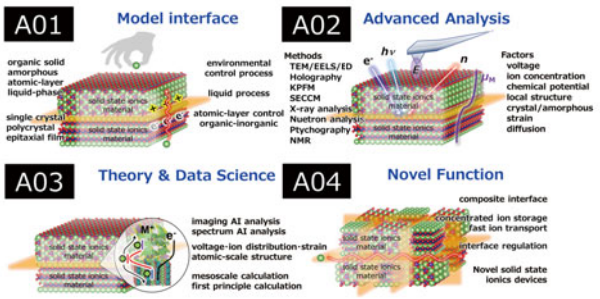


Fig. 2 Overview of research groups.

【Expected Research Achievements and Scientific Significance】

"Interface Ionics" clarifies design principle of interface in all-solid-state batteries where fast ion transport and concentrated ion storage is expected in the right space for high-rate charge-discharge reactions and high capacity electrode materials. Furthermore, those interfaces are effective to develop novel solid state ionics devices such as all-solid-state capacitor, superconductor, transistor, actuator, electret, et al.

【Key Words】

Solid State Ionics Devices; Advanced devices using SSIMs such as all-solid-state battery, all-solid-state capacitor, etc.
Interfacial Ion Dynamics; Unique ion dynamics generating around the hetero/homo interfaces of SSIMs.

【Term of Project】 FY2019-2023

【Budget Allocation】 1,127,800 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.interface-ionics.jp/

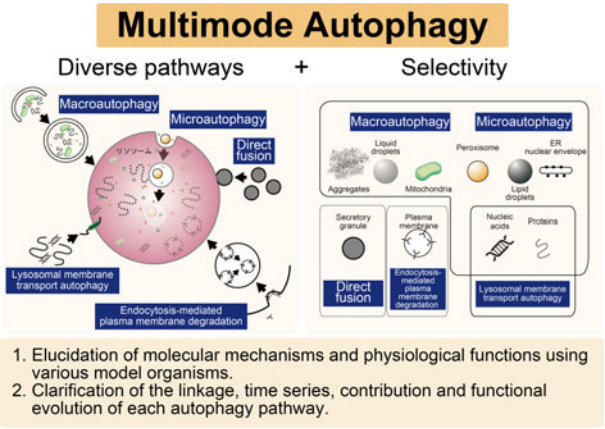
Title of Project：Multimode autophagy: Diverse pathways and selectivity

KOMATSU Masaaki
(Juntendo University, Graduate School of Medicine, Professor)

Research Project Number：19H05705　Researcher Number：90356254

【Purpose of the Research Project】

During the past two decades, studies on macroautophagy have explosively expanded from the molecular mechanism to disease states. However, autophagy research is not showing any signs of convergence; rather, new discoveries provide plenty of novel issues that should be resolved. In fact, although a large number of autophagy-related proteins have been identified and characterized so far, even the basic frame in which they operate for membrane biogenesis is not yet established. Furthermore, the existence of the mysteries beyond the conventional concept, that is, "diverse autophagy pathways" and "selectivity of autophagy" has become apparent. For an integrated understanding of these fundamental issues, it is essential to strategically promote high-quality autophagy research. In this project, various pathways of autophagy and their selective degradation mechanisms are integrated and defined as "multimode autophagy", and we will clarify their molecular mechanisms and physiological functions. Further, we aim to seek an understanding of the whole cellular self-degradation process by elucidation of the linkage, time series, contribution and functional evolution of each autophagy pathway (Figure). In addition, we will establish a working platform that can efficiently promote autophagy research by interdisciplinary fusion, training of young researchers and international activities.



【Content of the Research Project】

Group members are going to advance studies on diverse autophagy pathways such as macroautophagy, microautophagy, lysosomal membrane transport autophagy, endocytosis-mediated plasma membrane degradation and on their selective degradation using various model organisms. In addition, members who are experts for X-ray crystal structural analysis, three-dimensional electron microscopy, and omics analyses, elucidate the mechanism at the atomic level, visualize membrane dynamics, identify specific substrates, profile gene expression and metabolic variation and determine composition of membranes.

We are going to establish a website for "Multimode autophagy" and an “Autophagy web forum” to clarify the purpose of this research project and to announce research results, respectively. In order to foster joint research with researchers from public offering and new different fields, we will disclose the unresolved issues of multimode autophagy in the website and problems that are difficult to solve by the current members alone. Besides, we will hold group meetings in conjunction with open domestic autophagy conferences every year.

【Expected Research Achievements and Scientific Significance】

We will elucidate the complex and diverse mechanisms of membrane dynamics of multimode autophagy, and the overall picture of self-degradation. From the former, we will be able to propose a new basic axis of membrane dynamics in cell biology that has never been achieved, and from the latter, we will understand the entire intracellular degradation process combined with the ubiquitin-proteasome and other degradation systems.

【Key Words】

Multimode autophagy: Integration between diverse pathways of autophagy and their selectivity.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,199,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://proteolysis.jp/multimode_autophagy/
mkomatsu@juntendo.ac.jp

Biological Sciences

Title of Project：Program of totipotency: From decoding to designing

OGURA Atsuo
(RIKEN, BioResource Research Center, Division Head)

Research Project Number：19H05749　Researcher Number：20194524

【Purpose of the Research Project】

The genomes of terminally differentiated germ cells, spermatozoa and oocytes, acquire totipotency following genomic reprogramming at fertilization. This genomic reprogramming is the most large-scale one among those during the germline cycle. Totipotency is the most undifferentiated genomic status and the ability to contribute all the tissues and cells that constitute the body of newborns as well as the products during development such as placentas (**Fig. 1**). We aim to understand the mechanisms that ensure totipotency and to regulate and construct totipotency. Through these activities, in combination with cutting-edge analytical tools and unique reproductive engineering technologies, we will establish a new research core for totipotency study.

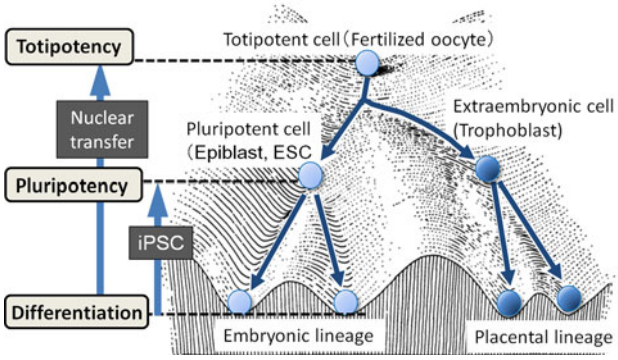


Fig. 1. Totipotency of mammalian development. The totipotent cell (fertilized oocyte) can contribute to both the embryonic and extraembryonic (placental) lineages. The pluripotent cells such as ESCs and iPSCs are at the early differentiating state, being exclusively destined to the embryonic lineage.

【Content of the Research Project】

Although more than 100 years have passed since the concept of "totipotency" was proposed, its underlying molecular mechanisms are unclear. Totipotency can be considered to be a feature in which multi-scale and multi-factor relationships are complicatedly involved. Therefore, for understanding the nature of totipotency, it may be the best way to identify the conditions or factors that are indispensable for the maintenance of totipotency. Our project consists of two research items; i.e., A01 "Decoding of the totipotent program" and A02 "Regulation and construction of totipotency" (**Fig. 2**). A01 aims to identify the basic mechanisms of totipotency including the genomic status, gene expressions, maternal factors, embryonic factors, and nuclear structure, which ensure the perfect developmental ability of fertilized oocytes. The time-dependent changes of these factors are also analyzed. A02 aims to verify the achievements of A01 by regulating or reconstructing the totipotent status or totipotent cells in vitro. To this end, we will maximize synergistic effects of our expertise through active intra-project collaborations.

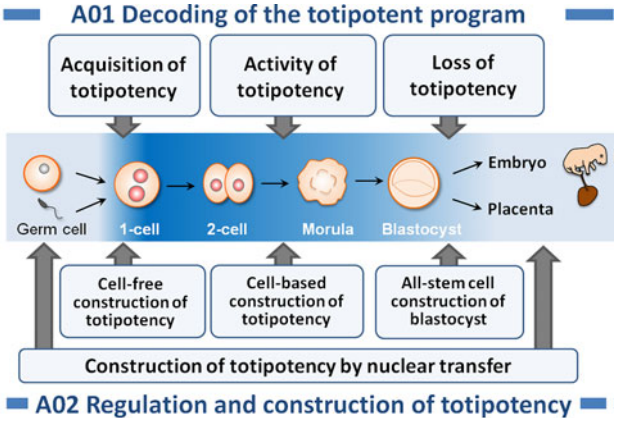


Fig. 2. Research subjects of our project. It consists of 2 items (A01 and A02), which are each divided into three subjects according to the developmental time course.

【Expected Research Achievements and Scientific Significance】

As there may be some common mechanisms exist in the totipotent state of different species, our achievements would contribute, at least partially, to better understanding of the principal molecular basis of totipotency. Moreover, through regulation of totipotency, a wide variety of applications could become practical; e.g., development of new reproductive engineering technologies will promote stock breeding, pharmaceutical industry, generation of primate models for human diseases, and conservation of endangered species. Our research achievements would also contribute to development of more effective assisted reproductive technology in humans.

【Key Words】

Totipotency: The genomic status of a cell that can contribute to the entire tissue/cells of newborns including appendix products such as the placenta.

【Term of Project】 FY2019-2023

【Budget Allocation】 1,139,100 Thousand Yen

【Homepage Address and Other Contact Information】

https://totipotency.biken.osaka-u.ac.jp

Title of Project：Mechanisms underlying replication of non-genomic codes that mediate plasticity and robustness for cellular inheritance

NAKANISHI Makoto
(The University of Tokyo, Institute of Medical Science, Professor)

Research Project Number：19H05739　Researcher Number：40217774

【Purpose of the Research Project】

Multicellular organisms consists of cells with diverse phenotypes even though their genomic information is essentially the same. The diversity of these cells is defined by non-genomic codes. Non-genomic information is coded by multi-layered mechanisms, such as DNA and histone modifications, non-coding RNA, higher ordered chromatin structures and transcription factor networks as well as the interconnections of these layers. Recent advances in understanding DNA replication and repair systems have made great contributions to the progression of many biological fields. In contrast, mechanisms underlying replication of non-genomic codes during cellular replication are largely unknown. In this research project, we focus on the elucidation of the mechanisms underlying replication of non-genomic codes such as DNA methylation and histone modifications during mitotic and meiotic cell cycle. We are also interested in the interconnections of multi-layered non-genomic mechanisms and biological processes regulated by these mechanisms such as cellular differentiation (Fig. 1).

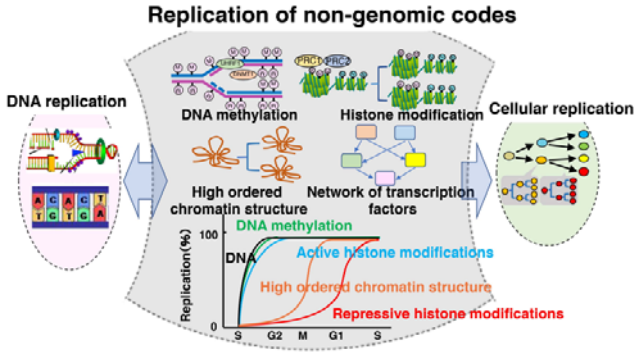


Fig. 1 Scheme of cellular replication regulated by DNA replication and replication of non-genomic codes

【Content of the Research Project】

In order to understand the mechanisms underlying replication of non-genomic codes comprehensively and systematically, the project focuses on two subjects (A01: Basic molecular mechanisms underlying replication of non-genomic codes and A02: Regulatory mechanisms of cellular function by replication of non-genomic codes). The main theme of A01 is to understand the replication mechanisms of non-genomic codes, such as DNA methylation, histone modifications, non-coding RNA, high ordered chromatin structures, and transcriptional networks. The structural analyses of the replication machineries are involved in this subject. The development of highly sensitive analytical methods, such as single cell analysis and single molecule analysis of non-genomic codes, are also involved.

In A02 subject, we aim to uncover the molecular basis of how replication mechanisms of non-genomic codes regulate plasticity and robustness of differentiated cells in multicellular organisms. These mechanisms should include stem cell renewal, maintenance of stemness, and cellular differentiation during symmetric and asymmetric divisions. By the use of mathematical and simulation analyses, the development of the methods to be able to consolidate big data from multiple layers into a single data store is also involved in this subject.

【Expected Research Achievements and Scientific Significance】

The diversity of cells in multicellular organisms is defined by non-genomic codes. The differentiated cells possess their specific non-genomic code patterns to maintain their specific cellular function. Therefore, non-genomic codes as well as DNA sequence have to be precisely replicated during proliferation of the differentiated cells. A better understanding of the mechanisms underlying replication of non-genomic codes will provide a cue to address the molecular basis of how cells regulate plasticity and robustness in multicellular organisms. Thus, we are confident that our findings will make significant contributions to advancing a variety of biological fields such as developmental biology, regenerative medicine, oncology, and gerontology.

【Key Words】

Non-genomic information: The factors regulating gene activities regardless of DNA sequences.

【Term of Project】 FY2019-2023

【Budget Allocation】 1,168,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.non-genome.com/
mkt-naka@ims.u-tokyo.ac.jp

Title of Project：Intrinsic periodicity of cellular systems and its modulation as the driving force behind plant development

NAKAJIMA Keiji
(Nara Institute of Science and Technology, Graduate School of Science and Technology, Professor)

Research Project Number：19H05670　Researcher Number：80273853

【Purpose of the Research Project】

Plants continue to produce new tissues and organs throughout their life. Owing to these growth characteristics, periodically repeated structures appear in many scales in plant bodies (Fig.1). An important point to note for plant periodic structures is that the periodicity can readily change in response to both internal and external cues. This "modulation of periodicity" appears to be the basis for developmental plasticity in plants.

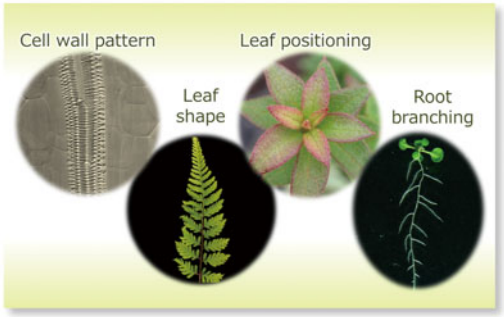


Fig.1 Plants produce periodic structures in many scales

Mechanisms producing periodic structures in organisms are best studied for somitogenesis and epidermal patterning in animals. In the case of plants, root branching and phyllotactic leaf patterning are known to be correlated with periodic hormonal responses in time and space. However, molecular determinants of their periodicity and upstream modulators are so far unknown.

【Content of the Research Project】

In this project, we work to elucidate the mechanisms of periodic structure development in plants and their role in establishing species-specific morphologies and growth plasticity. Special interests are directed to generators of oscillations and mechanisms modulating the periodicity. Close collaboration between plant biologists, information scientists, and mathematical biologists is one way to accelerate the project. Here, plant biologists analyze growth and developmental dynamics on many scales by live imaging analysis and searching for regulatory factors. Mathematical biologists take the approach of modelling oscillations and morphogenesis. Information scientists develop novel tools to help with the biologists' discoveries and data interpretations. Notably, organized collaboration between information scientists and plant developmental biologists is unprecedented, and one of the challenges of research which we are seeking to address in this project.

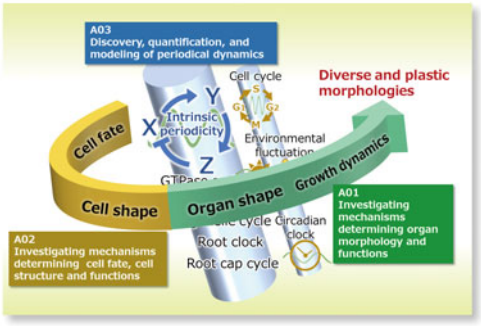


Fig.2 Reconstructing the principles of plant development based on periodicity and its modulation

Interdisciplinary collaboration in this project is meant to be not just a form of technical complementation, but also an ideology of working synergistically to develop new tools and technologies. Once established, such tools and technologies will be shared by the project members. Fostering young researchers with interdisciplinary mindsets is another important goal of this project.

【Expected Research Achievements and Scientific Significance】

Elucidation of mechanisms which generate periodic structures and their modulation will provide answers to fundamental questions in plant developmental biology. Additionally, identification of genes associated with plant periodic structures is important for crop breeding, as plant productivity can be dramatically improved through mutations affecting the number of repetitive units.

【Key Words】

Oscillation in biology: In many biological systems, mechanisms exist to produce periodic behaviors autonomously. Periodic structures in plants are thought to derive from some sort of autonomous oscillation, though their molecular identities are so far unknown.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,159,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://plant-periodicity.org

Title of Project：Non-equilibrium-state molecular movies and their applications

IWATA So
(Kyoto University, Graduate School of Medicine, Professor)

Research Project Number：19H05776　Researcher Number：60452330

【Purpose of the Research Project】

In order to understand the functions of biological macromolecules essential for life, it is most effective to capture their chemical reactions and structural changes in real time. X-ray free electron laser (XFEL) is a unique tool to observe these reactions and changes with outstanding time and spatial resolutions. Promote and develop this method as a versatile technology applicable to a wide range of biological macromolecules, we will integrate various methodologies including organic chemistry, computational science and biophysics to understand basic questions such as switching and signalling mechanisms of proteins and reaction mechanisms of enzymes. Based on these results, we will also develop controlling methods of biological macromolecules using light and other stimulations.

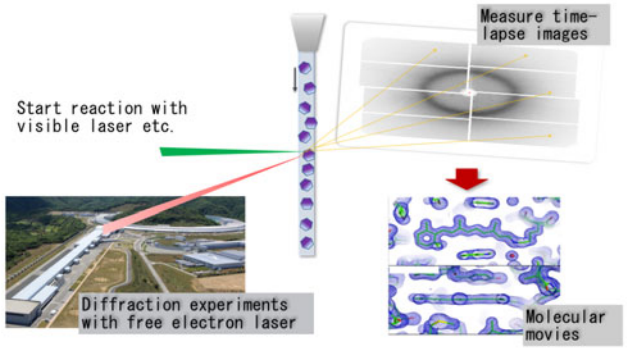


Figure 1. Making molecular movies

【Content of the Research Project】

We use XFEL's femtosecond pulses like strobes for making molecular movies to study macromolecular dynamics with a wide range of time resolution from femtoseconds to seconds. This research field is new and includes a wide range of disciplines such as physics, engineering, chemistry and biology. The group to study the chemical reactions and structural changes (A01, in the figure) in a wide variety of macromolecules, which forms the core part of this project, will closely collaborate with the group responsible for technical development of molecular movies (B01) and the group of computational science and physical chemistry (C01). In the group A01, we will study a variety of interesting biological and chemical systems to understand these molecular mechanisms. For this purpose, we will introduce and develop a wide range of new technologies. In addition, by using computational science, we aim to understand these systems theoretically and quantitatively to design proteins and compounds with new functions.

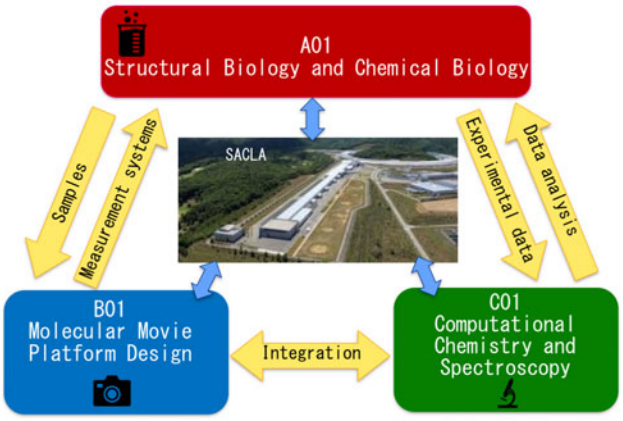


Figure 2. Project design

【Expected Research Achievements and Scientific Significance】

Outstanding time and spatial resolutions of the method will be used to study structural changes and chemical reactions in biological macromolecules to understand their functions at molecular level. Based on the results, rational molecular design will be carried out to produce proteins controlled by various stimulations and compounds switched *in vivo* controlling protein functions. Integrated research in a wide range of fields such as structural biology, protein engineering, chemical biology, and computational science is also expected to accelerate the further development of each field.

【Key Words】

X-ray free electron laser (XFEL): An X-ray laser characterized by ultrahigh brightness, ultrashort pulse duration and high spatial coherence. Using the source, one X-ray diffraction image can be collected within 10 femtosecond.

Molecular movies: Using XFEL, it is possible to capture extremely fast motions of molecules such as chemical reactions, at the time resolution of femtoseconds and spatial resolution of Angstroms and to visualize them as "molecular movies".

【Term of Project】

FY2019-2023

【Budget Allocation】

1,064,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.molmovies.med.kyoto-u.ac.jp
s.iwata@mfour.med.kyoto-u.ac.jp

Title of Project：Hyper-adaptability for overcoming body-brain dysfunction: Integrated empirical and system theoretical approaches

OTA Jun
(The University of Tokyo, School of Engineering, Research into Artifacts, Center for Engineering (RACE),Professor)

Research Project Number：19H05722　Researcher Number：50233127

【Purpose of the Research Project】

With coming of a super-aging society in Japan, we are facing the urgent problems of sensory-motor impairments, declining higher-order brain functions, cognitive impairment, loss of motivation, and mood disorders caused by aging, and in turn extreme decline of bodily and neurological functions. All of these problems have a common source: inability to adapt appropriately to a brain-body system changed with aging and impairments.

The human body has a high degree of redundancy. For example, “when a hand is paralyzed by a spinal cord injury, the ipsilateral motor cortex immediately joins its control by reactivating its pre-existing neural pathway, which is normally suppressed and preserved in the course of development” (Isa, 2019).

In light of such facts, we believe that clarifying the brain’s “hyper-adaptability” may resolve the abovementioned issues. The goal of our research project is to elucidate the neural and computational principles of hyper-adaptability in which the brain manages impairment of brain functions by linking neuroscience with systems engineering in order to comprehensively understand acute/chronic impairments and disorders, and the principle of frailty.

【Content of the Research Project】

When a person experiences acute/chronic impairment or disorder due to aging, the brain reorganizes neural networks by disinhibiting pre-existing neural network that is normally suppressed and searching for latent but available network that has long been unutilized through course of evolution and development. We call this process of functional compensation as “reconstruction of neural structure”, i.e. a neural entity that achieves hyper-adaptability. In order to implement practical functions to this reconstituted neural network, the network should acquire a new control policy of motor effectors based on precise recognition of the present states of the brain and the body. Here, the brain has to activate the new network by repeatedly performing neural computations and updates the network based on prediction error. We call this learning cycle in a new control space as “reconstitution of sensorimotor control rules”, i.e. neural computation principle that enables hyper-adaptability.

In order to verify the hypotheses described above, knowledge of neuroscience is essential. However, with only the “bottom-up” approach relying on experiments and analyses, it would be difficult to clarify hyper-adaptability that is manifested by systematic behavior of a neural network. Therefore, we apply an interdisciplinary approach that integrates the mathematical modeling technology of systems engineering with neuroscience (Fig. 1). We adopt two new analytical approaches: (a) Robotic-interventional neuroscience, i.e. combinatory use of well-controlled robotic technologies and biological approaches of viral vector, optogenetics, chemogenetics and brain stimulation. This allows verification of cause-effect relationship of neural activity and its generated functions and behaviors. (b) Function-oriented neural encoding, which constitutes a model that may incorporate any knowledge of brain functions into gray-box modeling or hypothesizes the structure of a model based on statistical methods.

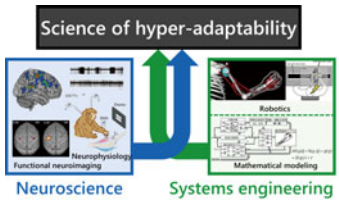


Fig. 1 Whole constitution of the project

【Expected Research Achievements and Scientific Significance】

1. Systematization of “science of hyper-adaptability” by elucidating its underlying neural mechanisms and through its computational modelings
2. Construction of mathematical modeling (gray-box model), which can describe brain functions by integrating multi-modal experimental data such as electrophysiology, brain imaging, and behavior.
3. Construction of a comprehensive theory that can explain adaptation principle from its neural entity to its neural computation principle.

【Key Words】

Hyper-adaptability: Capability of central nervous system (brain and spinal cord) to manage impairment of sensory, motor and cognitive functions including ageing-related ones, by reactivating and recruiting pre-existing, latent but available network with being implemented by new computational principles and practical functions.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,165,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.hyper-adapt.org

Title of Project：Integrated Biometal Science: Research to Explore Dynamics of Metals in Cellular System

TSUMOTO Kouhei
(The University of Tokyo, School of Engineering, Professor)

Research Project Number：19H05760　Researcher Number：90271866

【Purpose of the Research Project】

Several trace metal elements including iron, zinc, and copper play important roles in physiological functions such as energy conversion, material conversion and signal transduction. We call such metal and metalloid elements required to sustain life of all living organisms as “Biometal”. Dynamics of Biometals *in vivo* such as their uptake, transport, sensing and utilization are strictly regulated, and its failure causes diseases. Some other metal elements are toxic, and their toxicity is emerged by perturbation of the dynamics of Biometal *in vivo*. In this project, our goal is to unravel the dynamics of Biometal *in vivo* comprehensively through all levels of biological organization and to establish a novel research field of “Integrated Biometal Science”, in which the present research fields related to Biometal could be integrated. We will elucidate the strategy of living organisms, which was acquired during their evolution, to utilize effectively metal and metalloid elements for life and growth. Thus, “Biological Metal Element Strategy” will be established in this project.

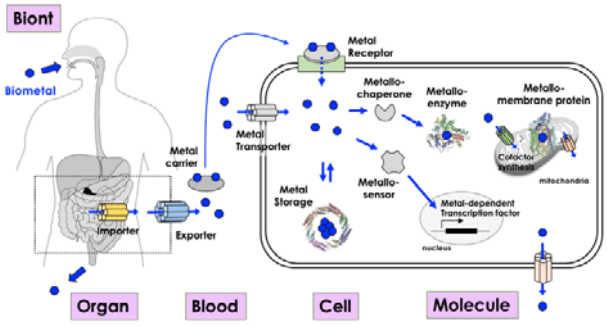


Fig 1 Dynamics of Biometal *in vivo* in physiologies

【Content of the Research Project】

In the research item A01, the functional roles of Biometal to maintain cellar homeostasis will be elucidated by studying the structure, interaction and function of proteins responsible for dynamics of Biometal *in vivo*. In the research item A02, the mechanisms of *in vivo* Biometal dynamics will be elucidated to develop its control method. In the research item A03, the mechanisms of development of toxicity of toxic metals will be elucidated in connection with *in vivo* Biometal dynamics. In the research item B01, measurement and analysis methods for Biometal research will be highly upgraded through collaboration with the project members in A01 ~ A03.

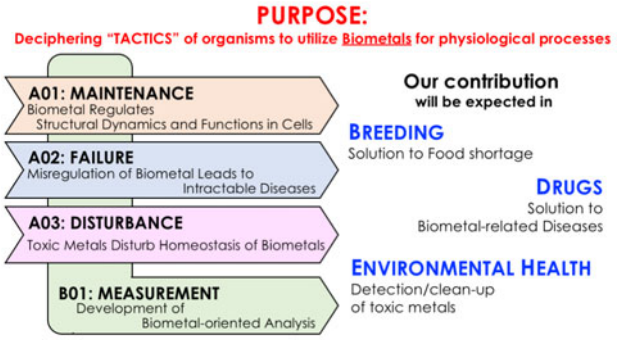


Fig 2 Integrated Biometal Science and its future

【Expected Research Achievements and Scientific Significance】

The scientific principle and interaction of researchers in the Biometal research will be established, which will contribute further development of the research field.

The following concrete results will be obtained by this project.

i New antimicrobial drugs will be developed.
ii. Therapeutic and diagnostic drugs that are able to regulate metal excess/deficiency in molecular level will be developed.
iii. New methodology to reduce metal toxicity will be developed.
iv. Novel metalloproteins will be discovered. New chemical model mimicking *in vivo* Biometal dynamics will be developed.

【Key Words】

Biometal: Metal and metalloid elements required to sustain life of all living organisms
In vivo Biometal dynamics: uptake, transport, sensing, storage, and utilization of metal ions or metal complexes in living organisms, which are involved in the various phenomena of life with many proteins and enzymes.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,166,600 Thousand Yen

【Homepage Address and Other Contact Information】

https://bio-metal.org
k-tsumoto@protein.t.u-tokyo.ac.jp

Interdisciplinary Area

Title of Project：Information physics of living matters

OKADA Yasushi
(The University of Tokyo, Graduate School of Science, Professor)

Research Project Number：19H05794　Researcher Number：50272430

【Purpose of the Research Project】

Information or signaling has been one of the core concepts to understand the biological systems. Recent progress in technologies has enabled quantitative measurements of biological phenomena even at a single molecule level. However, theoretical framework(s) are still missing that can handle information in biological systems in a quantitative and unified manner.

Meanwhile, in physics, a new theory is emerging at the interface of the thermodynamics and the information theory. Now, information can be treated as a physical quantity just like heat or mechanical works.

In this project, we aim at establishing a new interdisciplinary research field by applying this new information physics to biological systems. The theoretical frameworks of information physics will deepen our understanding of the biological systems. For example, we will be able to discuss the design principles of the existing biological systems through the quantitative analyses of their efficiencies, which will be enabled by the theoretical tradeoff relations among various (thermo) physical quantities and information. At the same time, many good model systems or interesting questions will be found in the real biological systems, which will stimulate the further development of the theory of information physics. We would build a research group to explore this new research field through active feedbacks between biologists and physicists.

【Content of the Research Project】

The goal of this project is to establish a new physics theory that unites information with other physical quantities based on the real biological problems. To explore such interdisciplinary area, it would be essential to establish real collaborations between biologists and physicists. Therefore, each of the three groups in this project has both physical theorists and biological experimentalists, so that they can collaborate to tackle the problems.

The main target of the group A is to dissect the biological molecular machineries, such as molecular motors. The behavior of a single protein will be measured and analyzed in the non-equilibrium environment of the cytoplasm. Moreover, the interactions between the biomolecules in the cytoplasm will also be discussed, which would help us to understand the basic physical principles of liquid-liquid phase separations in the cytoplasm.

Group B will work on the cellular level, such as the chemical reaction networks of the signal transduction or chemotaxis. The information thermodynamics theory will be extended by the application of the information geometry or other mathematical concepts to handle those problems. Quantitative measurements and perturbation experiments would enable us to examine the theory, and would guide the further development of the theory.

Group C will work on the emergence of the functions in the multi-cellular systems, such as the collective cell movement or the developmental processes of multi-cellular organisms. The theory would further cover the adaptation or evolution. These processes include the noisy feedbacks between individual cells and a whole population via a macroscopic field. Information physics will be expanded to discuss such processes.

【Expected Research Achievements and Scientific Significance】

The current abstract theory of information thermodynamics will be materialized by solving the real biological problems. For example, the discussion of the theoretical limits of the efficiency of the cell signaling pathways would not only deepen our understanding how good the existing biological systems is, but also enable us to establish a general theory of the efficiency of information-heat engines.

At the same time, such approach would also enable us to discuss the (design) principles of the biological systems rather than making up a list of the molecules involved in some specific functions.

【Key Words】

Information thermodynamics = A theory to integrate the information theory into the framework of thermodynamics.

【Term of Project】 FY2019-2023

【Budget Allocation】 1,150,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://infophys-bio.jp/

Title of Project：Studies on intelligent systems for dialogue toward the human-machine symbiotic society

ISHIGURO Hiroshi
(Osaka University, Department of Systems Innovation, Professor)

Research Project Number：19H05690　Researcher Number：10232282

【Purpose of the Research Project】

In the near future, various home appliances and robots will act autonomously and will have intentions and desires. As they have intentions and desires, they will be able to establish relationships with humans in which they understand each other's intentions and desires by using natural language to interact with each other (see the figure below). This kind of world is a society in which humans and intelligent robots and information media coexist in the next stage of the information society.

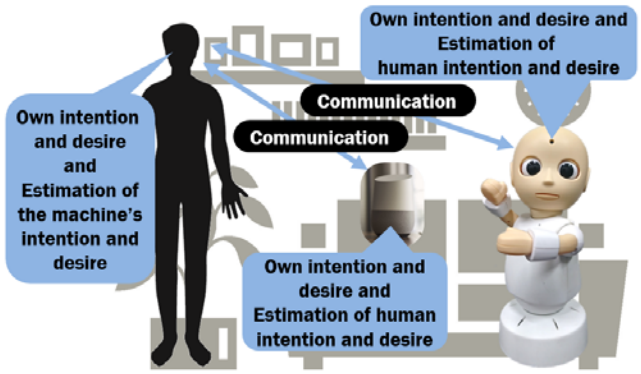


Figure1. Conversation with systems that have intentions and desires

In order to create an academic field that realizes this new symbiotic society, we will engage in research and development with four research groups: dialogue engagement and rapport research, communication understanding and generation research, behavioral decision model estimation research, and human-machine social norms research.

In addition, we will plan and manage field experiments and work on collaboration between the four research groups, as well as discovering and solving new research issues and fostering young researchers. We will study the influence of robots with intentions and desires on society, and propose social norms for a robot-symbiotic society.

【Content of the Research Project】

In order to achieve the above objectives, we will work on the following research while combining research in various fields.

Dialogue engagement and rapport research: we will realize the communication ability to maintain engagement and rapport even if the content of the communication is not completely understood.

Communication understanding and generation research: we will realize the communication ability to combine communication understanding and dialogue generation for a specific objective in a specific situation.

Behavioral decision model estimation research: we will realize the functions of robots that build behavioral decision models and that estimate the behavioral decision models of the other party.

Human-machine social norms research: Through public meetings held together with demonstrations of experiments, we will not only study the effects of robots with intentions and desires on people, but also propose social norms for a robot-symbiotic society.

Then, in this new academic field, under the leadership of the general manager group, we will work on field experiments using the developed information media and communication robots in the real world, and discover new problems to be solved through these field experiments. We will then prototype entirely new communication robots and information media with intentions and desires that can coexist with humans, and explore the possibilities of the intelligent robot/information media symbiotic society that will come after the information media society.

【Expected Research Achievements and Scientific Significance】

The research in this field departs from the unilateral tool-like relationship between humans and machines, where humans send instruction to machines, to establish a relationship between humans and machines where they mutually adapt to each other. Specifically, the autonomy of machines and information media will progress. In doing so, humans and machines and information media will create new relationships in which they interact with each other while deducing each other's intentions and desires through the use of natural language dialogue.

【Key Words】

Autonomous conversational robot: A robot that interacts autonomously based on its own intentions and desires.
Human-machine social norm: A social norm for building desirable relationships between humans and machines.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,088,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.commu-ai.org

Title of Project：Post-Koch Ecology: The next-era microbial ecology that elucidates the super-terrestrial organism system

TAKAYA Naoki
(University of Tsukuba, Faculty of Life and Environmental Sciences, Professor)

Research Project Number：19H05679　Researcher Number：50282322

【Purpose of the Research Project】

The Earth is home to a system of super-terrestrial organisms, where the terrestrial environment and diverse living organisms interact. Microorganisms account for half of all living organisms in the biosphere. The number of microorganism species ranges in the millions, much greater than the numbers of animal, plant, and insect species. Therefore, understanding microbial ecology is essential for understanding the overall ecology of super-terrestrial living organisms.

Many microorganism species have been isolated from the environment; however, those that have been isolated still only constitute less than 1% of all microbial species on Earth. Establishing a novel microorganism isolation technique will be the key to understanding the entire picture of super-terrestrial living organisms.

We will create a novel post-Koch microorganism isolation technique that integrates science, engineering, and microbiology to find microorganisms that have yet to be isolated. Furthermore, we will use functional informatics to take full advantage of ecological and information science to establish a novel ecological system model that is centered on microorganism species as well as their functions and growing environment. This post-Koch functional ecology model will be the basis for elucidation of principles of the super-terrestrial organism system.

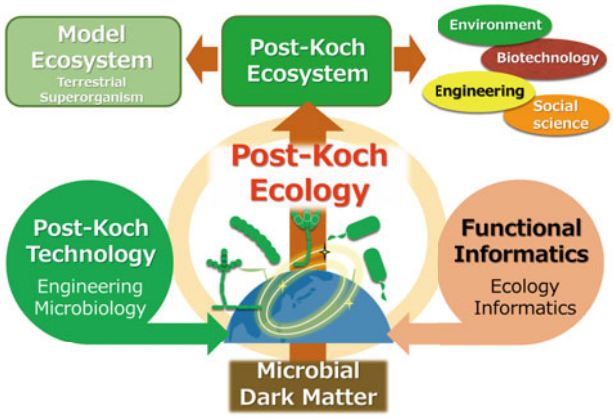


Figure 1 Research strategy and expected achievements

【Content of the Research Project】

Ten groups will advance research under two research tasks. Task A01 will be to develop an innovative post-Koch technique to isolate unknown microorganisms. Specifically, we aim to develop an innovative technique for the isolation, culturing, and analysis of microorganisms, utilizing diverse technologies such as micro-electronic mechanical systems, spectroscopy, and microscopic imaging. Discovery of new microbial species will elucidate their functions, and enhance the diversity of microorganisms. Task A02 will be to create a post-Koch ecology model by developing new bioinformatics technologies to integrate and perform network analysis on information about species, genes, functions, and the environment of microorganisms. The integrated analysis of environmental data and microorganism data will be addressed along with research on the functions of a complex organism system in the environment and technologies that transform enormous amounts of microorganisms into bioresources. Under these two research tasks, we aim to activate the whole research area through collaboration utilizing the shared experimental farm and data obtained therefrom.

【Expected Research Achievements and Scientific Significance】

A post-Koch functional ecology model that has one of the largest collections of information about species, genes, functions, and the environment of microorganisms will be established, allowing for ecology to be understood on the basis of the physiological functions of microorganisms in the environment. The outcomes from this research will contribute to agriculture, life science, engineering, biotechnology, and social sciences. Microorganisms are associated with many fields of study under the Sustainable Development Goals (SDGs). Therefore, this research area will evolve into a core academic area that supports SDGs beyond existing academic areas.

【Key Words】

Microorganism: A living organism that is too small to be seen with the naked eye. Microorganisms have the highest biodiversity on Earth and include bacteria, archaea, and fungi.

【Term of Project】

FY2019-2023

【Budget Allocation】

1,154,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://postkoch.jp/

List of the Continuing Projects for Grant-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area) of KAKENHI

Humanities and Social Sciences（ 6 Projects ）

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05964	NAKAMURA Shinichi 80237403	Kanazawa University, Faculty of Letters, Professor	Rice Farming and Chinese Civilization: Renovation of Integrated Studies of Rice-based Civilizations.	FY2015-2019	364,600
16H06546	SAKAI Keiko 40401442	Chiba University, Faculty of Law, Politics and Economics, Professor	Establishing a New Paradigm of Social/ Human Sciences based on Relational Studies: in order to Overcome Contemporary Global Crisis	FY2016-2020	529,300
16H06407	NISHIAKI Yoshihiro 70256197	The University of Tokyo, The University Museum, Professor	Cultural History of PaleoAsia -Integrative Research on the Formative Processes of Modern Human Cultures in Asia	FY2016-2020	664,800
17H06340	YAMAGUCHI K. Masami 50282257	Chuo University, Department of psychology, Professor	Construction of the Face-Body studies in transcultural conditions	FY2017-2021	573,300
17H06334	ASANO Toyomi 60308244	Waseda University, Faculty of Political Science and Economics, Professor	Creation of the study of reconciliation	FY2017-2021	243,100
18H05443	YAMADA Shigeo 30323223	University of Tsukuba, Faculty of Humanities and Social Sciences, Professor	The Essence of Urban Civilization: An Interdisciplinary Study of the Origin and Transformation of Ancient West Asian Cities	FY2018-2022	694,500

Science and Engineering（ 29 Projects ）

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05851	KAWAKAMI Norio 10169683	Kyoto University, Graduate School of Science, Professor	Frontiers of materials science spun from topology	FY2015-2019	1,003,600
15H05795	MASHIMA Kazushi 70159143	Osaka University, Graduate School of Engineering Science, Professor	Precise Formation of a Catalyst Having a Specified Field for Use in Extremely Difficult Substrate Conversion Reactions	FY2015-2019	1,221,200
15H05866	HIRAYAMA Yoshiro 20393754	Tohoku University, Graduate School of Science, Professor	Science of Hybrid Quantum Systems	FY2015-2019	1,045,300
15H05882	HARIMA Hisatomo 50211496	Kobe University Graduate School of Science, Professor	J-Physics: Physics of conductive multipole systems	FY2015-2019	1,173,100
15H05887	MURAYAMA Hitoshi 20222341	The University of Tokyo, Kavli Institute for the Physics and Mathematics of the Universe, Project Professor	Why does the Universe accelerate? - Exhaustive study and challenge for the future -	FY2015-2019	1,106,000
15H05826	TSUCHIYA Taku 70403863	Ehime University, Geodynamics Research Center, Professor	Interaction and Coevolution of the Core and Mantle: Toward Integrated Deep Earth Science	FY2015-2019	1,091,100
15H05835	FUKASE Koichi 80192722	Osaka University, Graduate School of Science, Professor	Middle Molecular Strategy: Creation of Higher Bio-functional Molecules by Integrated Synthesis.	FY2015-2019	1,108,100
15H05812	KUSANO Kanya 70183796	Nagoya University, Solar-Terrestrial Environment Laboratory, Professor	Solar-Terrestrial Environment Prediction as Science and Social Infrastructure	FY2015-2019	649,400

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
16H06413	FUJIOKA Hiroshi 50282570	The University of Tokyo, Institute of Industrial Science, Professor	Materials Science and Advanced Electronics Created by Singularity	FY2016-2020	1,103,800
16H06508	SHIONOYA Mitsuhiko 60187333	The University of Tokyo, Graduate School of Science, Professor	Coordination Asymmetry: Design of Asymmetric Coordination Sphere and Anisotropic Assembly for the Creation of Functional Molecules	FY2016-2020	1,168,000
16H06488	ASAI Shoji 60282505	The University of Tokyo, Graduate school of Science, Professor	New expansion of particle physics of post-Higgs era by LHC revealing the vacuum and space-time structure	FY2016-2020	1,017,400
16H06472	OBARA Kazushige 40462501	The University of Tokyo, Earthquake Research Institute, Professor	Science of Slow Earthquakes	FY2016-2020	1,070,800
16H06442	ABE Ikuro 40305496	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Creation of Complex Functional Molecules by Rational Redesign of Biosynthetic Machineries	FY2016-2020	1,106,300
16H06503	ISHIHARA Hajime 60273611	Osaka Prefecture University, Graduate School of Engineering, Professor	Nano-Material Manipulation and Structural Order Control with Optical Forces	FY2016-2020	1,049,900
16H06438	KAGEYAMA Hiroshi 40302640	Kyoto University, Graduate School of Engineering, Professor	Synthesis of Mixed Anion Compounds toward Novel Functionalities	FY2016-2020	1,022,800
17H06454	SEKINE Yasuhito 60431897	The University of Tokyo, Graduate School of Science, Associate Professor	Aqua planetology	FY2017-2021	1,079,400
17H06460	KOTANI Motoko 50230024	Tohoku University, Graduate School of Science, Professor	Discrete Geometric Analysis for Materials Design	FY2017-2021	1,002,900
17H06366	KATO Masako 80214401	Hokkaido University, Faculty of Science, Professor	Soft Crystals: Science and Photofunctions of Flexible Response Systems with High Order	FY2017-2021	1,012,200
17H06347	HAMACHI Itaru 90202259	Kyoto University,Graduate School of Engineering, Professor	Chemistry for Miscellaneous Crowding Biosystems	FY2017-2021	1,215,500
17H06357	TANAKA Takahiro 40281117	Kyoto University Graduate School of Pharmaceutical Sciences, Professor	Gravitational wave physics and astronomy: Genesis	FY2017-2021	1,079,000
17H06400	KAKEYA Hideaki 00270596	Kyoto University, Graduate School of Pharmaceutical Sciences, Professor	Frontier research on chemical communications	FY2017-2021	1,108,700
17H06441	KANAI Motomu 20243264	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Hybrid Catalysis for Enabling Molecular Synthesis on Demand	FY2017-2021	1,224,600
18H05512	ORIMO Shin-ichi 40284129	Tohoku University, WPI-AIMR, Professor	HYDROGENOMICS: Creation of Innovative Materials, Devices, and Reaction Processes using Higher-Order Hydrogen Functions	FY2018-2022	1,135,000
18H05436	INUTSUKA Shu-ichiro 80270453	Department of Physics, Nagoya University, Professor	A Paradigm Shift by a New Integrated Theory of Star Formation: Expanding Frontier of Habitable Planetary Systems in Our Galaxy	FY2018-2022	1,109,800
18H05535	NAKAYA Tsuyoshi 50314175	Kyoto University, Graduate School of Science, Professor	Exploration of Particle Physics and Cosmology with Neutrinos	FY2018-2022	1,129,900
18H05475	ABE Eiji 70354222	The University of Tokyo, Graduate School of Engineering, Professor	Materials Science on mille-feuille structure – Development of next-generation structural materials guided by a new strengthen principle	FY2018-2022	1,179,000

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
18H05400	NAKAMURA Takashi 50272456	Tokyo Institute of Technology, School of Science, Professor	Clustering as a window on the hierarchical structure of quantum systems	FY2018-2022	1,169,700
18H05450	INUI Haruyuki 30213135	Kyoto University, Faculty of Engineering, Professor	High Entropy Alloys: Science of New Class of Materials Based on Elemental Multiplicity and Heterogeneity	FY2018-2022	1,169,100
18H05457	TAKAHASHI Tadayuki 50183851	The University of Tokyo, Kavli Institute for the Physics and Mathematics of the Universe, Professor	Toward new frontiers: Encounter and synergy of state-of-the-art astronomical detectors and exotic quantum beams	FY2018-2022	1,093,000

Biological Sciences（ 20 Projects ）

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05897	ARITA Makoto 80292952	RIKEN, Center for Integrative Medical Sciences, Team Leader	Quality of lipids in biological systems	FY2015-2019	1,180,100
15H05927	TOMINAGA Makoto 90260041	National Institutes of Natural Sciences, Okazaki Institute for Integrative Bioscience, Professor	Integrative understanding of biological phenomena with temperature as a key theme	FY2015-2019	1,171,100
15H05970	SHIRAHIGE Katsuhiko 90273854	The University of Tokyo, Institute of Molecular and Cellular Biosciences, Professor	Chromosome Orchestration System	FY2015-2019	1,146,200
15H05947	MIYAWAKI Atsushi 80251445	RIKEN, Brain Science Institute, Laboratory Head	Resonance Biology for Innovative Bioimaging	FY2015-2019	1,198,000
15H05856	KONDO Shigeru 10252503	Osaka University, Graduate School of Frontier Biosciences, Professor	Discovery of the logic that establishes the 3D structure of organisms	FY2015-2019	1,102,300
15H05955	KINOSHITA Toshinori 50271101	Nagoya University, Institute of Transformative Bio-Molecules, Professor	Integrative system of autonomous environmental signal recognition and memorization for plant plasticity	FY2015-2019	1,184,500
16H06552	MINAGAWA Jun 80280725	National Institutes of Natural Sciences, National Institute for Basic Biology, Professor	New Photosynthesis: Re-optimization of the solar energy conversion system	FY2016-2020	1,057,500
16H06455	EMOTO Kazuo 80300953	The University of Tokyo, Department of Biological Sciences, Professor	Dynamic regulation of brain function by scrap & build system	FY2016-2020	1,179,100
16H06479	KAGEYAMA Ryoichiro 80224369	Kyoto University, Institute for Virus Research, Professor	Interplay of developmental clock and extracellular environment in brain formation	FY2016-2020	1,181,800
16H06495	MATSUMOTO Mitsuru 60221595	Tokushima University Institute for Enzyme Research, Professor	Creation, function and structure of neo-self	FY2016-2020	1,064,600
16H06429	KAWAOKA Yoshihiro 70135838	The University of Tokyo, Institute of Medical Science, Professor	Neo-virology: the raison d'etre of viruses	FY2016-2020	1,061,100
16H06464	HIGASHIYAMA Tetsuya 00313205	Nagoya University, Institute of Transformative Bio-molecules, Professor	Determining the principles of the birth of new plant species: molecular elucidation of the lock-and-key systems in sexual reproduction	FY2016-2020	1,208,400
17H06299	KURODA Shinya 50273850	The University of Tokyo, Graduate School of Science, Professor	Transomic Analysis of Metabolic Adaptation	FY2017-2021	1,224,700

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
17H06384	KURATANI Shigeru 00178089	RIKEN, Chief Scientist	Evolutionary theory for constrained and directional diversities	FY2017-2021	1,230,800
17H06470	UMEDA Masaaki 80221810	Nara Institute of Science and Technology, Graduate School of Biological Sciences, Professor	Principles of pluripotent stem cells underlying plant vitality	FY2017-2021	1,166,500
17H06413	SHIMIZU Shigeomi 70271020	Tokyo Medical and Dental University, Medical Research Institute, Professor	Toward an integrative understanding of functional zones in organelles	FY2017-2021	1,214,600
17H06423	TACHIBANA Makoto 80303915	Tokushima University, Institute of Advanced Medical Sciences, Professor	Spectrum of the Sex: a continuity of phenotypes between female and male	FY2017-2021	1,144,600
18H05428	HAYASHI-TAKAGI Akiko 60415271	Gunma Univ, IMCR, Full Professor	Constructive understanding of multi-scale dynamism of neuropsychiatric disorders	FY2018-2022	1,212,900
18H05544	HAYASHI Katsuhiko 20287486	Kyushu University, Graduate School of Medical Sciences, Professor	Ensuring integrity in gametogenesis	FY2018-2022	1,181,700
18H05526	KIMURA Hiroshi 30241392	Tokyo Institute of Technology, Institute of Innovative Research, Professor	Chromatin potential for gene regulation	FY2018-2022	1,181,500

Interdisciplinary Area（ 24 Projects ）

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
15H05907	MIYANO Satoru 50128104	The University of Tokyo, The Institute of Medical Science, Professor	Conquering Cancer through Neo-dimensional Systems Understanding	FY2015-2019	1,101,600
15H05817	YASUDA Ichiro 80270792	The University of Tokyo, Atmosphere and Ocean Research Institute, Professor	Ocean Mixing Processes: Impact on Biogeochemistry, Climate and Ecosystem	FY2015-2019	1,112,600
15H05871	NAMBU Atsushi 80180553	National Institute for Physiological Sciences, Division of System Neurophysiology, Professor	Non-linear Neuro-oscillology: Towards Integrative Understanding of Human Nature	FY2015-2019	1,149,700
15H05935	FURUKAWA Satoshi 20726260	Japan Aerospace Exploration Agency, Head of Space Biomedical Research Group, Astronaut	“LIVING IN SPACE” - Integral Understanding of life-regulation mechanism from “SPACE”	FY2015-2019	1,172,900
15H05914	NISHIDA Shin’ya 20396162	Nippon Telegraph and Telephone Corp, Human Information Science Lab, NTT Communication Science Laboratories, Senior Distinguished Scientist	Understanding human recognition of material properties for innovation in SHITSUKAN science and technology	FY2015-2019	1,086,200
16H06395	KASAI Kiyoto 80322056	The University of Tokyo, Department of Neuropsychiatry, Professor	Science of personalized value development through adolescence: integration of brain, real-world, and life-course approaches	FY2016-2020	1,112,800
16H06524	OSUMI Noriko 00220343	Tohoku University School of Medicine, Professor	Integrative Research toward Elucidation of Generative Brain Systems for Individuality	FY2016-2020	1,153,000
16H06535	HASHIMOTO Koichi 80228410	Tohoku University, Graduate School of Information Sciences, Professor	Systems Science of Bio-Navigation	FY2016-2020	1,087,100

Research Project Number	Head Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousands of Yen)
16H06573	TAKEKAWA Mutsuhiro 30322332	The University of Tokyo, The Institute of Medical Science, Professor	Integrative understanding of biological signaling networks based on mathematical science	FY2016-2020	1,022,900
16H06561	DOYA Kenji 80188846	Okinawa Institute of Science and Technology Graduate University, Neural Computation Unit, Professor	Correspondence and Fusion of Artificial Intelligence and Brain Science	FY2016-2020	1,119,100
16H06400	SAKURAI Takeshi 60251055	University of Tsukuba Faculty of Medicine, Professor	Creation and Promotion of the Will-Dynamics	FY2016-2020	1,153,800
17H06391	MATSUSHIMA Kouji 50222427	The University of Tokyo, Graduate School of Medicine, Professor	Preventive medicine through inflammation cellular sociology	FY2017-2021	1,195,200
17H06316	KAWAMURA Kenji 90431478	National Institute of Polar Research, Division for Research and Education, Associate Professor	Giant reservoirs of heat/water/material: Global environmental changes driven by the Southern Ocean and the Antarctic Ice Sheet	FY2017-2021	1,156,200
17H06378	OKANOYA Kazuo 30211121	The University of Tokyo, Graduate School of Arts and Sciences, Professor	Studies of Language Evolution for Co-creative Human Communication	FY2017-2021	1,078,400
17H06324	FUJITA Naoya 20280951	Japanese Foundation for Cancer Research, The Cancer Chemotherapy Center, Center Director	Integrated analysis and regulation of cellular diversity	FY2017-2021	1,189,600
17H06308	BITO Haruhiko 00291964	The University of Tokyo, Graduate School of Medicine, Professor	Brain information dynamics underlying multi-area interconnectivity and parallel processing	FY2017-2021	1,235,600
17H06433	SHEN Jian-Ren 60261161	Okayama University, Research Institute for Interdisciplinary Science, Professor	Creation of novel light energy conversion system through elucidation of the molecular mechanism of photosynthesis and its artificial design in terms of time and space	FY2017-2021	1,146,100
18H05497	SAEKI Yasushi 80462779	Tokyo Metropolitan Institute of Medical Science, Department of Advanced Science for Biomolecules, Associate Director	New frontier for ubiquitin biology driven by chemo-technologies	FY2018-2022	1,170,100
18H05520	KITAZAWA Shigeru 00251231	Osaka University, Graduate School of Frontier Biosciences, Professor	Chronogenesis: how the mind generates time	FY2018-2022	1,157,200
18H05465	SUZUMORI Koichi 00333451	Tokyo Institute of Technology, School of Engineering, Professor	Science of Soft Robot: interdisciplinary integration of mechatronics, material science, and bio-computing	FY2018-2022	1,194,200
18H05505	SAITOU Naruya 30192587	National Institute of Genetics, Division of Population Genetics, Professor	Deciphering Origin and Establishment of Japonesians mainly based on genome sequences date	FY2018-2022	658,800
18H05484	DEMURA Taku 40272009	Nara Institute of Science and Technology, Graduate School of Science and Technology,Professor	Elucidation of the strategies of mechanical optimization in plants toward the establishment of the bases for sustainable structure system	FY2018-2022	1,180,500
18H05418	KINBARA Kazushi 30282578	Tokyo Institute of Technology, School of Life Science and Technology, Professor	Molecular Engine: Design of Autonomous Functions through Energy Conversion	FY2018-2022	1,193,600
18H05408	NAGAI Takeharu 20311350	The Institute of Scientific and Industrial Research, Osaka University, Professor	Singularity biology	FY2018-2022	1,210,100

Grant-in-Aid for Scientific Research (S)

☐ Distribution of the Newly Adopted Projects

Purpose and Character of Grant-in-Aid for Scientific Research (S) (excerpt from the "Application Procedures for Grants-in-Aid for Scientific Research-KAKENHI-"):

1) **Funding target:**
Research plan conducted by a single or a relatively small number of researchers that aims at achieving a major development in creative and pioneering research

2) **Range of total budget:**
50 million yen to 200 million yen

3) **Research period:**
5 years as a general rule

【 New Projects 】

	Number of Applications			Total Grant Disbursements※ (FY2019)	Per-project Grants※ (FY2019)	
	Received	Adopted	Ratio		Average	Largest
			(%)	(Thousands of yen)	(Thousands of yen)	(Thousands of yen)
Total	659	81	12.3	3,114,800	38,454	91,600

【 New and Ongoing Projects 】

	Number of Applications	Total Grant Disbursements※ (FY2019)	Per-project Grants※ (FY2019)	
			Average	Largest
		(Thousands of yen)	(Thousands of yen)	(Thousands of yen)
Total	413	11,819,600	28,619	105,100

※ Direct expense only

List of the Newly Adopted Projects for Grant-in-Aid for Scientific Research (S) of KAKENHI, FY2019

○ Broad Section A（ 6 Projects ）

（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05589	KOIZUMI Masatoshi 10275597	Tohoku University, Graduate School of Arts and Letters, Professor	Field-based Cognitive Neuroscientific Study of Word Order in Language and Order of Thinking from the OS Language Perspective	FY2019-2023	32,000 / 153,500
19H05590	NOZAWA Sachiko 10749302	The University of Tokyo, Graduate School of Education, Associate Professor	The longitudinal study on the effects of early childhood education and care on child development	FY2019-2023	19,300 / 85,500
19H05591	KAWAI Kaori 50293585	Tokyo University of Foreign Studies, The Research Institute for Languages and Cultures of Asia and Africa, Professor	The Origin and Evolution of Sociality: Developing new theories of human evolution based on collaboration between anthropology and primatology	FY2019-2023	24,500 / 130,400
19H05592	FUJII Sumio 90238527	Kanazawa University, Emeritus Professor	The Origin of the Tribal Society in the Near East: Comprehensive Study of the Pre- and Proto-historic Nomadic Cultures in the Arabian Peninsula	FY2019-2023	24,000 / 136,700
19H05593	MIYAMOTO Kazuo 60174207	Kyushu University, Faculty of Humanities, Professor	Holistic research on the spread and acculturation of early agriculture and on the process of establishment of herding society in East Asia	FY2019-2023	12,100 / 70,700
19H05594	MINAGAWA Yasuyo 90521732	Keio University, Faculty of Letters, Professor	Development of speech communication and its correlates of brain, cognition and motor system: A longitudinal cohort study of typically and atypically developing infants	FY2019-2023	36,000 / 147,300

○ Broad Section B（ 16 Projects ）

（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05595	YAMAMOTO Masanobu 60332475	Hokkaido University, Faculty of Environmental Earth Science, Associate Professor	Reconstruction of atmospheric carbon dioxide concentration during the last 6 million years and the study of the interaction between atmospheric carbon dioxide and climate	FY2019-2023	53,400 / 155,500
19H05596	HINO Ryota 00241521	Tohoku University, Graduate School of Science, Professor	Head and tail of massive earthquakes: Mechanism arresting growth of interplate earthquakes	FY2019-2023	50,100 / 154,900
19H05597	OGAWA Takayoshi 20224107	Tohoku University, Graduate School of Science, Professor	Creation of advanced method in mathematical analysis on nonlinear mathematical models of critical type	FY2019-2023	22,200 / 100,900
19H05598	ESUMI Shinichi 10323263	University of Tsukuba, Faculty of Pure and Applied Sciences, Institute of Physics, Associate Professor	Search for a critical point and first order phase transition of high density quark-nuclear matter via higher order fluctuations and particle correlations	FY2019-2023	13,300 / 79,500
19H05599	ISHIGE Kazuhiro 90272020	The University of Tokyo, Graduate School of Mathematical Sciences, Professor	Systematical geometric analysis and asymptotic analysis for evolution equations	FY2019-2023	21,200 / 107,500
19H05600	SAITOH Eiji 80338251	The University of Tokyo, Graduate School of Engineering, Professor	Investigation of nuclear spin-current science and nuclear thermoelectric conversion	FY2019-2023	91,600 / 158,700
19H05601	SAKEMI Yasuhiro 90251602	The University of Tokyo, Graduate School of Science, Professor	Study for the violation mechanism of fundamental symmetry using the cold atom/molecular interferometer with optical lattice	FY2019-2023	37,600 / 154,200

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05602	IWASA Yoshihiro 20184864	The University of Tokyo, Department of Applied Physics, Professor	Physics and Functions of Van der Waals Heterostructures	FY2019-2023	43,700 154,600
19H05603	FUJISAWA Toshimasa 20212186	Tokyo Institute of Technology, School of Science, Department of Physics, Professor	Nonequilibrium states of low-dimensional quasiparticles in a mesoscopic quantum Hall system	FY2019-2023	30,900 153,500
19H05604	KAWABATA Takahiro 80359645	Osaka University, Graduate School of Science, Professor	Nucleosynthesis under the extreme conditions in the universe	FY2019-2023	51,400 132,600
19H05605	HAYASHI Yoshiyuki 20180979	Kobe University, Graduate School of Science, Professor	Comprehensive picture of atmospheric circulation of Venus revealed by AKATSUKI data assimilation	FY2019-2023	32,000 145,200
19H05606	UETAKE Satoshi 80514778	Okayama University, Research Institute for Interdisciplinary Science, Associate Professor	Precision test of electroweak theory and search for new physics beyond the Standard Model by laser spectroscopy of purely leptonic atoms	FY2019-2023	37,900 154,300
19H05607	OGIO Shoichi 20242258	Osaka City University, Graduate School of Science, Professor	Study of origins and propagation of very high energy cosmic rays with detailed measurements in the wide energy range	FY2019-2023	57,800 155,700
19H05608	TORII Shoji 90167536	Waseda University, Faculty of Science and Engineering, Professor Emeritus	Long-term observations to study the origins of Galactic Cosmic Rays and search for Dark Matter with CALET	FY2019-2023	44,200 154,800
19H05609	TAMAGAWA Toru 20333312	RIKEN, Cluster for Pioneering Research, Chief Scientist	Elucidation of ultra-strong magnetic field of neutron stars with highly-sensitive X-ray and Gamma-ray polarimetry	FY2019-2023	31,400 142,300
19H05610	TARUCHA Seigo 40302799	RIKEN, Center for Emergent Matter Science, Group Director	Electrical and optical creation and control of non-Abelian anyons	FY2019-2023	27,400 126,800

○ Broad Section C （ 8 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05611	TAKAKI Koichi 00216615	Iwate University, Faculty of Science and Engineering, Professor	Novel function control of plant and marine products by pulsed power and its scientifically deepening	FY2019-2023	37,400 153,100
19H05612	SAKUMA Akimasa 30361124	Tohoku University, Graduate School of Science and Engineering, Professor	Establishment of the new method for material synthesis utilizing light elements and their expansion to develop rare- earth-free magnet	FY2019-2023	25,300 146,400
19H05613	AOKI Takayuki 00184036	Tokyo Institute of Technology, Global Scientific Information and Computing Center, Professor	Innovative CFD simulation for multiphase flows including free surfaces	FY2019-2023	30,500 149,700
19H05614	YOSHIKAWA Nobuyuki 70202398	Yokohama National University, Graduate school of Engineering, Professor	Creation of extremely energy-efficient integrated circuit technology beyond the thermodynamic limit based on reversible quantum flux circuits	FY2019-2023	34,800 153,500
19H05615	YAMASHITA Taro 60567254	Nagoya University, Graduate School of Engineering, Associate Professor	Large-scale superconducting spintronics quantum computing circuits toward the realization of quantum supremacy	FY2019-2023	64,900 156,600
19H05616	HAMAYA Kohei 90401281	Osaka University, Graduate School of Engineering Science, Professor	Development of a germanium spin MOSFET	FY2019-2023	53,500 155,500

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05617	KISS Takanobu 00221911	Kyushu University, Graduate School of Information Science and Electrical Engineering, Professor	Systematization of characterization technologies for high-temperature superconducting wires, conductors and coil windings, and their development to highly reliable magnets	FY2019-2023	45,200	153,800
19H05618	FUJIMURA Norifumi 50199361	Osaka Prefecture University, Graduate School of Engineering, Professor	Establishment of evaluation methods for the physical properties of ferroelectrics using coherent state of the elementary excitation and the device applications	FY2019-2023	61,600	156,200

○ Broad Section D （ 11 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05619	Oliver B. Wright 90281790	Hokkaido University, Graduate School of Engineering, Professor	Development and quantitative interpretation of acoustic and phoxonic metamaterial devices from kHz to GHz frequencies	FY2019-2021	36,100	107,700
19H05620	SUGIMOTO Satoshi 10171175	Tohoku University, Graduate School of Engineering, Professor	Development of a Wideband Microwave Absorber – Contributing to the Internet of Things Society Through Dual-phase Engineering	FY2019-2023	30,000	122,600
19H05621	KOMEDA Tadahiro 30312234	Tohoku University, Institute of Multidisciplinary Research for Advanced Materials, Professor	Development of Spin Coherent Microscopy with Time and Space Resolutions Dedicated for Quantum Information Processes	FY2019-2023	33,500	147,100
19H05622	FUKAMI Shunsuke 60704492	Tohoku University, Research Institute of Electrical Communication, Associate Professor	Non-collinear spintronics	FY2019-2023	53,200	155,500
19H05623	OKABE Toru 00280884	The University of Tokyo, Institute of Industrial Science, Professor	Development of a new upgrade recycling technology for titanium	FY2019-2023	51,300	155,300
19H05624	NOJI Hiroyuki 00343111	The University of Tokyo, School of Engineering, Professor	Dynamic femtoliter reactor technology for next generation digital bioassays	FY2019-2023	33,000	138,800
19H05625	AZUMA Masaki 40273510	Tokyo Institute of Technology, Institute of Innovative Research, Laboratory for Materials and Structures, Professor	Novel Negative Thermal Expansion Materials for Thermal Expansion Control	FY2019-2023	48,800	155,000
19H05626	SHIMIZU Hiroshi 00226250	Osaka University, Graduate School of Information Science and Technology, Professor	High performance microbial cell factories development by model based metabolic design and adaptive laboratory evolution	FY2019-2023	26,200	144,200
19H05627	TAMADA Kaoru 80357483	Kyushu University, Institute for Materials Chemistry and Engineering, Professor	Super-resolution live-cell imaging of cell-attached nanointerface using LSPR sheets	FY2019-2023	35,500	149,100
19H05628	MIDORIKAWA Katsumi 40166070	RIKEN, Center for Advanced Photonics, Director	Attosecond Science in the sub-keV region	FY2019-2023	29,300	152,400
19H05629	OTANI Yoshichika 60245610	RIKEN, Center for Emergent Matter Science, Professor	Efficient spin current generation based on coherent magnetoelastic strong coupling state	FY2019-2023	32,800	137,200

○ Broad Section E（7 Projects）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05630	HAYASHI Yujiro 00198863	Tohoku University, Graduate School of Science, Professor	Practical synthesis of rare and structurally complex natural products and the development of the molecules with better biological functions	FY2019-2023	38,000 133,300
19H05631	YAMASHITA Masahiro 60167707	Tohoku University, Advanced Institute for Materials Research, Professor	Innovative Functions Originating from Unexploited Electronic States in Nanowire Metal Complexes	FY2019-2023	65,100 152,900
19H05632	URANO Yasuteru 20292956	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Comprehensive search of cancer specific enzymatic activities and creation of innovative neutron capture therapy probe	FY2019-2023	36,200 154,100
19H05633	Robert E. Campbell 40831318	The University of Tokyo, School of Science, Professor	Directed Evolution of a Palette of Optogenetic and Chemi-Optogenetic Indicators for Multiplexed Imaging of Cellular Metabolism	FY2019-2023	46,900 155,000
19H05634	TERANISHI Toshiharu 50262598	Kyoto University, Institute for Chemical Research, Professor	Nanoscale Element Replacement Science: Structural Transformation of Nanocrystalline Phases and Development of Novel Functions	FY2019-2023	61,900 155,100
19H05635	TOKITOH Norihiro 90197864	Kyoto University, Institute for Chemical Research, Professor	New Main Group Element Chemistry and Materials Science Based on Heavy Aryl Anions	FY2019-2023	49,200 154,700
19H05636	MIYASAKA Tsutomu 00350687	Toin University of Yokohama, Project Professor	Efficiency and durability enhancement of solar cells using lead-free high dimensional halide perovskite materials	FY2019-2023	45,900 151,900

○ Broad Section F（4 Projects）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05637	FUJIWARA Toru 80242163	The University of Tokyo, Graduate School of Agricultural and Life Sciences, Professor	Study on the mechanism of nutrient recognition and coordination of nutrient response in plants	FY2019-2023	33,800 153,900
19H05638	YAZAKI Kazufumi 00191099	Kyoto University, Research Institute for Sustainable Humanosphere, Professor	Molecular basis of bulk transport machinery playing key roles in lipid secretion in plant cells	FY2019-2023	59,000 127,400
19H05639	TAKAGI Hiroshi 50275088	Nara Institute of Science and Technology, Graduate School of Science and Technology, Professor	Integrated understanding of nitric oxide in yeasts and fungi and its application to microbial breeding and drug development	FY2019-2023	33,000 153,800
19H05640	YOSHIDA Minoru 80191617	RIKEN, Center for Sustainable Resource Science, Group Director	Innovative chemical genetics on novel function of endogenous metabolites	FY2019-2023	42,900 154,700

○ Broad Section G（8 Projects）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05641	KONDOH Michio 30388160	Tohoku University, Graduate School of Science, Professor	Regime shifts in coastal marine ecosystems: an empirical approach based on advanced monitoring and nonlinear dynamical theory	FY2019-2023	34,100 153,700
19H05642	OHKI Kenichi 50332622	The University of Tokyo, Graduate School of Medicine, Professor	Elucidation of cognitive and learning mechanism of cerebral cortex by multiscale optogenetics	FY2019-2023	67,000 156,200

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05643	YOSHIMURA Takashi 40291413	Nagoya University, Graduate School of Bioagricultural Sciences, Professor	Understanding the seasonal adaptation mechanism and its application	FY2019-2023	27,800 153,500
19H05644	MORI Ikue 90219999	Nagoya University, Graduate School of Science, Professor	Dissecting the mechanism underlying behavioral regulation through real-time spatiotemporal manipulation of neural circuits	FY2019-2023	22,900 121,700
19H05645	SUGITA Yuji 80311190	RIKEN, Cluster for Pioneering Research, Chief Scientist	Multi-scale molecular dynamics simulation on biomolecular dynamics in crowded cellular environments	FY2019-2023	22,300 152,400
19H05646	Thomas McHugh 50553731	RIKEN, Center for Brain Science, Team Leader	Elucidating the Dynamics of Memory	FY2019-2023	28,300 127,900
19H05647	SAKO Yasushi 20215700	RIKEN, Cluster for Pioneering Research, Chief Scientist	Comprehensive approach toward understanding cell surface receptor functions coupled with membrane structure and lipid composition	FY2019-2023	34,700 117,700
19H05648	ENDO Tamao 30168827	Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology, Senior Fellow	Biology of sugar-alcohol modification in glycan	FY2019-2023	33,700 135,000

○ Broad Section H（4 Projects）　(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05649	YAMAMOTO Masayuki 50166823	Tohoku University, Graduate School of Medicine, Professor	Deciphering Molecular Basis for the Anti-Oxidative Stress Response and Application of the Basis for Disease Prevention and Therapy	FY2019-2023	32,700 153,000
19H05650	NAKAYAMA Toshinori 50237468	Chiba University, Graduate School of Medicine, Professor	Elucidation of pathogenic immunological memory to understand the pathogenesis of intractable inflammatory diseases	FY2019-2023	49,500 155,400
19H05651	KITAGAWA Daiju 80605725	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Comprehensive analysis of molecular machineries for mitotic spindle formation in human cells and its application to development of next generation anti-cancer drug.	FY2019-2023	33,000 153,800
19H05652	SAITO Kazuki 00146705	RIKEN, Center for Sustainable Resource Science, Deputy Director	Genomic origin of chemodiversity in medicinal plants	FY2019-2023	46,000 154,600

○ Broad Section I（7 Projects）　(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget / Budget throughout for the Entire Research Period
19H05653	IWAMA Atsushi 70244126	The University of Tokyo, The Institute of Medical Science, Professor	Deciphering of the epigenetic machinery that determines the hallmarks of hematopoietic stem cell aging	FY2019-2023	33,000 153,800
19H05654	TANAKA Sakae 50282661	The University of Tokyo, The University of Tokyo Hospital, Professor	Establishment of an integrated locomotive science including dynamics of bone-articular cells and regulation by immune system	FY2019-2023	42,900 154,300
19H05655	ISHIKAWA Fuyuki 30184493	Kyoto University, Graduate School of Biostudies, Professor	Anti-cancer therapies aiming for cure through inhibiting tumor-specific responses to environmental fluctuation	FY2019-2022	41,300 128,100
19H05656	OGAWA Seishi 60292900	Kyoto University, Graduate School of Medicine, Professor	Comprehensive studies on the molecular basis of early development and clonal evolution in cancer using advanced genomics.	FY2019-2023	33,000 153,800

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05657	ISHII Masaru 10324758	Osaka University, Graduate School of Frontier Biosciences, Professor	Identification and control of pathogenic osteoclasts	FY2019-2023	30,500	153,700
19H05658	TSUDA Makoto 40373394	Kyushu University, Graduate School of Pharmaceutical Sciences, Professor	Elucidation of abnormal functioning of neuronal circuits underlying neuropathic pain and its application for drug discovery	FY2019-2023	31,400	153,700
19H05659	NODA Masaharu 60172798	Tokyo Institute of Technology, Institute of Innovative Research, Cell Biology Center, Professor	Integrative study of brain mechanisms to induce hypertension	FY2019-2023	35,000	140,500

○ Broad Section J （ 6 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05660	KAGEURA Kyo 00211152	The University of Tokyo, Interfaculty Initiative in Information Studies, Professor	Developing a translation process model and constructing an integrated translation environment through detailed descriptions of translation norms and competences	FY2019-2023	31,400	136,700
19H05661	HIROSE Michitaka 40156716	The University of Tokyo, Graduate School of Information Science and Technology, Professor	Psychological foundations of body scheme transformation via co-embodiment in virtual reality and its application	FY2019-2023	40,200	154,200
19H05662	NAKAJIMA Kengo 20376528	The University of Tokyo, Information Technology Center, Professor	Innovative Methods for Scientific Computing in the Exascale Era by Integrations of (Simulation+Data+Learning)	FY2019-2023	20,300	152,700
19H05663	UENO Maomi 50262316	The University of Electro-Communications, Graduate School of Informatics and Engineering, Professor	Development of e-Testing platform ensuring sustainable reliability	FY2019-2023	29,900	123,900
19H05664	HASHIMOTO Masanori 80335207	Osaka University, Graduate School of Information Science and Technology, Professor	Muon-induced soft error evaluation platform: future prediction based on measurement and simulation	FY2019-2023	62,300	156,300
19H05665	HIGASHINO Teruo 80173144	Osaka University, Graduate School of Information Science and Technology, Professor	Context Recognition of Humans and Objects by Distributed Zero-Energy IoT Devices	FY2019-2023	36,200	154,000

○ Broad Section K （ 4 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Annual Budget	Budget throughout for the Entire Research Period
19H05666	HIRANO Takashi 20208838	Hokkaido University, Research Faculty of Agriculture, Professor	Effects of land conversion from tropical peat swamp forest to oil palm plantations on ecosystem functions and the atmospheric environment	FY2019-2023	27,200	119,200
19H05667	NAGATA Toshi 40183892	The University of Tokyo, Atmosphere and Ocean Research Institute, Professor	Aggregate-biosphere: Unveiling hidden regulatory processes in the oceanic carbon cycle	FY2019-2023	39,500	154,300
19H05668	HIYAMA Tetsuya 30283451	Nagoya University, Institute for Space-Earth Environmental Research, Professor	Pan-Arctic Water-Carbon Cycles	FY2019-2023	45,200	154,700
19H05669	TAKEMURA Toshihiko 90343326	Kyushu University, Research Institute for Applied Mechanics, Professor	Assessment on climate impacts of short-lived climate forcers by composition and region with hierarchical numerical models	FY2019-2023	34,700	153,900

Title of Project：Field-based Cognitive Neuroscientific Study of Word Order in Language and Order of Thinking from the OS Language Perspective

KOIZUMI Masatoshi
(Tohoku University, Graduate School of Arts and Letters, Professor)

Research Project Number：19H05589　Researcher Number：10275597
Keyword：Psycholinguistics, Neurolinguistics, Cognitive Science

【Purpose and Background of the Research】

Many studies have shown that sentences in which Subject precedes Object (SO sentences) have a processing advantage, and hence are preferred, over OS sentences. This empirical evidence of the preference for SO word order, however, is not conclusive, because it comes exclusively from SO languages. It is not clear, therefore, whether the SO word-order preference represented the basic word order of individual languages (= individual grammar view) or reflected a more universal cognitive characteristic of humans (= universal cognition view).

In order to clearly distinguish the impacts of these two types of factors, it is necessary to verify them based on OS languages. This study compares SO languages (Japanese, Tongan) with OS languages (Truku, Kaqchikel) in order to clarify factors that determine word-order preference in human languages and the relationship between word order in language and order of thinking.

【Research Methods】

Specifically, this study will examine the following:

(A) Effects of word order and context on sentence processing load in natural discourse: We will investigate the main effects and interactions (and their timing) of (i) individual grammatical factors, (ii) universal cognitive factors, and (iii) contextual factors, affecting sentence processing load in natural discourse comprehension and production, by means of behavioral experiments, functional brain imaging, and so on.

(B) Effects of context on word order choice in sentence production: We will investigate the main effects and interactions (and their timing) of (i) individual grammatical factors, (ii) universal cognitive factors, and (iii) contextual factors, affecting the choice of word order during natural discourse production, by means of corpus studies, behavioral experiments, eye tracking, and functional brain imaging.

(C) Language acquisition: We will investigate the developmental changes in (A) and (B) above during language acquisition, using naturally occurring utterances, behavioral experiments, eye tracking, functional brain imaging, and so on.

(D) Order of thought: It has been suggested that the most natural order of thought is universally "Actor-Patient-Act" regardless of the mother tongue of the speakers (e.g., Goldin-Meadow et al. 2008). We will test whether this generalization holds true of native speakers of OS languages through the analysis of gesture production, eye tracking, and other.

【Expected Research Achievements and Scientific Significance】

Research such as the above will correct past theories that were biased towards the properties of SO languages and contribute to clarifying cognitive mechanisms that determine language. Furthermore, past research on the relationship of language and thought mainly studied meanings or ideas at the vocabulary level, but this research transcends this to positively clarify the "relationship of language and thought" at higher levels such as the sentence or conversation level. In addition, the United Nations has decided that "endangered languages must be preserved to secure and encourage cultural diversity," and one key significance of this study is its ability to contribute to society in this regard. In conclusion, this study intends to create a new research area that may be called "the Integrated Field-based Comparative Cognitive Neuroscience of Language," which is expected to foster the academic development of young researchers and produce many academic and social ripple effects such as those described above.

【Publications Relevant to the Project】

・Koizumi, Masatoshi, Yoshiho Yasugi, Katsuo Tamaoka, Sachiko Kiyama, Jungho Kim, Juan Esteban Ajsivinac Sian, Lolmay Pedro Oscar García Mátzar. On the (non)universality of the preference for subject-object word order in sentence comprehension: A sentence-processing study in Kaqchikel Maya. *Language* 90: 722-736. 2014.
・Yasunaga, Daichi, Masataka Yano, Yoshiho Yasugi, and Masatoshi Koizumi. Is the subject-before-object preference universal? An ERP study in Kaqchikel Maya. *Language, Cognition and Neuroscience* 30: 1209–1229. 2015.

【Term of Project】FY2019-2023

【Budget Allocation】153,500 Thousand Yen

【Homepage Address and Other Contact Information】

https://researchmap.jp/read0184124/?lang=english

Title of Project：The longitudinal study on the effects of early childhood education and care on child development

NOZAWA Sachiko
(The University of Tokyo, Graduate School of Education, Associate Professor)

Research Project Number：19H05590　Researcher Number：10749302
Keyword：early childhood education and care, child development

【Purpose and Background of the Research】

Numerous longitudinal studies conducted in western countries have shown that the quality of early childhood education and care (ECEC) exerts long-term effects on child development and well-being. The enhancement of the quality of ECEC is issues that take precedence for many countries. However, the quality of the ECEC on offer has not been adequately examined in Japan.

This study will first, longitudinally examine the effects of the quality of ECEC on the development and the sense of well-being of children. The multidimensional quality of ECEC environment including their structural and process-related quality will be scrutinized in detail and will be evaluated. Second, the efforts by local governments to ensure and to improve the quality of ECEC will be assessed. Third, an effective means of ensuring and improving the quality of ECEC will be contemplated and implemented on the basis of the outcomes of the first tow investigations.

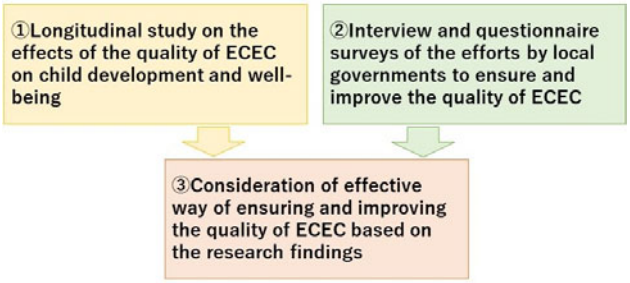
【Research Methods】

In the first part of the study, the factors that influence the development and the sense of well-being of children in ECEC settings will be examined longitudinally from age 0. Consent to participation in the study will be obtained in writing and privacy protection will be ensured for all participants. The study is designed to be unique because it intends to examine the environmental properties of ECEC settings such as the temperature, humidity, CO2 concentrations, and noise levels as indicators of structural quality. These properties will be measured via an environmental sensing system developed by members of the research team for the present study. This same team has also developed a Japanese process quality assessment tool. This tool and the conventional early childhood environmental rating scale (ITERS, ECERS) will be utilized to evaluate process quality. The emotional availability of teachers will also be assessed.

The second aspect of the study, will incorporate interview surveys and a nation-wide questionnaire will be administered to local government officials to examine the efforts of local authorities to ensure and to advance the quality of ECEC environments.

The third part of the study, will be grounded on the findings obtained from the first and second parts. At this stage, the researchers will consider and will implement an effective method of ensuring and augmenting the quality of ECEC settings.

【Expected Research Achievements and Scientific Significance】



Very few longitudinal studies have been conducted in Japan on the effects of ECEC on child development. The present study provides valuable data on the quality of Japanese ECEC. In particular, measurement tools newly developed by the research team of the current study will be used and unique data will be collected. Therefore, this study is expected to inform ECEC policy and practice and to contribute to guarantee and to ameliorate the quality of childcare and education in Japan.

【Publications Relevant to the Project】

S. Nozawa, Y. Yodogawa, M. Takahashi, T. Endo, & K. Akita 2017 Review of International Research on the Quality of Infant and Toddler Education and Care. Bulletin of the Graduate School of Education, The University of Tokyo, Vol.56, 399-419.

Y. Obuchi, T. Yamasaki, S. Toriumi, M. Hayashi, S. Nozawa, M. Takahashi, T. Endo, & K. Akita 2017 Environment Measurement and Action Analysis in Nursery Schools using IoT Cameras. IMPS 2017, P5-8, Nov. 20-22, 2017.

【Term of Project】 FY2019-2023

【Budget Allocation】 85,500Thousand Yen

【Homepage Address and Other Contact Information】

http://www.cedep.p.u-tokyo.ac.jp/projects_ongoing/kaken_s/

【Grant-in-Aid for Scientific Research (S)】

Broad Section A

Title of Project：The Origin and Evolution of Sociality: Developing new theories of human evolution based on collaboration between anthropology and primatology

KAWAI Kaori
(Tokyo University of Foreign Studies, The Research Institute for Languages and Cultures of Asia and Africa, Professor)

Research Project Number：19H05591　Researcher Number：50293585
Keyword：sociality, human evolution, anthropology, primatology, field study

【Purpose and Background of the Research】

Many primates, including humans, are gregarious, living with others in a variety of ways: sometimes peaceful, and sometimes hostile/competitive. Humans in particular are able to coexist not only face-to-face, such as in pairs, families, and co-habitation groups, but also in extremely large, more abstract, “imaginary” groupings, as evidenced by the co-existence of ethnic groups, peoples, and even mankind as a whole. Underpinning these diverse forms of coexistence is nothing less than the higher-order "sociality". The purpose of this study is to construct a new human evolution theory with "sociality" as a key. To this end, we will develop interdisciplinary joint research focusing on dialogue with neighboring fields, and in particular based on collaboration between two field studies: anthropology and primatology.

【Research Methods】

In this study, we will adopt the humanities and social science perspective and methodology of ethnography in the broad sense to observe and describe the interaction process between individuals who meet as social beings, paying attention to "locality" and "totality" in the fields of human cohabitation groups and wild primate groups. However, it is difficult to collect data for comparative analysis of comparable quality and quantity from different types of cohabitant populations with starkly different activities and complexities, for example, across species. Therefore, one of the main research objectives of this study is to develop the survey method itself. The first step will be to apply “focal individual sampling”-a methodological approach common in primatology for observing and describing interactions between individuals - to anthropology, as well as elaborating upon a method of collecting qualitative data on said interactions between individuals.

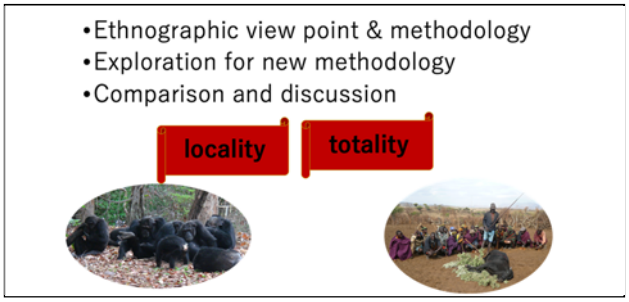


Figure 1　Research methods

【Expected Research Achievements and Scientific Significance】

Studies of various human characteristics within the framework of evolution are under way in many disciplines today. Humanities and social sciences can add new perspectives to the discussion on evolution. In this research, we will conduct a comparative study on "sociality" across regions and cultures, as well as species. This raises the possibility of overcoming the tendency often seen in studies describing evolution towards reductive formulation and reliance on mathematical theory to reduce explanations of social behavior and cultural phenomena to a matter of individuals and genes. After all, the ultimate challenge of anthropology is to reveal "where we come from, who we are, and where we are going," and so it must look for ways to answer those questions.

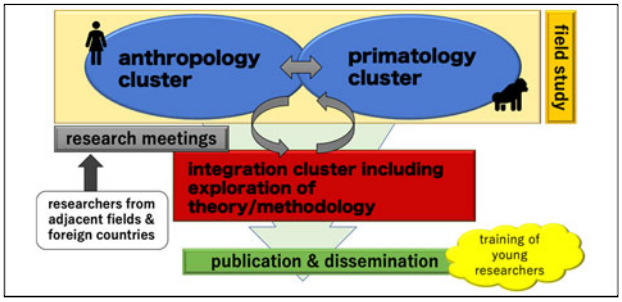


Figure 2　Research procedure and organization

【Publications Relevant to the Project】

Kawai, K.(ed.), *Others: The Evolution of Human Sociality*, Kyoto University Press & Trans Pacific Press. (2019)
Kawai, K.(ed.), *Institutions: The Evolution of Human Sociality*, Kyoto University Press & Trans Pacific Press. (2017)
Kawai, K.(ed.), *Groups: The Evolution of Human Sociality*, Kyoto University Press & Trans Pacific Press. (2013)

【Term of Project】 FY2019-2023

【Budget Allocation】 130,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://human4.aa-ken.jp

Title of Project：The Origin of the Tribal Society in the Near East: Comprehensive Study of the Pre- and Proto-historic Nomadic Cultures in the Arabian Peninsula

FUJII Sumio
(Kanazawa University, Emeritus Professor)

Research Project Number：19H05592　Researcher Number：90238527
Keyword：Arabian Peninsula, nomadic society, tribalism, Neolithic, Bronze Age

【Purpose and Background of the Research】

Our current understanding of the Near East falls into two extremes: ancient civilizations as romantic images, and the Islam as a less familiar geo-political entity. In this sense, it is highly vulnerable and far from comprehensive. Among others, the nomadic society, another aspect of the Near Eastern society, is trivialized into one of historical, geographical and ethnological landscapes and, for this reason, not subject to full-scale human and social sciences with the only exception of anthropological surveys. Archaeology is no exception to this. The only way for breaking through this situation is to step into the drylands outside the *Fertile Crescent* and patiently collect up the archaeological footprints of ancient nomadic tribes.

This study aims to: 1) reorganize the study of pastoral nomadization in the Near East from the conjecture-level argument based on indirect information from the urban-rural society within the Fertile Crescent to the substantive discussion associated with specific site names and precise dates; and, in so doing, 2) shed new light on the historical peculiarity of the Near Eastern society, tracing back to the formation process of nomadic tribes.

【Research Methods】

Toward this goal, this research project implements the comprehensive investigation of pre- and proto-historic nomadic cultures in the Arabian Peninsula, focusing on the five millennia spanning from the early Neolithic when sheep and goats were first domesticated to the Early Bronze Age when full-scale nomadic society based on tribalism is supposed to have been established (**Fig. 1**). The target research fields include the al-Jafr Basin (southern Jordan), the Hijaz Highlands (NW Saudi Arabia), the Majma/Thumamah Plain (central Saudi Arabia), Bahrain Island, and the eastern desert of Egypt.

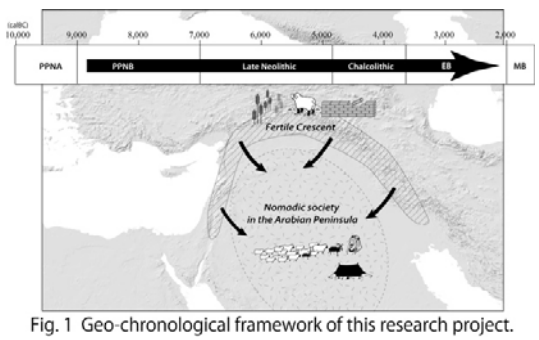


Fig. 1 Geo-chronological framework of this research project.

The focal points of our discussion are the social organization of pre- and proto-historic local nomads and its diachronic and synchronic change during the key five millennia. The investigation approaches the issues from multiple perspectives including palaeo-environment and climatic changes, burial practice and social organization of local nomads and their diachronic/synchronic transition, migration pattern of nomadic tribes viewed from production and circulation of prestige goods and wool-shearing flint tools (i.e. *tabular scrapers*), appearance and expansion of rock-engraved tribe signs (i.e. *wasm*), history of water-use technology, osteological and genetic characteristics of tribesmen and their livestock, and structure and history of corrals. In addition, with a view to exploring the relationship between the internal structure of a cemetery and the social organization behind it, the investigation also plans sociological and anthropological studies of cemeteries of modern nomadic tribes.

【Expected Research Achievements and Scientific Significance】

This study is expected to fundamentally revise the Near Eastern history greatly biased to the urban-rural society within the Fertile Crescent. The challenging revision would deepen our understanding of the bimodality or dimorphism of Near Eastern society past and present.

【Publications Relevant to the Project】

・Fujii, S. (2013) Chronology of the Jafr Prehistory and Protohistory: A key to the process of pastoral nomadization in the southern Levant. *Syria* 90: 49-125.
・Fujii, S. (2018) Bridging the enclosure and the tower tomb: new insights from the Wadi al-Sharma sites, north-west Arabia. *Proceedings of Seminar for Arabian Studies* 48: 83-98.

【Term of Project】FY2019-2023

【Budget Allocation】136,700 Thousand Yen

【Homepage Address and Other Contact Information】

Under construction.

【Grant-in-Aid for Scientific Research (S)】

Broad Section A

Title of Project : Holistic research on the spread and acculturation of early agriculture and on the process of establishment of herding society in East Asia

MIYAMOTO Kazuo
(Kyushu University, Faculty of Humanities, Professor)

Research Project Number : 19H05593 Researcher Number : 60174207
Keyword : Secondary agricultural societies, Herding societies, Environmental change, Immigration, Language spread

【Purpose and Background of the Research】

Prehistoric societies in East Asia consisted of the following four areas: agricultural societies (Chinese mainland), secondary agricultural societies (northeast Asia, southwest China), and herding societies (northern Asia). Among these, temporary cooler and drier climatic conditions triggered the cultural spread and acculturation of secondary agricultural societies in northeast Asia. On the other hand, it is believed that herding societies in the western part of Eurasia became established in areas where agriculture had originally spread due to these cooler and drier climatic conditions. However, little progress has been made in research on how agriculture spread to the Great Wall Region and Mongolian Plateau in East Asia. Therefore, there is a need to clarify the processes by which herding societies came into being as result of cooler and drier climate conditions around 3000 BC. In addition, there is also a need to determine whether herding societies developed from agricultural societies as in the western Eurasian grassland area, or the movement of herding people to the Mongolian Plateau from the middle Eurasian grass land area.

【Research Methods】

We should understand the process of spread or rice agriculture in East Asia in terms of secondary agricultural society. In this case, an original culture of rice agriculture existed, such as unique agricultural stone tools, small rice paddy fields with foot passes and temperate Japonica, which is different to that of the original location in the lower and middle Yangtze River basin. It is probable that these agricultural cultures were established in the eastern Shandong Peninsula. The occurrence of cooler and drier climatic conditions around 3000 BC caused extensive damage on the Shandong Peninsula, probably triggering the production of small rice paddy fields with foot passes and temperate Japonica more suited to the cooler environment. The results of boring core and phytolith analysis carried out at Yanjiaquan Site, Qixia Prefecture, Shandong Province suggest that the Longshan culture probably had rice paddy fields. We will conduct excavations at Yanjiaquan Site to measure and analyze the DNA of charred rice grains in order to elucidate the processes by which small rice paddy fields with foot passes and temperate Japonica were established. And we will also make clear the processes by which domesticated grains spread through the analysis of the kernel stamps of pottery. On the other hand, in order to understand how herding societies became established from early agriculture in northern Asia, we will clarify changes in subsistence activities between the Neolithic and Bronze ages in the Mongolian Plateau by examining dietary changes through the C13 isotopic analysis of human bones. We will excavate at burial cemeteries dating to the Neolithic or early Bronze Age to collect human bones for research on the Mongolian Plateau. Research on the musculoskeletal stress markers (MSMs) of humans proves the existence of differences in subsistence activities during this transitional time. In addition, physical anthropological research and strontium isotopic analysis of human bones will serve to elucidate human movements during prehistoric times.

【Expected Research Achievements and Scientific Significance】

By comparing secondary agriculture in northeast Asia and herding societies in northern Asia, we will shed light on original aspects of human history in East Asia which differ to those of Europe and West Asia. This research will provide insights into the background behind the establishment of independent ancient states in each area. In addition, we will also seek to provide an understanding of human movements and the spread of language groups in the prehistory of East Asia.

【Publications Relevant to the Project】

Kazuo Miyamoto. Early Agriculture in North-east Asia and the Origin of the Yayoi culture. Douseisha Press: Tokyo, pp.311, 2017 (in Japanese).
Kazuo Miyamoto ed. Excavations at Emeelt Tolgoi Site: The third Report on Joint Mongolian -Japanese Excavations in Outer Mongolia. Kyushu University, pp.87, 2018.

【Term of Project】 FY2019-2023

【Budget Allocation】 70,700 Thousand Yen

【Homepage Address and Other Contact Information】

Under construction

Title of Project： Development of speech communication and its correlates of brain, cognition and motor system: A longitudinal cohort study of typically and atypically developing infants

MINAGAWA Yasuyo
(Keio University, Faculty of Letters, Professor)

Research Project Number：19H05594　Researcher Number：90521732
Keyword：Autistic spectrum disorder, Language acquisition, Social cognition, Functional connectivity, fNIRS

【Purpose and Background of the Research】

Autistic spectrum disorder (ASD) is characterized by difficulties with verbal and social communication. Previous studies on cognitive neuroscience have pointed out that ASD primarily involves problems with brain function, in particular with brain connectivity. Although it is assumed that this difference in functional brain connectivity is expressed from an early developmental stage, there is hardly any studies examining both the typical and atypical development of language, social functions, functional brain connectivity and activities in the first year of life.

This study aims to reveal the longitudinally evolving characteristics of brain function development, including functional brain connectivity, various perceptions, cognitions, and motor abilities in infants who are at risk for ASD (risk infants) and typically developing (TD) infants (Figure 1). The purpose of this project is to clarify (1) how these developmental characteristics are involved in the acquisition of language communication, and (2) which developmental characteristics predict future developmental disorders.

【Research Methods】

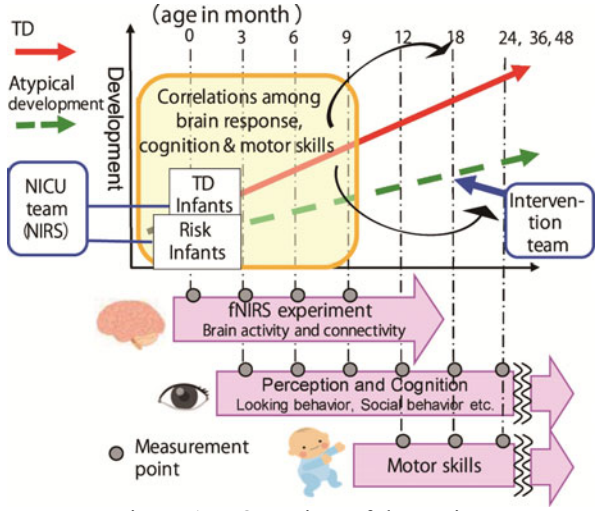


Figure 1.　Overview of the project

The cohort consists of two groups, namely risk infants (siblings of ASD or very premature infants) and typically developing infants. Their brain function, cognitive functions, and motor abilities will be measured longitudinally every 3 or 6 months until 3-4 years-old. Since this study aims to continue and develop the small-scale cohort of the previous project (Kiban A), this study, as in the past, consists of 3 types of experiments: (1) brain function tests using fNIRS (speech and social stimuli), (2) tests for various cognitive functions using behavioral methods (e.g. eye tracking, tests for fine and gross motor skills), (3) developmental examinations and questionnaires. We will develop new analysis methods for the brain function data and motor skill data. In particular, the motor data involves the use of the latest image engineering techniques to quantify and evaluate the data and is modeled by applying deep learning to the large-scale data sets obtained. While conducting this study, a system will be in place to appropriately evaluate and intervene when necessary should participating infants develop language or other problems.

【Expected Research Achievements and Scientific Significance】

From objective (1), it will be possible to explain the relationships between motor skills and social cognitive abilities and how these relationships are involved in language acquisition and development. This will not only illustrate the cognitive neuroscience basis behind language development but will also provide important insights into the specificity and universality of human language. We will also elucidate the mechanisms behind the communication disorder in ASD and provide insights into the intervention methods. Objective (2) will be significant in that it will provide adjunct indicators to help with the early detection and diagnosis of ASD.

【Publications Relevant to the Project】

・Arimitsu, T., Minagawa, Y* et al. (2018) The cerebral hemodynamic response to phonetic changes of speech in preterm and term infants: The impact of postmenstrual age. *Neuroimage: Clinical*, 19: 599-606.
・Liang, Z., Minagawa, Y. et al. (2018) Symbolic time series analysis of fNIRS signals in brain development assessment. *Journal of Neural Engineering* 15(6): 066013.

【Term of Project】 FY2019-2023

【Budget Allocation】 147,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://duallife.web.fc2.com/i/next.html
keio.infantg@gmail.com

【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project：Reconstruction of atmospheric carbon dioxide concentration during the last 6 million years and the study of the interaction between atmospheric carbon dioxide and climate

YAMAMOTO Masanobu
(Hokkaido University, Faculty of Environmental Earth Science, Associate Professor)

Research Project Number：19H05595　Researcher Number：60332475
Keyword：Climate change, Environmental change, carbon dioxide, global warming, greenhouse effect, ocean drilling

【Purpose and Background of the Research】

Ice cores have provided a highly valuable archive of past CO_2 levels spanning the past 800 ka. Beyond ice core records, marine sediment archives using foraminifera $\delta^{11}B$ and alkenone $\delta^{13}C$ proxies have been used for CO_2 reconstruction, but they do not yield high resolution records sufficient to resolve orbital-scale cycles. Blue ice provided spot data at 1 Ma and 2.7 Ma. There has been no continuous high resolution CO_2 record beyond 800 ka (Fig. 1).

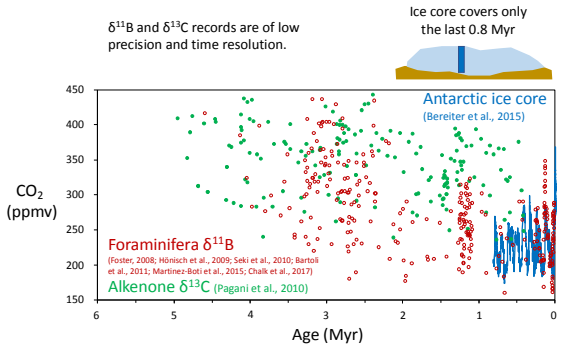


Fig. 1. Limitation of atmospheric CO_2 reconstruction.

In this study, we analyze the $\delta^{13}C$ of long-chain n-fatty acids ($\delta^{13}C_{FA}$) in sediments from International Ocean Discovery Program (IODP) Site U1445 on the Indian margin, Bay of Bengal, to generate a 1,700-year resolution record of CO_2 spanning the last 6 Myr. Based on reconstructed CO_2 record, we estimate climate sensitivity in the Pliocene, and understand the mechanisms of CO_2 variation and the interaction between CO_2 and climate.

【Research Methods】

We estimate CO_2 concentration from 6 ma to 1.5 Ma, estimate climate sensitivity in the Pliocene, discuss the mechanisms of CO_2 variability, the origin of glacial -interglacial cycles, and the cause of global warming around 5.6 Ma. Samples are the sediments taken from Site U1445 in the Indian margin of the Bay of Bengal. The $\delta^{13}C$ of long-chain n-fatty acids is analyzed to estimate the CO_2 concentration of the past. The $\delta^{18}O$ of benthic foraminifera is analyzed to create the age-depth model of Site U1445.

【Expected Research Achievements and Scientific Significance】

Interaction between CO_2 and climate is a key process in climate changes. However, robust CO_2 records are available only during the last 800 ka. The reconstruction of CO_2 concentration before 800 ka will be highly significant, enabling us to discuss the interaction between CO_2 and climate based on robust evidence.

Climate sensitivity is necessary to be determined to project future warming trend. The warmer Pliocene period (3 Ma) is now a target to determine climate sensitivity in the warmer Earth. The reconstruction of CO_2 concentration during the Pliocene should increase the accuracy of the climate sensitivity, which contributes to the projection of future climate.

Glacial-interglacial cycles became significant around 2.7 Ma. CO_2 decrease is a candidate of this trigger, but this is not proven by paleoclimte evidence. The high resolution CO_2 record enables us to discuss how carbon cycles were involved in the beginning of glacial-interglacial cycles.

Global warming occurred from 5.7 Ma to 5.5 Ma. This warming was a unique warming in the general cooling trend during the last 10 million years. The CO_2 record in this period enables us to discuss how CO_2 concentration was related to this global warming.

【Publications Relevant to the Project】

None

【Term of Project】

FY2019-2023

【Budget Allocation】

155,500 Thousand Yen

【Homepage Address and Other Contact Information】

https://geos.ees.hokudai.ac.jp/yamamoto/

Title of Project：Head and tail of massive earthquakes: Mechanism arresting growth of interplate earthquakes

HINO Ryota
(Tohoku University, Graduate School of Science, Professor)

Research Project Number：19H05596　Researcher Number：00241521
Keyword：megathrust earthquake, slow-slip, tsunami-earthquake, deep-sea paleoseismology

【Purpose and Background of the Research】

The behavior of the shallow part of the plate boundary fault, which is deeply involved in the growth of megathrust earthquakes, shows remarkable variations along the Japan Trench. This study will reveal the mechanism arresting growth of interplate earthquakes by clarifying the characteristics of the shallow plate boundary in the northern part of the Japan Trench, where no massive earthquake such as the 2011 Tohoku earthquake has occurred. In the northern part of the Japan Trench, slow-slips that occur repeatedly over several years and tsunami earthquakes, medium-sized slip events near the trench axis that occur at intervals of > 100 years, play major roles in releasing slip deficit. The occurrence history (especially frequency) of the tsunami earthquake, and the balance of the relative motion between the land and the oceanic plates in this region is modeled.

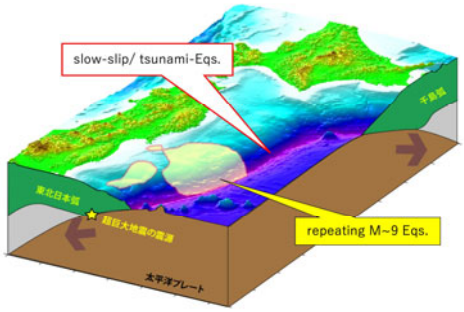


Figure 1　Along-trench variation of behaviors of megathrust

【Research Methods】

- Slip distribution of periodic slow-slip

We will clarify the spatiotemporal evolution of slow-slips by monitoring small repeating earthquakes. The slip distribution of slow-slips up to the shallowest part of the plate boundary will be imaged by seafloor broadband seismic and crustal deformation observations.

- Deep-sea paleoseismology of tsunami earthquake

The generation history of tsunami earthquakes is reconstructed by identifying and dating traces corresponding to tsunami earthquakes from deep-sea sediment cores around the Japan Trench. Analysis of physical property of the cores is key to identification of subtle traces of tsunami earthquakes as well as inspection of sediment cores from the landward slope.

- Modeling of slow-slip and tsunami earthquake

We build models of slow-slips and tsunami earthquakes based on observation results. We seek the mechanism prohibiting large-scale slips along the middle Japan Trench from propagating to the north, based on the topographic and geological structures delimiting the rupture zone. Combining these element models, we will simulate the process composed of repeating huge earthquakes in the middle and dominance of slow-slips/tsunami earthquakes in the north.

【Expected Research Achievements and Scientific Significance】

Identifying the conditions under which a large earthquake occurs is not only important in understanding the nature of earthquakes, but it is also effective to give reliable estimation of the size of future earthquakes. Through this study, focusing on the area where large-scale slips have never occurred while adjacent to the area where large-scale earthquakes occur, we unravel the conditions that large-scale earthquakes do not occur. Together with the features common to areas of past massive earthquakes, the results of this study deepen the understanding what make massive earthquakes of subduction thrusting events.

【Publications Relevant to the Project】

・Ikehara, K., K., Usami, T. Kanamatsu, et al., Spatial variability in sediment lithology and sedimentary processes along the Japan Trench: Use of deep-sea turbidite records to reconstruct past large earthquakes, Geological Society, London, Special Publications, 456, DOI: 10.1144/SP456.9, 2018.
・Uchida, N., T. Iinuma, R. M. Nadeau, R. Bürgmann, R. Hino, Periodic slow slip triggers megathrust zone earthquakes in northeastern Japan, Science, 351, 488-492, doi: 10.1126/science.aad3108, 2016.

【Term of Project】FY2019-2023

【Budget Allocation】154,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://jdash.org
hino@tohoku.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section B

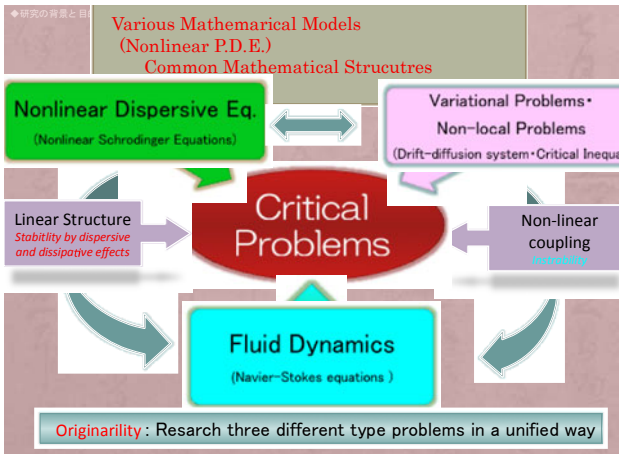
Title of Project：Creation of advanced method in mathematical analysis on nonlinear mathematical models of critical type

OGAWA Takayoshi
(Tohoku University, Graduate School of Science, Professor)

Research Project Number：19H05597　Researcher Number：20224017
Keyword：Nonlinear Partial Differential Equations, Variational Method, Critical Inequalities, Harmonic Analysis

【Purpose and Background of the Research】

Many of mathematical models are described by nonlinear partial differential equations and such equations typically have both linear and nonlinear structures therein. The linear part is described by partial differential operators by local space-time variables and the nonlinear part is produced by the interaction between different physical quantities and the linear structure stabilize the system while the nonlinear part causes instability of the model. Between those effects, there exists a sort of problems where the both effects are analytically balanced. We call this type of problem as the "Critical Problems" and it is our main subject of this project. Problems of this type are interesting both from an applied and a theoretical mathematical point of view. They often lead to new and fascinating open problems. A serious difficulty in the study of such "critical problems", is that the analysis derived through perturbation theory is not directly applicable and a new methodology has to be developed.



【Research Methods】

The critical problems are in general equipped by standard and natural structures corresponding to conservation laws, for the conservation of mass, momentum and energy. These standard structures are given by entropy dissipation, Galilei invariance as well as by conformal invariance. These structures are essential in the study of the critical problems. One of the main tools used for this research are variational methods. Also fundamental for our study is the possibility of developing new functional inequalities of critical type. In particular with the aid of functional and harmonic analysis tools such as real interpolation methods, we develop a new critical inequalities such as Trudinger-Moser type involving Shannon-Renyi Entropy functionals and develops the linear estimates for dispersive space time estimates and end-point maximal regularity for the dissipative system which will be then used to better understand the ``critical problems" and even beyond the critical problem.

【Expected Research Achievements and Scientific Significance】

Important unsolved problems, such as the well known millennium ones, which describe central issues in mathematics are still wide open. An important challenge is to find unified methods to overcome the difficulties that stem from the interaction of both dissipative and dispersive behaviors. We believe that a finer analysis on the nonlinear structure make us possible to treat those unsolved problems after establishing a new type of critical estimates for linear and nonlinear structures including dissipative and dispersive estimate such as Strichartz estimate and maximal regularity estimates.

【Publications Relevant to the Project】

「Real Analytic Method for Nonlinear Evolutional Partial Differential Equations」 Springer-Verlag 570pp, 2019, to appear.

【Term of Project】 FY 2019-2023

【Budget Allocation】 100,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.math.tohoku.ac.jp/~ogawa-staff/

Title of Project：Search for a critical point and first order phase transition of high density quark-nuclear matter via higher order fluctuations and particle correlations

ESUMI Shinichi
(University of Tsukuba, Faculty of Pure and Applied Sciences, Institute of Physics, Associate Professor)

Research Project Number：19H05598　Researcher Number：10323263
Keyword：critical point, 1st order phase transition, QCD phase structure, Quark Gluon Plasma

【Purpose and Background of the Research】

High-temperature and/or high-density state of matter in early universe or inside of neutron star is called as Quark Gluon Plasma (QGP) and is being formed and studied in high energy heavy ion collisions in order to reveal the QCD phase diagram of quark-nuclear matter that is governed by Quantum Chromo Dynamics (QCD). The phase transition at high-temperature region is considered as smooth cross-over transition as investigated at RHIC and LHC experiments, while the transition at the high-density region is supposed to be the 1st order that would have dis-continuous boundary between quark and hadron phases. In between these regions, we expect critical point at the end of the 1st order phase transition, however they are not yet experimentally observed. Finding the critical point and the 1st order phase transition is one of the ultimate goals of QGP physics to understand the QCD phase structure.

【Research Methods】

Going from the cross-over phase transition in the high-temperature region of QCD phase diagram towards the rich phase structures in the high-density region, we focus on the critical point and the 1st order phase transition in the high-density area of the phase diagram by scanning the beam energy of heavy-ion collisions around a few 10 GeV per nucleon-nucleon at the center of mass in order to search for a possible existence of the critical point and the 1st order phase transition. The higher order fluctuations of conserved quantities and the multi-particle correlations including directed anisotropic flows will be investigated as they are sensitive to a possible signal from the critical point and the 1st order phase transition.

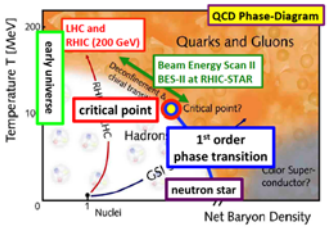


Figure 1: QCD phase diagram

【Expected Research Achievements and Scientific Significance】

The conserved number can also vary within a selected acceptance window, such number fluctuation could be used to measure the correlation length of the system and to search for the critical phenomena. Especially the higher order fluctuations are expected to be more sensitive to the critical point and the phase transition. Figure 2 (left) shows the net-proton 4th order fluctuation as a function of colliding beam energy, and an interesting non-monotonic behavior has been observed around 10-30GeV, which might be a possible indication of the critical point. In order to confirm the possible signature from the critical phenomena, we establish collaboration between experimental and theoretical groups with improved measurements and data analysis methods as well as model calculations. The expected improvement of detection sensitivity from the non-statistical fluctuation can be seen in Figure 2 (right) as a function of |Δη| acceptance.

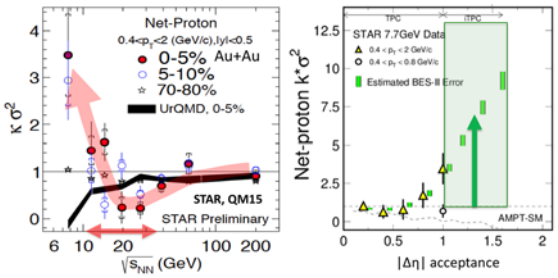


Figure 2: net-proton 4th order fluctuation as a function of energy (left) and expected Δη dependence (right)

【Publications Relevant to the Project】

・Energy dependence of moments of net-proton multiplicity distributions at RHIC, The STAR collaboration, L. Adamczyk, et al., Phys. Rev. Lett. 112 (2014) 32302
・A general procedure for detector–response correction of higher order cumulants, T.Nonaka, M.Kitazawa, S.Esumi, Nucl. Instr. Meth. A906 (2018) 10-17

【Term of Project】

FY2019-FY2023

【Budget Allocation】

79,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.star.bnl.gov
http://www.u.tsukuba.ac.jp/~esumi.shinichi.gn/welcome.html
esumi.shinichi.gn@u.tsukuba.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project：Systematical geometric analysis and asymptotic analysis for evolution equations

ISHIGE Kazuhiro
(The University of Tokyo, Graduate School of Mathematical Sciences, Professor)

Research Project Number：19H05599　Researcher Number：90272020
Keyword：evolution equation, geometric analysis, asymptotic analysis, power concavity, blow-up problems

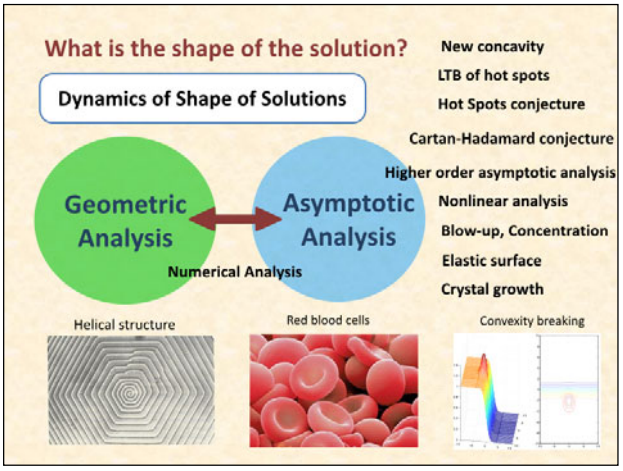
【Purpose and Background of the Research】

Many of the mathematical models appearing in mathematical sciences such as physics, chemistry, biology and astronomy are described by use of solutions of partial differential equations. Geometric analysis and asymptotic analysis give fruitful information in the study of the mathematical models. In particular, it is a natural intellectual desire to know the behavior of the solutions and their geometric properties. Furthermore, geometric analysis and asymptotic analysis are strong methods for the study of nonlinear phenomena related to blow-up and aggregation. In this research project we study the behavior of solutions of evolution equations and their system by use of geometric analysis and asymptotic analysis and investigate qualitative properties of the solutions. Furthermore, we try to find new interesting problems and the directions of their related fields.

【Research Methods】

This research project concerns with the simple problem "what is the shape of solutions of evolution equations and their systems?" We study geometric properties of the solutions and try to understand the mechanism of the change of the shape of the solutions. This project is based on the geometric analysis and the asymptotic analysis. Firstly, we study power concavity of solutions of elliptic equations and evolution equations and their systems and try to find a new notion of concavity. Our analysis is based on viscosity solutions and we expect that it is applicable to various nonlinear evolution equations. Furthermore, developing the asymptotic analysis, we study the behavior of landmark points such as hot spots and critical points of the solutions. As applications of our studies, we treats various nonlinear phenomena such as blow-up problems, aggregation of diffusion substances, convexity breakings, higher-order asymptotic analysis of solutions of evolution equations including higher-order parabolic equations and their systems, the structure of solutions of nonlinear elliptic equations, the movement of elastic surfaces and crystals, and the solutions with dynamical boundary conditions.

We hire several postdoc students and research assistants for our research project. We also organize international workshops related to geometric properties of solutions of evolution equations and blow-up problems.



【Expected Research Achievements and Scientific Significance】

The Research organization has unique viewpoints and research methods for geometric analysis and asymptotic analysis. Combining recent progresses in mathematical sciences, we can expect to obtain creative research results. We think that the results in this project greatly contribute to the development of the entire analysis since the project is related to fundamental inequalities in analysis and various fields in nonlinear phenomena.

【Publications Relevant to the Project】

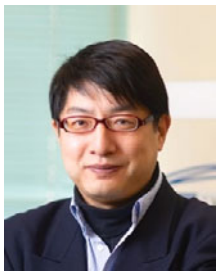
F. Gazzola, K. Ishige, C. Nitsch, P. Salani eds., "Geometric Properties for Parabolic and Elliptic PDE's", Springer Proceedings in Mathematics & Statistics, Vol. 176, Springer International Publishing Switzerland (2016).
K. Ishige and P. Salani, Parabolic power concavity and parabolic boundary value problems, Math. Ann. 358 (2014), 1091−1117.

【Term of Project】 FY2019-2023

【Budget Allocation】 107,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ms.u-tokyo.ac.jp/teacher/ishige.html
ishige@ms.u-tokyo.ac.jp



Title of Project：Investigation of nuclear spin-current science and nuclear thermoelectric conversion

SAITOH Eiji
(The University of Tokyo, Graduate School of Engineering, Professor)

Research Project Number：19H05600　Researcher Number：80338251
Keyword：Spintronics, Spin current, Nuclear spintronics, Nuclear spin current

【Purpose and Background of the Research】

In this project, we will explore a new research field "Nuclear spin-current science" connecting nuclear spins and spin-current science. Over the past decade, the spin-current science has produced various functions for electronic devices by utilizing spin angular momentum of electrons. On the other hand, spin angular momentum of nuclei has not been used in terms of spin currents. Therefore, in this project, we will investigate spin current phenomena caused by nuclear spins and expand the spin current science into a larger framework including nuclear spin currents.

Spintronics aims to produce new physical properties and electronic functions by utilizing electron spins. Spintronic devices have been developed as basic technologies essential to information society, such as the realization of magnetic random access memories (MRAMs). Spin current, the spin counterpart of the electronic charge current, is one of the most important concepts in spintronics, with most of the spintronic functions related to the angular momentum carried by the spin currents. Various other concepts related to angular momentum in solids, such as magnetizations and phonons, have already been united to the spin current framework. In contrast, despite the potential of nuclear spins to be utilized in quantum sensing and information transport technologies, they have remained unconnected to the spin-current science.

Under such backgrounds, we recently discovered "nuclear spin pumping" which generates spin currents from nuclear spins. The discovery established a detection method for nuclear spin currents, enabling investigations of nuclear spin-current physics. In this project, we will investigate nuclear spin-current phenomena and explore a new research field "Nuclear spin-current science".

【Research Methods】

The discovery of the nuclear spin pumping realizes spin current generation from nuclear spins and opens the way for connecting nuclear spins and spin current science.

Thanks to this discovery, the detection and quantitative evaluation methods for the nuclear spin currents are established for the first time. By combining the detection method and conventional wisdom of the electron spin-current science, it is now possible to discover and develop further nuclear spin-current phenomena and explore the nuclear spin-current science.

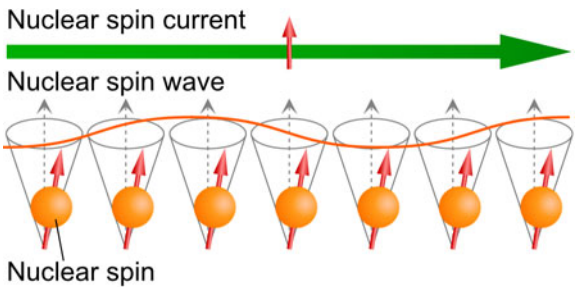


Figure 1 Nuclear spin current

【Expected Research Achievements and Scientific Significance】

In this project, we will explore a new research field "Nuclear spin-current science". By combining nuclear spins and spin current science, we will realize intrinsically new and valuable phenomena, and construct an extended framework of spin current science. The nuclear spin-current science paves the way to utilize the spintronics technologies in various research fields such as solid state chemistry, materials chemistry, and biology, where nuclear spins are used as a probe for physical properties. We aim to contribute not only to the nuclear spin-current physics but also to a wide range of sciences.

【Publications Relevant to the Project】

・E. Saitoh, M. Ueda, H. Miyajima, and G. Tatara, "Conversion of spin current into charge current at room temperature: Inverse spin-Hall effect" Applied Physics Letters **88**, 182509 (2006).
・Y. Shiomi, J. Lustikova, S. Watanabe, D. Hirobe, S. Takahashi, and E. Saitoh, "Spin pumping from nuclear spin waves" Nature Physics **15**, 22-26 (2019).
・K. Harii, Y.-J. Seo, Y. Tsutsumi, H. Chudo, K. Oyanagi, M. Matsuo, Y. Shiomi, T. Ono, S. Maekawa, and E. Saitoh, "Spin Seebeck mechanical force" Nature Communications **10**, 2616 (2019).

【Term of Project】FY2019-2023

【Budget Allocation】158,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://saitoh.t.u-tokyo.ac.jp
eizi@ap.t.u-tokyo.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project：Study for the violation mechanism of fundamental symmetry using the cold atom/molecular interferometer with optical lattice

SAKEMI Yasuhiro
(The University of Tokyo, Graduate School of Science, Professor)

Research Project Number：19H05601　Researcher Number：90251602
Keyword：Fundamental symmetry, EDM, Optical lattice, Cold molecule, Baryon generation

【Purpose and Background of the Research】

In the Standard Model (SM) of elementary particle physics, the fundamental discrete symmetries of charge conjugation (C), parity (P) and time reversal (T) play a significant role, and advance our knowledge about different interactions. Of these, the combined CP symmetry are the least well understood, and they hold valuable clues for unraveling the secrets of nature. All subatomic particles are postulated to possess an intrinsic property known as a permanent electric dipole moment (EDM) due to their spin. The EDM of an atom is a combination of those of each constituent particle and also CP-violating interactions between the particles.

Paramagnetic atoms such as Fr, which have a single valence electron in their outer shell, are sensitive to subtle signals associated with CP violations in the leptonic sector, i.e., the EDM of the electron. Since an electron is a point particle with a non-zero spin, it may possess an intrinsic EDM. However, the electron EDM is predicted to be very small. If the e-EDM was identified, it could be used to indirectly investigate particles with masses of tera electron Volts or higher, which are beyond the reach of even planned high-energy particle colliders. The mass hierarchy of super-symmetry (SUSY) particles could also be studied.

【Research Methods】

The EDM for Fr atoms will be measured by atomic interferometry. In this experiment, we will use quantum optics techniques such as laser cooling and trapping in an optical lattice to achieve longer interaction times.

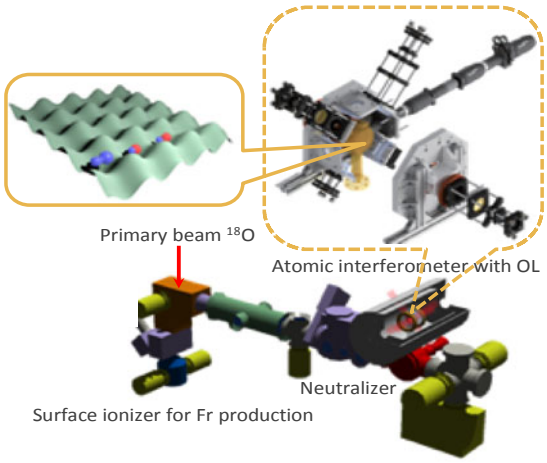


Figure 1 Experimental apparatus for EDM search with optical lattice interferometer

Low-energy Fr ions will be produced by nuclear fusion reactions at RIKEN AVF cyclotron, and will be neutralized, rapidly decelerated and trapped by laser cooling in a magneto-optical trap (MOT). They will then be transferred to an optical lattice equipped with electric field plates (Figure 1). The spin precession of the Fr atoms will be measured using the Ramsey resonance method. We will try to realize the cold polar-molecule: Fr-Sr in the optical lattice to achieve the higher EDM measurement accuracy ~10^{-30}ecm.

【Expected Research Achievements and Scientific Significance】

Although the standard model succeeds in explaining various phenomena, the number of parameters possessed in the theory is unnatural. Then aiming at a more fundamental understanding, it is necessary to pursue the origin of conservation law and fundamental symmetry. In this project, by controlling the atoms/molecules to an extreme quantum state, the quantum correction effects from SUSY is amplified, and ultra-precision measurement technique of the EDM will be established. Furthermore, information on the mass hierarchy of heavy SUSY particles of 10 TeV or more will be obtained.

【Publications Relevant to the Project】

・Correlation Trends in the Hyperfine Structures of ^{210,212}Fr B.K.Sahoo, D.K. Nandy, B.P. Das, and Y. Sakemi
Phys.Rev. A91 (2015) 042507
・Effective multiple sideband generation using an electro-optic modulator for a multiple isotope magneto-optical trap A.Uchiyama, K.Harada, and Y.Sakemi et al. Review of Scientific Instruments 89 (2018) 123111

【Term of Project】FY2019-2023

【Budget Allocation】154,200 Thousand Yen

【Homepage Address and Other Contact Information】

https://sites.google.com/cns.s.u-tokyo.ac.jp/fundamental-symmetry-group
sakemi@cns.s.u-tokyo.ac.jp

Title of Project：Physics and Functions of Van der Waals Heterostructures

IWASA Yoshihiro
(The University of Tokyo, Department of Applied Physics, Professor)

Research Project Number：19H05602　Researcher Number：20184864
Keyword：Two-dimensional materials, Van der Waals heterostructures, nonlinear phenomena, magnetism, field effect

【Purpose and Background of the Research】

Recent progress of materials science has uncovered that monolayer or a few layer materials can exist and exhibit peculiar properties that are distinct from their bulk counterpart. Nowadays so called two-dimensional (2D) materials have grown one of the largest field in materials science. Van der Waals (vdW) heerostructures, formed by laminating different 2D materials, are revolutionary materials, because they do not require any lattice matching which used to be a prerequisite in the conventional epitaxy.

The purpose of this research is to fabricate a variety of vdW heterostructures and to discover novel properties and functions that are impossible to realize in single materials.

In particular we focus on two subjects. One is the symmetry control of vdW heterostructures, and their nonreciprocal transport and anomalous photovoltaic effects. The second is the novel superconducting and magnetic phases arising from the proximity effects at the vdW heterointerfaces.

【Research Methods】

The project employ both the transfer lamination methods and molecular beam epitaxy (MBE) methods. The former includes stacking of monolayer materials with twisted angles, which allow us fabrication of materials that never exit in nature. That former allows us to fabricate monolayer materials that are hardly cleaved with large areas. We are also able to combine these two methods for making new vdW heterostructures.

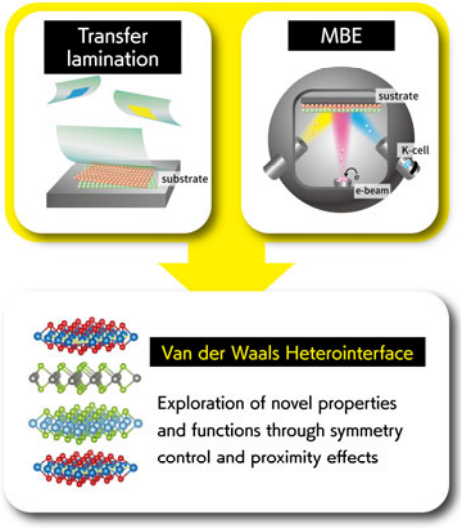


Figure 1

【Expected Research Achievements and Scientific Significance】

First, we fabricate a variety of vdW heterostructures taking the advantage of wealthy materials family with controlled symmetry. For instance, when we make a vdW heterostructure using materials of three-fold symmetry and two-fold symmetry, the heterostructure loses its rotational symmetry. When the structure is formed in such a way that the mirror axes of the two 2D materials coincide with each other, the in-plane dipole emerges. Such a controllability is substantially increased by introducing twisting angles. With this symmetry reduced system, we measure the nonlinear transport properties, including nonreciprocal transport and anomalous photovoltaic effect. With these, we clarify the effect of quantum phases in the momentum space, such as Berry connection, Berry curvature, and Berry curvature dipole.

Second, we aim at realizing new magnetic and superconducting phases originated from the proximity of distinct states of matter as well as elementary particles in neighboring materials. Particularly, in optics, we will focus on the exciton-magnon interaction in the vdW interface, which have been investigated in single materials so far. This offers a new opportunity to apply the vdW interfaces to the highly efficient conversion from microwave to visible light.

【Publications Relevant to the Project】

・Enhanced intrinsic photovoltaic effect in tungsten disulfide nanotubes, Y.J. Zhang, T. Ideue, M. Onga, F. Qin, R. Suzuki, A. Zak, R. Tenne, J. H. Smet and Y. Iwasa, *Nature*, **570**, 349 (2019).
・Bulk rectification effect in a polar semiconductor T. Ideue, K. Hamamoto, S. Koshikawa, M. Ezawa, S. Shimizu, Y. Kaneko, Y. Tokura, N. Nagaosa & Y. Iwasa, *Nature Physics*, **13**, 578 (2017).

【Term of Project】FY2019-2023

【Budget Allocation】154,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://iwasa.t.u-tokyo.ac.jp/index.html
iwasa@ap.t.u-tokyo.ac.jp

Title of Project：Nonequilibrium states of low-dimensional quasiparticles in a mesoscopic quantum Hall system

FUJISAWA Toshimasa
(Tokyo Institute of Technology, School of Science, Department of Physics, Professor)

Research Project Number：19H05603　Researcher Number：20212186
Keyword：mesoscopic system, quantum Hall system, low-dimensional quasiparticle, nonequilibrium state

【Purpose and Background of the Research】

Quasiparticles play essential roles in condensed matter physics, where collective motion that cannot be explained with a single-particle picture can be understood with quasi-particles. The quantum Hall system, which is a kind of two-dimensional topological insulators that appear in a high magnetic field, shows intriguing excitation modes in the insulating bulk states and peculiar non-equilibrium states in the unidirectional chiral edge states. These characteristics can be explained with low-dimensional quasiparticles, such as fractional charges like $e/3$ and $e/5$ and skyrmions (spin texture) in the bulk and plasmons (charge) and spinons (spins) in the edge, as shown in Fig. 1. It would be innovative if one can find a novel application scheme by controlling nonequilibrium states of these characteristic quasiparticles.

The objective of this work is to explore novel nonequilibrium dynamics of such low-dimensional quasiparticles and to develop application schemes for nonequilibrium thermodynamics and topological quantum engineering. The specific focus of interest in this project is controlling quasiparticles toward braiding operations and quantum-Hall heat engines.

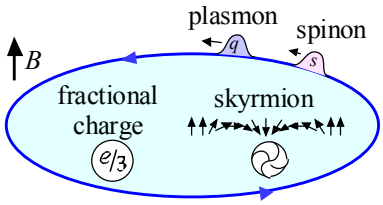


Fig. 1. Low-dimensional quasiparticles.

【Research Methods】

We develop mesoscopic quantum Hall systems by fabricating nanostructures on an AlGaAs/GaAs heterostructure. Nonequilibrium quasiparticles can be controlled and analyzed with a tailored mesoscopic quantum Hall system. One can integrate functional devices such as quantum point contacts (QPCs), quantum dots (QDs), and quantum anti-dots to construct a circuit for low-dimensional quasi-particles, as shown in Fig. 2.

Nonequilibrium charge, spin, and heat transport associated with quasiparticles can be investigated for example with an ultra-fast scanning optical polarization microscope. A wave packet can be injected by applying a pulse to a QD (charge injector) and can be analyzed with a QD energy spectrometer, a time-resolved charge detector, and a current noise analyzer. Microscopic edge structure can be identified particularly in the fractional quantum Hall regime. Manipulation of single quasiparticles can be extended to design a braiding operation. A quantum-Hall heat engine can be implemented by designing an efficient conversion between heat and work.

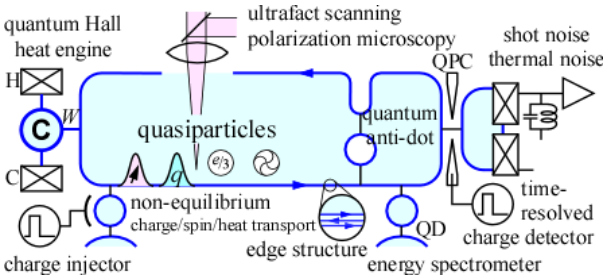


Fig. 2. A mesoscopic quantum Hall system.

【Expected Research Achievements and Scientific Significance】

Experimental and theoretical studies on mesoscopic quantum Hall system will be devoted to exploring non-equilibrium dynamics of low-dimensional quasiparticles. We will develop manipulation schemes for single quasiparticles that can be used for topological quantum engineering and quantum-Hall heat engines.

【Publications Relevant to the Project】

・K. Itoh, R. Nakazawa, T. Ota, M. Hashisaka, K. Muraki, and T. Fujisawa, "Signatures of a nonthermal metastable state in copropagating quantum Hall edge channels", Phys. Rev. Lett. 120, 197701-1-5 (2018).
・M. Hashisaka, N. Hiyama, T. Akiho, K. Muraki and T. Fujisawa, "Waveform measurement of charge- and spin-density wavepackets in a chiral Tomonaga–Luttinger liquid", Nature Physics 13, 559-562 (2017).

【Term of Project】

FY2019-2023

【Budget Allocation】

153,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://fujisawa.phys.titech.ac.jp
fujisawa@phys.titech.ac.jp

Title of Project：Nucleosynthesis under the extreme conditions in the universe

KAWABATA Takahiro
(Osaka University, Graduate School of Science, Professor)

Research Project Number：19H05604　Researcher Number：80359645
Keyword：Triple alpha reaction, Nucleosynthesis, Active target, Neutron beam

【Purpose and Background of the Research】

There is a close relationship between the universe with a vast spread more than 10^{26} m and atomic nuclei with extremely small radii of ~ 10^{-15} m. There was no element at the beginning of the universe, but various elements exist in the present universe. All the elements have been synthesized by nuclear reactions in the 13.8-billion-year history of the universe.

One of the most important reactions in the nucleosynthesis in the universe is the triple alpha (3α) reaction. In the 3α reaction, ^{4}He (α) is captured by ^{8}Be, which is a resonance state of two α particles. However, the 3α reaction rate in an extreme environment such as high temperature and high density might increase several to 100 times compared to the known value.

In the present project, we aim to determine the 3α reaction rate in an extreme environment and clarify the nucleosynthesis in the universe.

【Research Methods】

As shown in Fig. 1, 3α resonance states are formed as intermediate states in the 3α reaction. Most of these 3α resonance states decay back to 3α particles, but a tiny fraction of the resonance states decay to the ground state to synthesize ^{12}C. In order to determine the 3α reaction rate, it is necessary to measure the decay probability of these 3α resonance states to the ground state.

3α reaction rate at high temperature

The 3α reaction at normal stellar temperature (10^8 K) mainly proceeds through the 0^+_2 state, but the 2^+_2, 3^-_1 and 0^+_3 states with higher excitation energies play important roles at higher temperature than 10^9K. Although the decay probability of the 0^+_2 and 2^+_2 states to the ground state are already known, those of the 3^-_1 and 0^+_3 states have never been measured so far because those are extremely low (10^{-6}—10^{-8}). Therefore, we will measure the inelastic α scattering from ^{12}C under inverse kinematical conditions to determine the decay probabilities of the 3^-_1 and 0^+_3 states to the ground state.

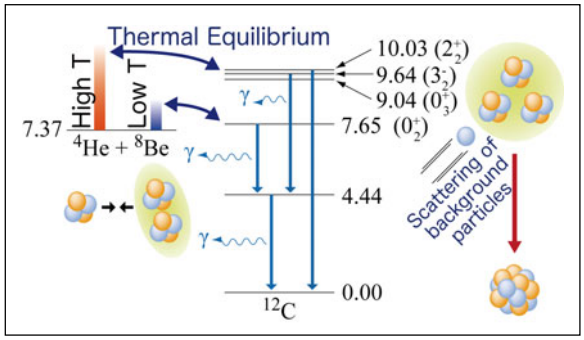


Figure 1　Triple alpha reaction

3α reaction rate at high density

In the normal 3α reaction, the 3α resonance state formed as an intermediate state decays to the ground state by emitting γ ray. On the other hand, in a high-density environment, endothermic inelastic scattering of background particles enhances the de-excitation of the 3α resonance states to the ground state. Especially, the contribution of the inelastic scattering of neutron is dominant. It is, therefore, necessary to measure cross sections of inelastic neutron scattering from the 3α resonance states, but it is impossible to measure the cross sections because lives of the 3α resonance states are very short.

In the present project, we will measure the cross section of the time-reversal reaction instead of the normal reaction to de-excite the 3α resonance states. The cross sections of the normal reaction can be determined from the time-reversal reaction using the detailed balance principle. However, it is not easy to measure the cross sections of the time reversal reaction because energies of the 3α particles emitted from the reaction are quite low (< 0.5 MeV). To detect such low- energy α particles, we will develop a new active target system.

【Expected Research Achievements and Scientific Significance】

The 3α reaction rate is a very important parameter to clarify the nucleosynthesis in the universe. For example, high-temperature and high-density ^{4}He phases emerge in the gravity-collapsed supernova and heavy-element synthesis is ignited by the 3α reaction. Therefore, the abundance of heavy elements drastically changes if the 3α reaction rate increases. If the 3α reaction rate in an extreme environment is determined by the present project, theoretical predictions of heavy element abundances are improved and provide an insight into mechanisms of supernova explosions, which still remain unclear.

【Publications Relevant to the Project】

S. Wanajo et al., Astrophys. J. 729, 46 (2011).
M. Beard et al., Phys. Rev. Lett. 119, 112701 (2017).

【Term of Project】

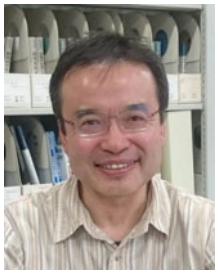
FY2019-2023

【Budget Allocation】

132,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://nucl.phys.sci.osaka-u.ac.jp/
kawabata@phys.sci.osaka-u.ac.jp



Title of Project：Comprehensive picture of atmospheric circulation of Venus revealed by AKATSUKI data assimilation

HAYASHI Yoshiyuki
(Kobe University, Graduate School of Science, Professor)

Research Project Number：19H05605　Researcher Number：20180979
Keyword：atmospheric general circulation model, Venus, AKATSUKI, super-rotation, data assimilation

【Purpose and Background of the Research】

The structures of atmospheric circulation of Venus still remains to be revealed. The thick cloud layer around 45-70km hides the lower part of the atmosphere. The most impressive characteristic of the Venus atmosphere is “super-rotation” (four-day circulation), which is the intense zonal wind with around 100m/s at the cloud top level. The rotation rate is tens of times higher than that of the solid Venus, 243 days. To understand the structures that produce and sustain the super-rotation is one of the fundamental problems in the fields of meteorology.

Japanese Venus explorer AKATSUKI has been launched to perform intensive meteorological observations for the first time in the world, carrying four types of cameras to gather information at various altitudes. Before AKATSUKI, observations of the Venus atmosphere were fragmentary, while numerical simulation models, which should have been compared to observations, were primitive because of the insufficiency of understandings on the circulation structures.

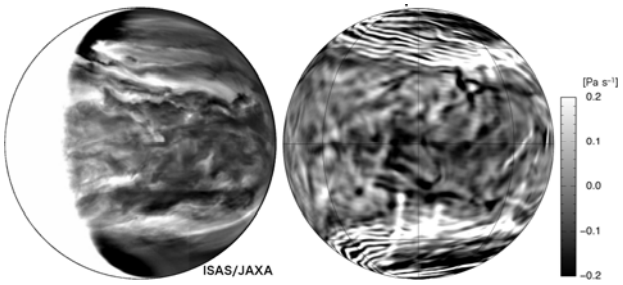


Figure 1 AKATSUKI IR2 image (left), AFES-Venus vertical wind (right).（Kashimura et al., 2019）

Now, we found that the images obtained by AKATSUKI show remarkable resemblance with the results of high resolution simulations by AFES-Venus, which is a general circulation model of the Venus atmosphere being developed by our group optimized for the Earth Simulator (Fig. 1). AKATSUKI and Earth Simulator enables us to compare the observations with the models. The purpose of the present research is to realize the comparisons by introducing leading edge methodology, to promote the development of the atmospheric model, and to try to reveal the circulation structures which sustain the super-rotation.

【Research Methods】

AKATSUKI observations and analyses are combined with AFES-Venus developments and numerical simulations by the use of data assimilation method (e.g. Sugimoto et al., 2017) to produce Venusian circulation fields which are dynamically and also observationally consistent (Fig. 2). AKATSUKI occultation observations, imageries, cloud tracking winds are utilized, and cloud and radiation transfer models are developed to realize AKATSUKI observation simulations.

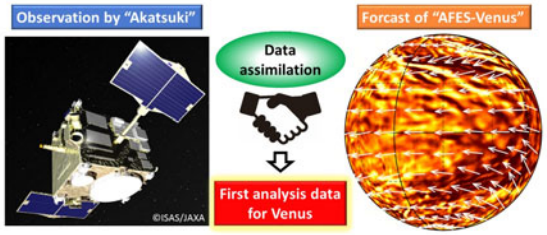


Figure 2 Image of fusion between observation and model development by data assimilation

【Expected Research Achievements and Scientific Significance】

By the use of assimilated data, we will try to reveal atmospheric disturbances, tracer transport and cloud structure, and meridional circulation and angular momentum transport to understand the structures which realize the super-rotation. “AKATSUKI Venus atmosphere dataset” thus obtained will be a base for further researches on Venusian and planetary atmospheres in general.

【Publications Relevant to the Project】

・Kashimura, H., et al., Planetary-scale streak structure reproduced in high-resolution simulations of the Venus atmosphere with a low-stability layer. *Nature Communications*, **10** (23), 1-11, doi:10.1038/s41467-018-07919-y. (2019).
・Sugimoto, N., et al., Development of an ensemble Kalman filter data assimilation system for the Venusian atmosphere. *Scientific Reports*, **7**, 9321, doi:10.1038/s41598-017-09461-1, (2017).

【Term of Project】

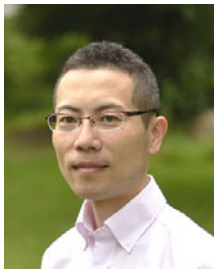
FY2019-2023

【Budget Allocation】

145,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.cps-jp.org/~akatsuki/
shosuke@gfd-dennou.org



Title of Project：Precision test of electroweak theory and search for new physics beyond the Standard Model by laser spectroscopy of purely leptonic atoms

UETAKE Satoshi
(Okayama University, Research Institute for Interdisciplinary Science, Associate Professor)

Research Project Number：19H05606　Researcher Number：80514778
Keyword：Muonium, precision laser spectroscopy, electroweak theory, new physics beyond the Standard Model

【Purpose and Background of the Research】

Search for new physics beyond the Standard Model is one of the most important subjects in the elementary particle physics. In this project, we precisely measure energy levels of "purely leptonic atoms" by using modern techniques for atomic spectroscopy. The results provide a precision test of the electroweak theory –a part of the Standard Model– and pave the way to search a yet unknown new particle couples to the electron and the muon.

Atomic physics experiments using simple hydrogen atoms have played the most important role in the evolution of physics during the 20th century. In addition, after the invention of optical frequency comb in 1999, the technique of precise optical frequency measurements is rapidly advanced. Nowadays the experimental uncertainty of 1S-2S transition of hydrogen atoms (~10^{15} Hz) becomes ~10 Hz. However, theoretical calculations of hydrogen energy levels have not been confirmed very well by experiments. This is because the nucleus in the 'ordinary atoms' consists of composite particle of hadrons. As a result, the proton radius is impossible to predict by theories, and the energy level uncertainty originated from it is >100 kHz even such a simple hydrogen atom. The uncertainty is 4 order of magnitude larger than the experiment.

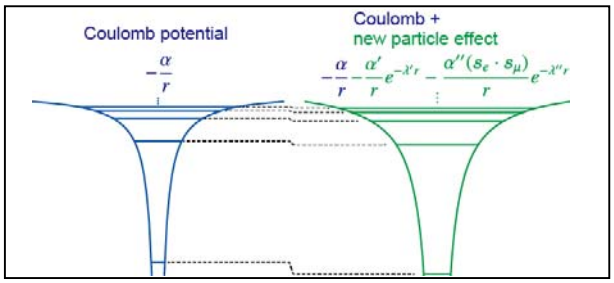


Figure 1: Potential energy and energy levels of atom

【Research Methods】

The difficulties can be overcome by using Muonium (Mu) –purely leptonic atoms. Mu can be seen as an isotope of hydrogen but the big difference between Mu and ordinary atoms is that Mu consists of leptons: elementary particles with no complex structure. Thus the precise calculation of its energy levels is feasible. Actually, energy shifts of -65 Hz originate from the electroweak interaction has already been predicted. In the previous experiments, however, large number Mu production was difficult, so the statistical uncertainty was the primary source of uncertainty.

In this project, we perform precision spectroscopy of purely leptonic atoms by using (1) the latest technique of laser spectroscopy, (2) high-quality muon beam at J-PARC, and (3) precise calculation method based on the electroweak theory. The results provide a stringent test of electroweak theory. Moreover, we can investigate effects of new physics through the Mu spectroscopy.

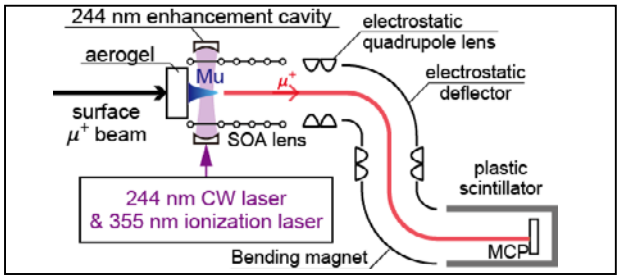


Figure 2: 1S-2S Laser spectroscopy system

【Expected Research Achievements and Scientific Significance】

The present uncertainty in the muon mass (one of the fundamental physical constants) can be greatly reduced by improving the experimental precision of the 1S-2S transition frequency of Mu, which is measured in this project. As a result, uncertainties in the calculation of Mu energy levels is greatly reduced. If we found any difference between the energy levels predicted by the electroweak theory and measurement, that implies effects of new physics. Such results would make a big paradigm shift in the elementary particle physics.

【Publications Relevant to the Project】

・A. Yamaguchi, S. Uetake, S. Kato, H. Ito, Y. Takahashi, "High-resolution laser spectroscopy of a Bose-Einstein condensate using the ultranarrow magnetic quadrupole transition", New. J. Phys. 12, 103001 (2010)
・Y. Miyamoto, S. Uetake, M. Yoshimura *et al.*, "Externally triggered coherent two-photon emission from hydrogen molecules", PTEP2015, 081C01 (2015)

【Term of Project】FY2019-2023

【Budget Allocation】154,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.xqw.okayama-u.ac.jp/

【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project：Study of origins and propagation of very high energy cosmic rays with detailed measurements in the wide energy range

OGIO Shoichi
(Osaka City University, Graduate School of Science, Professor)

Research Project Number：19H05607　Researcher Number：20242258
Keyword：cosmic rays, chemical composition, origins of cosmic rays, the Galaxy, inter-galactic space, astrophysics

【Purpose and Background of the Research】

The Telescope Array (TA) experiment in Utah, USA continues observations of very high-energy cosmic rays from 2008. The TA collaboration reported the cosmic ray energy spectrum in the wide energy range from 2 PeV to above 10^{20} eV. The energy spectrum has complicated structures showing several kinks and dips rather than a simple power law. The galactic and extra-galactic components coexist in the lower energy range than 10^{18} eV, and the spectrum of the extra-galactic component has convolved information of source spectra, the redshift evolution of sources, integration of energy losses during propagations and the shielding by the galactic magnetic field. In contrast, the spectrum of the galactic component has a convolution of the physics processes limiting the accelerated energy at galactic sources and the confinement of cosmic rays in the Galaxy.

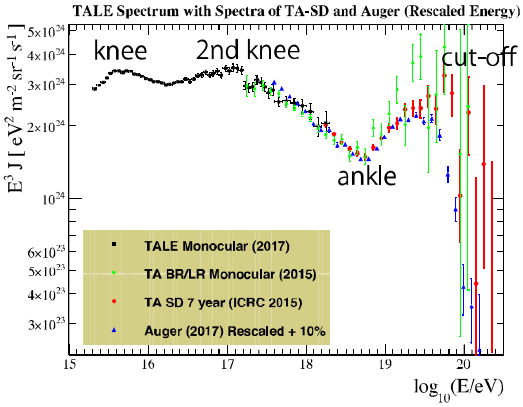


Figure 1: Cosmic ray energy spectrum plotted along with measurements by TA and by TALE, also shown is the Auger spectrum.

In order to unfold and resolve the convolved information in the galactic and the extra-galactic spectra, precise measurement for the chemical composition is essentially needed as well as a precisely measured energy spectrum.

【Research Methods】

The TA experiment consists of the surface detector (SD) array of 700 km^2 coverage and 38 fluorescence detectors (FDs), and it continues operations from 2008 by an international collaboration of 35 institutes from six countries, such as Japan, USA, Korea, Russia, Belgium and Czech. In 2012, we started TA Low energy Extension (TALE) experiment additionally installing ten FDs pointing higher elevation, i.e., observing lower energy. In 2018, we constructed the TALE SD array with installing 80 SDs with 400 m spacing covering 30 km^2 at the bottom of the observation volume by the TALE FDs, and we developed the hybrid observation system for the SD array to be operated with FD-to-SD cross-trigger.

In this project, we will additionally install the other 50 SDs with 200 m spacing to make the hybrid threshold energy down to lower, to 10^{15} eV.

【Expected Research Achievements and Scientific Significance】

This is the world first experiment to cover the knee region and the very wide energy region from 10^{15} to 10^{20} eV with the FD-SD hybrid technique. We expect a precise composition measurement for galactic cosmic rays and to obtain precise data for studies of the galactic magnetic field, the galactic wind, the galactic halo, the cosmological evolution of the extragalactic cosmic ray origins.

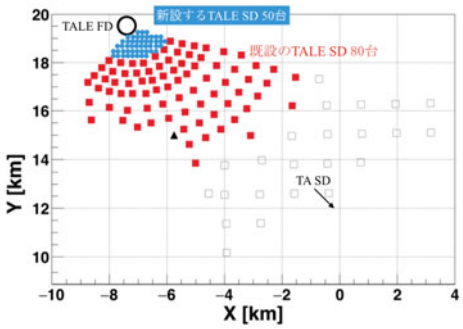


Figure 2: The layout of TALE and infill SDs

【Publications Relevant to the Project】

R. U. Abbasi, et al., Ap. J., 865, 1(2018)
R. U. Abbasi, et al., Ap. J., 858, 76(2018)

【Term of Project】

FY2019-2023

【Budget Allocation】

155,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.telescopearray.org
http://www-ta.icrr.u-tokyo.ac.jp
http://www.cosmicray-ocu.jp

Title of Project：Long-term observations to study the origins of Galactic Cosmic Rays and search for Dark Matter with CALET

TORII Shoji
(Waseda University, Faculty of Science and Engineering, Professor Emeritus)

Research Project Number：19H05608　Researcher Number：90167536
Keyword：high-energy cosmic ray, Galactic cosmic ray, nearby sources, dark matter, International Space Station

【Purpose and Background of the Research】

We are carrying out a precise measurement of cosmic rays in space with the CALET detector onboard the Japanese Experiment Module "KIBO" on the International Space Station. Launched in August, 2015, CALET (Fig.1) is a detector composed of a very thick (30 radiation lengths) calorimeter uniquely capable of containing and imaging high-energy cosmic-ray showers to enable observations of electrons up to the TeV region. CALET is also capable of measuring the charge of incident particles in the range of Z=1-40, and the spectra of the major primary heavy nuclei in the energy range from several tens of GeV to 1 PeV.

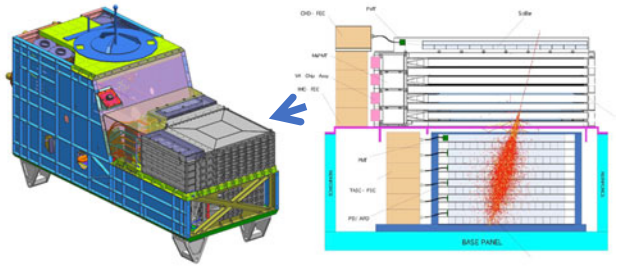


Figure 1: CALET overview (left) and side view of the calorimeter with a superimposed 1TeV electron shower simulation (right).

With this novel detector, we are achieving a high-precision measurement of the cosmic rays, at energies at which the observations have not yet successfully been accomplished. CALET addresses unresolved problems concerning the acceleration and propagation mechanisms of the Galactic cosmic rays and performs a new search for dark matter--one of the greatest puzzles in astrophysics.

【Research Methods】

We set up the Waseda CALET Operations Center (WCOC) where the mission operations and data analysis are carried out by receiving the observed data from the Tsukuba Space Center at JAXA, transferred from the ISS. The raw data sent instantly are used for real-time monitoring, and the full analysis is performed on the data received at a frequency of once per one hour after correcting for data loss during transmission by the relay satellites. After calibrations and revisions of the data at the WCOC, the data volume is provided to the international collaboration teams in Japan, Italy, and the US for independent scientific analysis. We also perform a quick analysis by using the raw data for transient astrophysical phenomena, i.e. gravitational wave events and gamma-ray bursts etc., to report the observations quickly to the science communities.

Scientific achievements are presented at international and domestic conferences as soon as possible, and important results are submitted to high-impact journals and made public on the collaboration Web pages.

【Expected Research Achievements and Scientific Significance】

Direct observations of cosmic rays made great strides in the 2000's, bringing us a "standard model" of the acceleration and propagation mechanism of the Galactic cosmic rays. We will verify key concepts of the model for both electrons (leptons) and nuclei (hadrons) including their acceleration in supernova remnants and diffusive propagation through the Galaxy.

We will attempt to detect the acceleration limit expected in the 100 TeV region for the nuclear component, and search for nearby sources of electrons in the TeV region. Even if these searches are not successful, valuable limits to the source and acceleration components of the model will certainly be obtained. For the propagation model, we will measure precisely the fluxes of heavy nuclei up to nickel (Z=28) and the secondary to primary ratio, i.e. the boron/carbon ratio etc., over a wide energy range.

Moreover, we will perform a search for dark matter with a mass in the TeV range by looking for structures in the electron + positron energy spectrum.

【Publications Relevant to the Project】

・"Extended Measurements of Cosmic-ray Electron and Positron Spectrum from 11 GeV to 4.8 TeV with the Calorimetric Electron Telescope on the International Space Station", Y.Asaoka, S.Torii, *et al.* (CALET collaboration), Phys. Rev. Lett. 120, 261102 (7pp) (2018).
・"Direct Measurement of the Cosmic-Ray Proton Spectrum from 50 GeV to 10 TeV with the Calorimetric Electron Telescope on the International Space Station", Y.Asaoka, P.S.Morrocchesi, S.Torii, *et al.* (CALET collaboration), Phys. Rev. Lett. 122, 181102 (2019).

【Term of Project】 FY2019-2023

【Budget Allocation】 154,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://calet.jp
torii.shoji@waseda.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project：Elucidation of ultra-strong magnetic field of neutron stars with highly-sensitive X-ray and Gamma-ray polarimetry

TAMAGAWA Toru
(RIKEN, Cluster for Pioneering Research, Chief Scientist)

Research Project Number：19H05609　Researcher Number：20333312
Keyword：Astrophysics, X-ray and Gamma-ray Polarimetry, Ultra-strong Magnetic Field, Neutron Stars

【Purpose and Background of the Research】

"Are the neutron stars called Magnetar really extreme objects with a magnetic field above 10^{10} Tesla where the perturbative calculation of quantum electrodynamics (QED) breaks? In such a celestial object, is our knowledge on QED valid?" In this research, we aim to directly verify the hypothesis that Magnetar is strongly magnetized neutron star by the world's first highly sensitive X-ray and gamma-ray polarization observations.

A neutron star is an object with a radius of about 10 km, which remains after a massive star explosion, and is the densest substance (2-3 times of the nucleus density) in our universe. Most of the periodically blinking neutron stars called pulsars are known to have a strong magnetic field of about 10^8 Tesla and knowing the interior and the origin of the magnetic field is one of the important themes not only in astrophysics and astronomy but also elementary particle physics and nuclear physics.

"Magnetar", a species of neutron stars, is believed to have a strong magnetic field of as high as $10^{10\text{-}11}$ Tesla and to shine by releasing its magnetic energy. However, this is only a hypothesis, and direct observational verification of ultra-high magnetic field is competed worldwide.

【Research Methods】

We set the following two goals to verify the strong magnetism of Magnetar.

(Goal-1) The existence of a QED effect "vacuum resonance" is verified in a neutron star binary whose magnetic field is known by the presence of cyclotron absorption lines (about 10^8 Tesla).

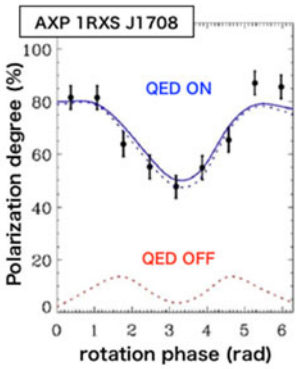


Figure 1 Expected polarization of magnetar.

(Goal-2) By observing another QED effect "vacuum birefringence" which can be notable only at 10^{10} Tesla or more, we will proof the ultra-strong magnetic field of Magnetar observationally (Fig. 1).

To realize these goals, we will conduct NASA's X-ray polarimetry small satellite IXPE (launch in 2021), which we provide hardware and participate as core members, and the US-Japan joint balloon experiment XL-Calibur (flights in 2021, 2023). We will achieve the world's first sensitive polarimetry of neutron star binaries and Magnetars in X-ray and gamma-ray band (Fig. 2).

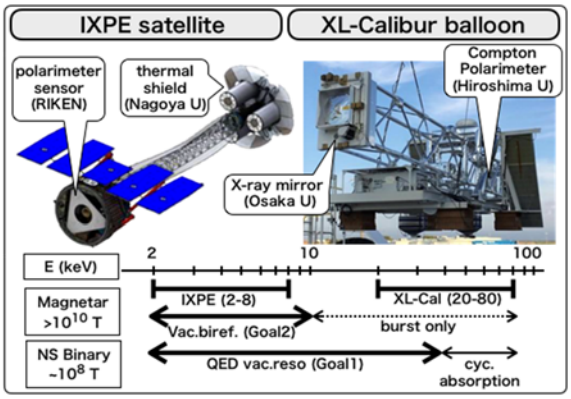


Figure 2 Methods and goals.

【Expected Research Achievements and Scientific Significance】

By demonstrating that Magnetar has an ultra-high magnetic field, we will pioneer the field "highly-magnetized nuclear matter" as an experimental field of basic science. This is complementary to the observation of the QED limit in the electric field using the high-intensity laser, and leads to the research progress of "physics in strong field" connecting space observation and ground experiment. In addition, as our study opens up new methods of X-ray and gamma-ray polarimetry, it must have a large ripple effect on high energy astrophysics in general.

【Publications Relevant to the Project】

・S. O'dell, et al., "The Imaging X-ray Polarimetry Ex-plorer (IXPE): technical overview", Proc. of SPIE 10699, 10699X1 (2018).
・A. Yatabe and S. Yamada, " Systematic Analysis of the Effects of Mode Conversion on Thermal Radiation from Neutron Stars", Astrophys. J. 850, 185 (2017).

【Term of Project】

FY2019-2023

【Budget Allocation】

142,300 Thousand Yen

【Homepage Address and Other Contact Information】

https://astro.riken.jp/ks-xpol.html

Title of Project：Electrical and optical creation and control of non-Abelian anyons

TARUCHA Seigo
(RIKEN, Center for Emergent Matter Science, Group Director)

Research Project Number：19H05610　Researcher Number：40302799
Keyword：non-abelian anyon, topological superconductivity, Majorana Fermion, Exciton-polariton

【Purpose and Background of the Research】

Particles in three-dimensional are classified into either bosons or fermions, acquiring a 0 or π phase as their positions are exchanged, respectively. In contrast, for lower-dimensional systems, this phase can take an arbitrary value, and the resulting particles are called anyons. A more exotic type of anyon, known as a non-Abelian anyon, is known to be capable of performing quantum operations which are inherently robust to errors from environmental noise and thus highly sought-after for a future generation of quantum computer. However, the currently studied platforms have not been able to realize robust and easily controllable non-Abelian anyons, which might be used in the development of *topological quantum computing*.

In this project, we aim to develop accessible platforms exhibiting robust non-abelian anyons, and study both the fundamental physics of these exotic particles, and also evaluate the feasibility of their use in topological quantum information processing. The target systems are (1) superconducting junctions of double nanowires and two-dimensional topological insulators (2) superconducting junctions of three-dimensional topological insulators (3) quantum Hall states of exciton-polaritons in two-dimensional lattices.

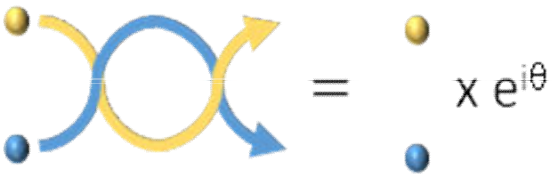


Figure 1:Acquisition of phase by anyon exchange

【Research Methods】

(1) We will detect the signatures of Majorana fermion zero-modes in superconducting junctions of double nanowires and two-dimensional topological insulators without a magnetic field. Furthermore, we will develop the on/off operation of the Majorana fermions by electrical techniques and evaluate the construction of qubits.

(2) We will generate, and implement techniques to control Majorana fermion zero-modes appearing at the center of vortices in Corbino-geometry Josephson junctions of three-dimensional topological insulators.

(3) We will generate robust topological states in structured 2D potentials in exciton-polariton microcavities and investigate new materials and methods for inducing strong particle correlations in these topological bands. Further, we will implement ultra-fast optical methods capable of anyon exchange and detection.

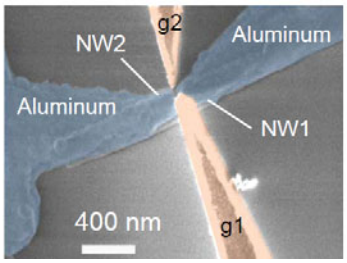


Figure 2: SEM image of a superconducting junction of double InAs nanowires.

【Expected Research Achievements and Scientific Significance】

Non-Abelian anyons are amongst the most exotic particles in condensed matter systems, however platforms exhibiting robust and controllable non-Abelian anyons are yet to be demonstrated. In this project, we will generate, control and study the properties of anyons in several novel and original platforms, investigating both electrical and optical techniques. Our studies toward the generation, exchange and measurement of robust non-Abelian anyons promises a significant advance in the understanding of the fundamental properties and experimental control of these particles, in addition to their applicability in future topological quantum computing applications.

【Publications Relevant to the Project】

・ S. Baba, S. Matsuo, S. Tarucha, “Cooper-pair splitting in two parallel InAs nanowires”, New Journal of Physics 20, 063021-063028 (2018).
・ R.S. Deacon, J. Wiedenmann, S. Tarucha, “Josephson Radiation from Gapless Andreev Bound States in HgTe-Based Topological Junctions”, Phys. Rev. X, 7, 021011-1-7 (2017).

【Term of Project】

FY2019-2023

【Budget Allocation】

126,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://qfsrg.riken.jp/Todai-HP/english/index.html
tarucha@riken.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section C

Title of Project：Novel function control of plant and marine products by pulsed power and its scientifically deepening

TAKAKI Koichi
(Iwate University, Faculty of Science and Engineering, Professor)

Research Project Number：19H05611　Researcher Number：00216615
Keyword：pulsed power, plasma, plant, food

【Purpose and Background of the Research】

Pulse-electric field and electrostatic effects have been used in agriculture and food processing as electro-spray, electroporation. Recently, pulse voltage and plasma are newly used in agriculture and food processing as seed germination promotion, seedling growth enhancement and inactivation of bacteria. Objective of the study is development of novel function control of plant and marine products based on pulsed power technologies and its scientifically deepening for contribution in agriculture and food science. Multi-reaction field of plasma and intense electric field are produced and controlled spatially and temporally with micro-meter and nano-second range using highly optimized pulsed power generators. The novel control of plant activity and marine product functional content are produced using the multi-reaction field.

【Research Methods】

Key issue of the project is production of multi-reaction field of plasma and intense electric field with spatially and temporally control to adapt whole bio-scale as shown in **Fig. 1**. Especially, pulse width of the intense electric field is deigned to match relaxation time (nano-second or lower scale) of water molecule and protein. The pulsed power generator is also designed to match temporally changed impedance of bio-specimen by choosing optimum system (pulse forming line, inductive and capacitive energy storage circuit, H-bridge circuit) and semiconductor switching devise such as SiC-FET. In the plant activity control, seed germination, effect of the multi-reaction on seedling growth enhancement, resistance for pathogenic bacteria and photosynthesis are evaluated through redox, metabolism, phytohormone and gene expression analysis.

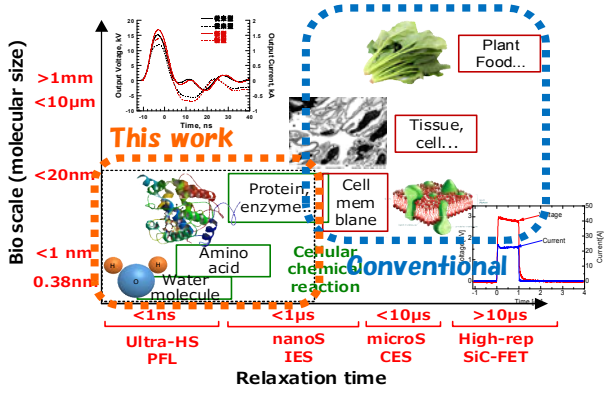


Fig. 1　Relation between bio-scale and relaxation time.

In the food safety issue, the effect on qualities (freshness) of agricultural and marine products are evaluated by k-value, bacteria number density, color index for ripening, enzyme activity and protein conformational change. In the functional food issue, the effect on functional group content in processed food from agricultural and marine products is evaluated by enzyme activity analysis, nutritional analysis, fermentability of yeast, SDS-PAGE, LC and GC analysis and conformational change of protein which is analyzed by UV absorption spectra.

【Expected Research Achievements and Scientific Significance】

This project focus on pulsed power based multi-reaction field effect on plant activity and food function in science based on not only relaxation time of each bio-scale but also bio-activity of each growth phase as shown in **Fig. 2.** This approach is highly motivated challenge and has possibility to contribute the cutting-edge science.

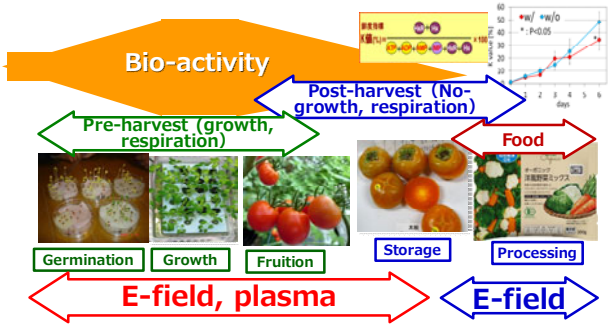


Fig. 2　Multi-reaction fields for each growth phase.

【Publications Relevant to the Project】

- K. Takaki et al, "Topical Review; High-voltage technologies for agriculture and food processing", J. Phys. D: Appl. Phys. (accepted) (42pp).
- K. Takaki et al, "High-Voltage Methods for Mushroom Fruit-Body Developments", in "Plant and Mushroom Development" (IntechOpen Limited, London, 2018.9)

【Term of Project】

FY2019-2023

【Budget Allocation】

153,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.se.iwate-u.ac.jp/en/teacher/takaki-koichi
takaki@iwate-u.ac.jp

Title of Project : Establishment of the new method for material synthesis utilizing light elements and their expansion to develop rare-earth-free magnet

SAKUMA Akimasa
(Tohoku University, Graduate School of Science and Engineering, Professor)

Research Project Number : 19H05612 Researcher Number : 30361124
Keyword : Magnet, Rare earth free, Magnetic material, Rare earth, Light element

【Purpose and Background of the Research】

The sales unit of world-wide x-EV (electric vehicles) is predicted to rise to 100 million across 50% of whole car unit in 2035. In addition, the rapid spread of robots and wind power generation are predicted, and the huge demand expansion of the permanent magnet necessary for a motor or generator constituting them is anticipated. There are only two kinds of permanent magnets now, one is ferrite which has low price and low magnetic properties, and the other is NdFeB magnet which has high price and high magnetic properties. Therefor it has been desired that the magnets where the cost performance is located between NdFeB and ferrite. In addition, as for the rare-earth elements such as Nd used for NdFeB alloy exist mostly in China, we can not wipe out the uncertainty of constant supply. Therefor the development of rare-earth-free magnet materials is necessary. Recently China raises a production technology of the NdFeB magnet and has come to already occupy two thirds of the worldwide production as showed

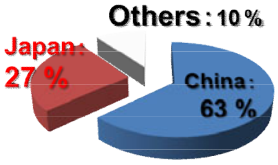


Fig. 1 Worldwide production of NdFeB magnet.

in Figure 1. So it comes urgent issues that “How does our country face with the huge demand of magnet by the rapid popularization of x-EV, wind power generation and robots and also the technical catch up by China ? ". We aim at continuing to be the world leader in the field of magnets by creating of rare-earth-free magnet materials having magnetic properties between NdFeB and ferrite magnet as showed in Figure 2.

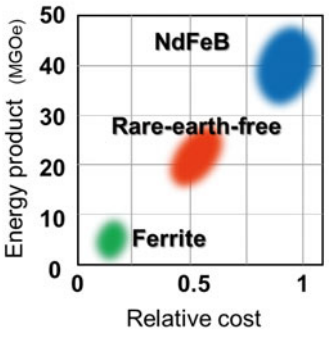


Fig. 2 Rare-earth-free magnet materials which is aimed in this research.

【Research Methods】

As a candidate of rare-earth-free magnet materials having magnetic properties between NdFeB and ferrite magnets, we will investigate the Fe alloy including the light element (H, C, O and N) interstitially. Theory group will try to predict the magnetism of these Fe alloys by the first principal calculation. On the other hand, experiment group will make efforts to introduce H, C, O, and N into Fe. In other words, we focus on the materials creation of the rare-earth-free magnet including the light element by combining a theoretical calculation and processing technique.

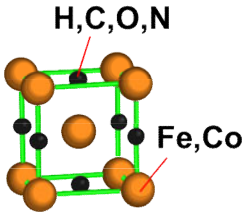


Fig. 3 Crystal structure of Fe-Co alloy including light element.

【Expected Research Achievements and Scientific Significance】

We will try to establish a new category by the development of the rare-earth-free magnet having a middle performance of NdFeB and the ferrite. It is significant strategy to win international competition through technical superiority of motor design technology of our country. If rare-earth-free magnet showing superior cost performance will be created, the market of magnets will change drastically.

【Publications Relevant to the Project】

・Y. Kota, A. Sakuma, Degree of Order Dependence on Magnetocrystalline Anisotropy in Body-Centered Tetragonal Eco Alloys, Appl. Phys. Express, 5, 113002 (2012)
・M. Tobise, S. Saito, M. Doi, Challenge to the synthesis of α”-$(Fe,Co)_{16}N_2$ nanoparticles obtained by hydrogen reduction and subsequent nitrogenation starting from α-(Fe,Co)OOH, AIP Advances JMI2019, 035233 (2019)

【Term of Project】 FY2019-2023

【Budget Allocation】 146,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://sakuma.apph.tohoku.ac.jp

Title of Project：Innovative CFD simulation for multiphase flows including free surfaces

AOKI Takayuki
(Tokyo Institute of Technology, Global Scientific Information and Computing Center, Professor)

Research Project Number：19H05613　Researcher Number：00184036
Keyword：multiphase flow, free-surface flow, non-Newtonian fluid, fluid film, AMR

【Purpose and Background of the Research】

Whereas the field of fluid dynamics has matured, and computational fluid dynamics (CFD) has been well-developed, however the study has been behind with simulations for multiphase flows including free surfaces for a long time. It is especially difficult to describe gas-liquid interfaces because of their large density jumps and dynamic deformations. These difficulties come from computational method, modeling and implementation on supercomputers.

For incompressible (low Mach number) multiphase flows including free surfaces, we introduce a weakly compressible fluid computational method and many techniques of high-performance computing, adaptive mesh refinement (AMR), dynamics load balance, GPU computing and so on. In this project, we study the following three topics over an extremely wide range from nanometers to kilometers, (1) natural disasters of flows including a lot of floating debris, (2) dynamics of liquid film and formation-collapse of foams, and (3) motions of low water-containing slurry in a solid-liquid-gas dispersed system. We reveal macroscopic features of the flows directly solving the detailed models and obtain new findings in the fluid dynamics of multiphase flows.

Figure 1　Gas-liquid two-phase flow simulation using a weakly compressible computational method.

【Research Methods】

We simulate multiphase flows by solving compressible fluid equations with a fully explicit time integration. The numerical method consists of finite volume method (FVM) and finite difference method (FDM) to compute the sound wave propagation accurately. Since the time step (Δt) is determined by the sound speed, we artificially reduce it for 10-30 times the flow speed (Mach number 0.1-0.03) and accept weak compressions.

We introduce an AMR method adapting fine meshes to the region near free surfaces and solid bodies. In addition, dynamic domain partitioning for complex AMR mesh structures makes their large-scale computation efficient on supercomputers.

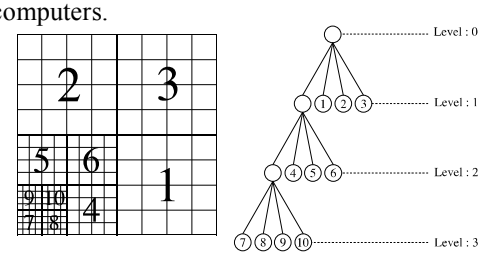


Figure 2　Recursive mesh refinement based on algorithm of tree data structure.

【Expected Research Achievements and Scientific Significance】

(1) In heavy rain or slope disasters, large-scale simulations taking account of the detailed interaction of free-surface flow and a lot of floating debris are used to understand debris trapping, impact to building structures, damage area and so on. We can also expect contributions to disaster prevention.

(2)Very high-resolution gas-liquid two-phase flow simulations make it possible to understand the stability of liquid films and foams. Furthermore, the heat transfer and material transportation through liquid film will be solved.

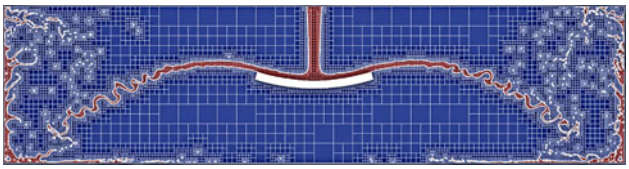


Figure 3　Liquid film generated by a spoon with AMR.

(3)We can construct a non-Newtonian macroscopic viscoelasticity model for low water-containing slurry by directly simulating liquid bridges among solid particles.

【Publications Relevant to the Project】

- S. Matsushita, T. Aoki: A weakly compressible scheme with a diffuse-interface method for low Mach number two-phase flows, J. Comput. Phys., 376, pp.838-862, 2019
- Y. Sitompul, T. Aoki: A filtered cumulant lattice Boltzmann method for violent two-phase flows, J. Comput. Phys., 390, pp.93-120, 2019

【Term of Project】 FY2019-2023

【Budget Allocation】 149,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.sim.gsic.titech.ac.jp/

Title of Project：Creation of extremely energy-efficient integrated circuit technology beyond the thermodynamic limit based on reversible quantum flux circuits

YOSHIKAWA Nobuyuki
(Yokohama National University, Graduate school of Engineering, Professor)

Research Project Number：19H05614　Researcher Number：70202398
Keyword：Electronics devices, integrated circuits

【Purpose and Background of the Research】

To reduce the recent explosive increase in power consumption of information systems, fundamental power reduction based on the new device operating principle is essential. On the other hand, it is expected that calculation with infinitesimal energy can be achieved by using a reversible computation, where bi-directional calculation from input to output or from output to input is performed.

This study investigates the reversible logic circuits using adiabatic quantum parametron (AQFP) circuits characterized by low energy operation and realizes ultimate low energy integrated circuits beyond the thermodynamic energy limit. As a result, the energy consumption of logic circuits can be reduced by more than six orders of magnitude compared with current semiconductor logic circuits, which brings about sufficient advantage even in consideration of the cooling power. In this research, we utilize the reversible AQFP as a core technology, and research new processor architecture, a phase shift AQFP using magnetic material, a 3D high-density integrated circuit technology to establish basic technologies for extremely energy-efficient integrated circuits. The goal of the project is to realize a low-power reversible AQFP processor.

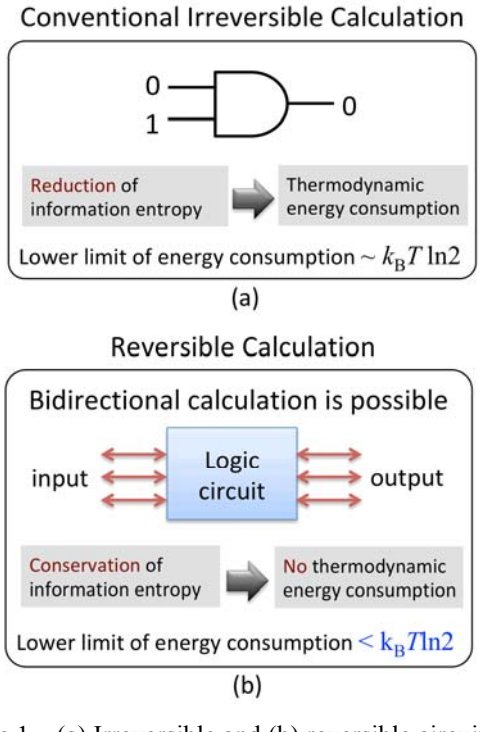


Figure 1　(a) Irreversible and (b) reversible circuits.

【Research Methods】

Conventional logic circuits such as semiconductor CMOS circuits perform the irreversible operation as shown in Figure 1(a), where the entropy of information (the complexity of information) decreases after the logic operation. According to Landauer's prediction, thermodynamic energy is consumed at this logic operation, which is considered to limit the lower energy limit in computation. On the other hand, in the reversible logic circuit shown in Figure 1 (b), bi-directional calculation from input to output or from output to input is possible. Since the entropy of information is conserved in this case, the energy consumption in calculation can be made infinitesimal. In this research, a reversible logic gate is proposed using a superconducting logic gate called adiabatic quantum flux parametron (AQFP), by which extremely energy efficient logic circuits are realized. In addition to clarifying the lower limit of energy consumption in the reversible logic circuit, we will establish an integrated circuit technology based on the proposed reversible circuit.

【Expected Research Achievements and Scientific Significance】

In this research, we aim to create integrated circuit technology that operates with energy consumption more than six orders of magnitude lower than current semiconductor circuits. As a result, significant power reduction of high-performance information processing systems such as data centers and supercomputers can be achieved. Moreover, application to control circuits for quantum computers is also expected.

【Publications Relevant to the Project】

・N. Takeuchi, Y. Yamanashi, N. Yoshikawa, "Reversible logic gate using adiabatic superconducting devices," Scientific Reports, 4, 6354 (2014).
・T. Yamae, N. Takeuchi, N. Yoshikawa, "A reversible full adder using adiabatic superconductor logic," Supercond. Sci., Technol., 32, 035005 (2019).

【Term of Project】FY2019-2023

【Budget Allocation】153,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.yoshilab.dnj.ynu.ac.jp/jpn/
nyoshi@ynu.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section C

Title of Project：Large-scale superconducting spintronics quantum computing circuits toward the realization of quantum supremacy

YAMASHITA Taro
(Nagoya University, Graduate School of Engineering, Associate Professor)

Research Project Number：19H05615　Researcher Number：60567254
Keyword：superconducting device, spintronics, quantum computing

【Purpose and Background of the Research】

Recently, the development of superconducting quantum computers becomes extremely active worldwide. A key to realize the superconducting quantum computers is whether the large-scale quantum circuits with many quantum bits (qubits) can be realized or not without degrading their performances. One of the important performance indices of the qubit is the coherence time which indicates the lifetime of the quantum state. However, the coherence time becomes smaller due to the increases of noises and/or difficulty in the qubit control when the number of the qubits increases, and the quantum supremacy has not been demonstrated yet. In this research, we develop the large-scale quantum computing circuits by introducing the superconducting spintronics techniques and aim for the demonstration of the quantum supremacy.

【Research Methods】

In conventional superconducting flux qubits, the external magnetic field is required for the operation, and the precise control of the field is essential to realize the optimum point leading to the longest coherence time. In this research, the magnetic Josephson junction (π junction), which is one of the superconducting spintronics devices, is implemented to the qubit (π qubit). Due to the π junction, the π qubit requires no external magnetic field to operate at the optimum point. This feature of the π qubit relaxes the difficulty of the qubit control and is expected to suppress the enlargement of the external noise when the number of the qubit increases. In addition, the material option is also important to achieve the good coherence time. Here we adopt the nitride-based junctions without any oxides which degrades the coherence (Fig. 1(a)) to realize the quantum circuit with the good coherence time. Fig. 1(b) shows the image of the developed π quantum circuit.

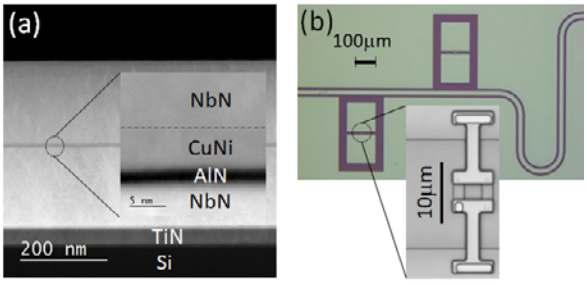


Figure 1 (a) Transmission electron microscope (TEM) image of a nitride-based magnetic Josephson junction. (b) Photograph of the π quantum circuit with the π qubits.

Furthermore, the external noise via the control lines from the room temperature environment will increase when the number of the qubits increases. In this research, we adopt the superconducting logic circuits operated at low temperatures to control the quantum states, and aim for the ultimate reduction of the external noises. To realize the milli-Kelvin operation, we develop a novel half-flux-quantum circuit with π junction which is expected to show the ultralow power consumption.

【Expected Research Achievements and Scientific Significance】

The realization of the large-scale quantum computing circuit with the quantum circuits and the control circuits (Fig. 2) and the demonstration of the quantum supremacy are expected as well as the clarification of the physical origin to limit the coherence time.

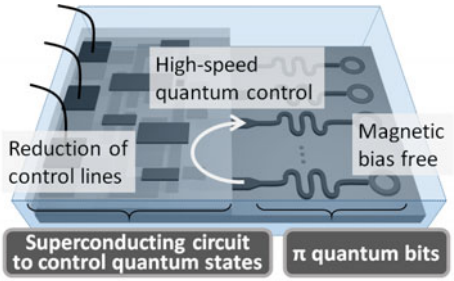


Figure 2 Schematics of large-scale quantum computing circuit in the research.

【Publications Relevant to the Project】

・T. Yamashita, K. Tanikawa, S. Takahashi, and S. Maekawa, "Superconducting π Qubit with a Ferromagnetic Josephson Junction," Physical Review Letters, vol. 95, pp. 097001-1-4 (2005).
・T. Yamashita, A. Kawakami, and H. Terai, "NbN-Based Ferromagnetic 0 and π Josephson Junctions," Physical Review Applied, vol. 8, no. 5, pp. 054028-1-5 (2017).

【Term of Project】

FY2019-2023

【Budget Allocation】

156,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.super.nuee.nagoya-u.ac.jp/
yamashita@nuee.nagoya-u.ac.jp

Title of Project：Development of a germanium spin MOSFET

HAMAYA Kohei
(Osaka University, Graduate School of Engineering Science, Professor)

Research Project Number：19H05616　Researcher Number：90401281
Keyword：Semiconductor spintronics, Germanium

【Purpose and Background of the Research】

Semiconductor electronics has brought us technological innovation in the field of information industries. From now on, the further developments of semiconductor technologies will become the core of the industries in artificial intelligence, IoT devices, and some related technologies. In recent years, for high speed operation and low power dissipation, novel semiconductor devices are strongly required. One of the key devices is the spin MOSFET, which was proposed by Sugahara and Tanaka, as schematically shown in Fig.1. If one can realize the high-performance spin MOSFET on the Si platform, the nonvolatile memory devices can be integrated into the CMOS transistors. By using Ge channel and S/D contacts without using insulator tunnel barriers, scalable spin MOSFETs with ultra-low power consumption, reducing the parasitic resistance between S/D contacts, will be developed.

For that reason, we have so far developed a new spin injection technology for Ge (SiGe) with using ferromagnetic Heusler alloy and without using insulator tunnel barriers at the S/D contacts, as shown in Fig. 1. In this project, we will further enhance the spin injection efficiency without using insulator tunnel barriers. Also, we will develop some of important Ge technologies for channel and gate-stack structures. As a result, we would like to develop a Ge-MOSFET device with nonvolatile memory effect (high MR ratio) and low-power current switching (on/off operation) at room temperature.

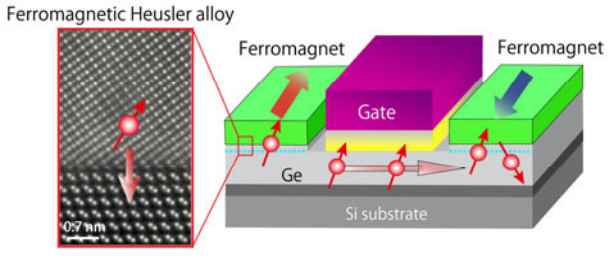


Fig.1. Schematic of spin MOSFET (right) and TEM image of a ferromagnetic Heusler alloy/Ge interface (left).

【Research Methods】

In this research project, we focus on the following four experiments. First, we study high-quality formation technologies of ferromagnetic Heusler alloy/Ge heterointerfaces for enhancing spin injection efficiency at room temperature. Second, we study new Ge (SiGe) channel structures for suppressing spin relaxation at room temperature even on a Si platform. Third, we have to develop low-temperature gate-stack fabrication processes for Ge spin MOSFET with a top-gate structure. Finally, we will develop a specialized microfabrication process for integration of the above technologies for operation of Ge spin MOSFET.

【Expected Research Achievements and Scientific Significance】

From the above research and developments, we will simultaneously perform a highly-enhanced MR ratio and low-power current switching (on/off operation) at room temperature in Ge-MOSFET structures. This project will demonstrate an integration of nonvolatile memory effect with high-performance semiconductor devices. The developed Ge spin MOSFET will contribute to some of novel technologies with high speed operation and low power consumption for artificial intelligence, IoT devices, and some related technologies in future.

【Publications Relevant to the Project】

・M. Yamada, M. Tsukahara, Y. Fujita, T. Naito, S. Yamada, K. Sawano, and K. Hamaya, “Room-temperature spin transport in *n*-Ge probed by four-terminal nonlocal measurements”, Appl. Phys. Express **10**, 093001 (2017).
・K. Hamaya, Y. Fujita, M. Yamada, M. Kawano, S. Yamada, and K. Sawano, “Spin transport and relaxation in germanium (Topical Review)”, J. Phys. D: Appl. Phys. **51**, 393001 (2018).

【Term of Project】

FY2019-2023

【Budget Allocation】

155,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.semi.ee.es.osaka-u.ac.jp/hamayalab/
hamaya@ee.es.osaka-u.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section C

Title of Project：Systematization of characterization technologies for high-temperature superconducting wires, conductors and coil windings, and their development to highly reliable magnets

KISS Takanobu
(Kyushu University, Graduate School of Information Science and Electrical Engineering, Professor)

Research Project Number：19H05617　Researcher Number：00221911
Keyword：High temperature superconducting wires, Conductors, Coils, Magnets, Electrical materials engineering

【Purpose and Background of the Research】

High temperature superconductors allows us to develop ultra-high-field magnets and superconducting applications using simple cooling systems. However, local non-uniformity of the long wire and instability of magnet winding have become obvious, and establishment of designability, stability and reliability are urgent issues.

While the superconducting wire itself has a long length of km class as a practical material, its electromagnetic performance strongly depends on how the quantized flux behavior in the mesoscopic scale can be controlled by controlling nano-sized defects (introduction of artificial pinning centers), and essentially, multi-scale control of the microstructure is required in the wire development.

The purpose of this study is to systematize characterization technologies of superconducting wires, conductors, and coils developed by the authors. Based on that, we will integrate the development of wires, conductors, and coils that have been independently developed so far, in order to dramatically improve the robustness and reduce the cost of the wires, and lead to highly reliable magnets and coiling technologies.

【Research Methods】

(1) Innovation of Characterization Technology for Superconducting Wire, Conductor and Coil: With the integration of AI technology, we will further enhance the advanced characterization method including the reel-to-reel high speed magnetic microscope shown in Fig. 1. This leads to improvement of wire uniformity and establishment of winding technology. In addition, high precision modeling of current transport characteristics will be developed as a base for conductor and magnet design method in consideration of the spatial critical current distribution of the wire.

(2) Improvement of Robustness by Proposing a New Conductor Architecture: A new conductor architecture for realizing robustness and reduction of cost is established. In parallel, a manufacturing process for making a conductor is examined, and the effectiveness of the proposed conductor architecture is verified by prototyping.

(3) Establishment of Elemental Technology for Coiling: Based on the new conductor design, electromagnetic characteristics of the coil windings are analyzed, and are evaluated using the advanced diagnostic technique developed in (1), and the coiling technique is established.

(4) Prototype Evaluation of Small Magnets: On the basis of the results mentioned above, small magnets are prototyped to demonstrate the improvement of reliability, stability and low loss of high temperature superconducting magnets.

Fig. 1 Reel-to-reel scanning Hall probe microscope.

【Expected Research Achievements and Scientific Significance】

The realization of a magnet that maximizes the potential of a high temperature superconducting wire makes it possible to use a high magnetic field and a high speed varying magnetic field, which is difficult in the conventional technology, and contributes to the development of innovative equipment and academic fields related to electrical energy applications such as high field magnets for accelerators, contactless power feeding (application to high-Q coils handling large electric power), and superconducting rotating machines (compact, light-weight, high-power).

【Publications Relevant to the Project】

- Takanobu Kiss, *OYO BUTURI (in Japanese)*, Vol. 85, No. 5, pp. 377-388, 2016.05.
- K. Higashikawa et al., *IEEE Tran. Appl. Supercond.*, Vol. 27, No. 4, 6603004, 2017.06.

【Term of Project】 FY2019-2023

【Budget Allocation】 153,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://super.ees.kyushu-u.ac.jp/
kiss@sc.kyushu-u.ac.jp

Title of Project：Establishment of evaluation methods for the physical properties of ferroelectrics using coherent state of the elementary excitation and the device applications

FUJIMURA Norifumi
(Osaka Prefecture University, Graduate School of Engineering, Professor)

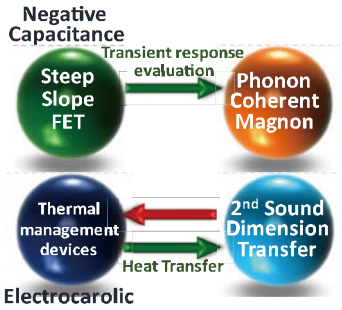
Research Project Number：19H05618　Researcher Number：50199361
Keyword：Ferroelectrics, Elementary excitation, Steep slope transistors, Solid-state thermal diode

【Purpose and Background of the Research】

Ferroelectrics are used in various forms all around us, including in ultra-small capacitors that use large dielectric constants and actuators that use piezoelectricity. The need for sensors and memory devices has increased in the IoT society, and the use of energy harvesters has been also considered. These devices have been developed with the phenomenological theory of ferroelectric phase transition as support. However, it became clear that the electrical polarization of ferroelectrics originated from the geometrical phase of the wave function, and theoretical understanding of this has progressed dramatically in the last 25 years. New physical properties have been found experimentally in response to the progress of theory, and device applications are expected. This project elucidate the high-speed operation mechanism of two such innovative devices: a steep slope field-effect transistor (FET) that operates with ultra-low power and a thermal management device that cools electronic equipment with high efficiency. In addition, the principles of device design will be established using evaluation methods built on the coherence states of elementary excitation.

【Research Methods】

The final goals of this project are to elucidate an operation model of these new devices using the coherent states of elementary excitation in ferroelectrics and to construct the guiding principles that will enable device design. This project will be configured as shown below. We focus on a steep slope FET that uses negative capacitance and on a thermal management device that exploits electrocaloric effects. The phonon, magnon, and thermal solitons (waves) are used as the elementary excitations across the five-year research period. In the steep slope FET, we evaluate phonon modulation and differences in potential change at the semiconductor surface during ferroelectric polarization switching with a time constant of nsec order by using the coherence states of elementary excitation. Regarding the thermal management device, data on heat transport, absorption, and generation caused by the electrocaloric effect inside the ferroelectrics are collected through real-time measurement and simulation of polarization entropy using elementary excitation, and guiding principles for the design of a solid state heat pump is established.



【Expected Research Achievements and Scientific Significance】

Because various effects are superimposed on the electrically measured device properties, it becomes difficult to clarify the physical picture of the operation mechanism. The use of elementary excitation is an effective method of model verification because the physical phenomenon of coherence in elementary excitation is unique to a device, and the method can be applied to measuring the dynamic behavior of device operation in a specific time domain. In addition, a theory of the quantum mechanical phase interface of ferroelectrics can be constructed based on these results. This research develops not only methods for evaluating device performance but also the science of elucidating the physical picture of operation mechanisms that is important for designing optimized devices. It is now possible to provide physical models of various devices, and the potential ripple effect on society is significant.

【Publications Relevant to the Project】

- Time-resolved simulation of the negative capacitance stage emerging at the ferroelectric/semiconductor hetero-junction, AIP Advance, 9 (2019) 025037
- Ferroelectric Thin Films-Basic Properties and Device Physics for Memory Applications, Topics in Applied Physics vol.98, (2005) Springer
- Second Sound in $SrTiO_3$, Phys. Rev. Lett., 99 (2007) 265502
- Light Scattering in a Phonon Gas, Phys. Rev. B, 80 (2009) 165104
- Writing and reading of an arbitrary optical polarization state in an antiferromagnet, Nature Photonics, 9(2015) 25
・Directional control of spin wave emission by spatially shaped light, Nature Photonics, 6 (2012) 662

【Term of Project】FY2019-2023

【Budget Allocation】156,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.pe.osakafu-u.ac.jp/device7/

Title of Project：Development and quantitative interpretation of acoustic and phoxonic metamaterial devices from kHz to GHz frequencies

Oliver B. Wright
(Hokkaido University, Graduate School of Engineering, Professor)

Research Project Number：19H05619　Researcher Number：90281790
Keyword：acoustic, metamaterial, phonon, electromagnetic, plasmon, microscope, metasurface

【Purpose and Background of the Research】

Metamaterials, locally-resonant materials not found in nature that contain artificial sub-wavelength structure, offer new opportunities in physics, materials science and technology. Electromagnetic varieties consist of split rings, giving negative permeability, or I-shaped wire elements, giving negative permittivity, for example. Acoustic varieties often show negative bulk modulus and density. Single-negative acoustic metamaterials (one negative parameter) can be used for damping, with applications in vibration isolation. Double-negative versions can focus acoustic waves into tiny areas below the diffraction limit. Enhanced acoustic transmission, either using resonances in small sub-wavelength apertures—a phenomenon known as extraordinary transmission—or using impedance matched miniature meta-atoms placed between highly mismatched media, can also be achieved. We propose the development and quantitative interpretation of acoustic and phoxonic, i.e. simultaneous photonic and phononic, metamaterial devices from kHz to GHz frequencies.

【Research Methods】

We aim to make scanning acoustic microscopes based on metamaterial extraordinary transmission in air, as well as make a metasurface for efficient acoustic transmission between highly mismatched media, in particular from water to air and vice versa. We also aim to create simple lightweight single-component acoustic metamaterials based on pillars or beams engraved with cavities or slits that can stop all modes of vibration over a wide band of frequencies or support plate flexural modes with double-negative behaviour (see Fig. 1). In addition, we aim to make phoxonic metamaterials (see Fig. 2) based on silicon or metallodielectric nanostructures, and to characterize their behaviour through optical and acoustic spectroscopy.

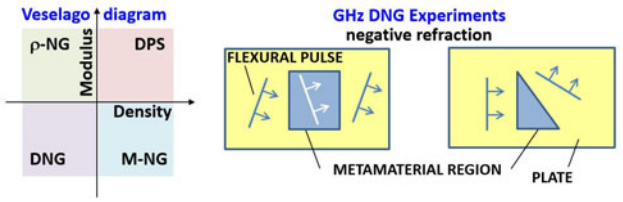


Figure 1 Veselago diagram (elastic modulus M vs density ρ) and our proposed experiments on GHz DNG (double-negative) metamaterials. ρ-NG: negative density, M-NG: negative modulus, DPS: double positive.

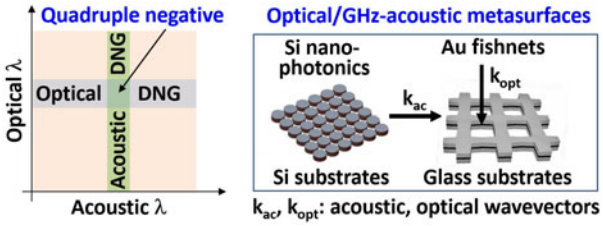


Figure 2 Phoxonic metasurfaces with optical and GHz-acoustic metamaterial bandgaps and "quadruple negative" metamaterials.

【Expected Research Achievements and Scientific Significance】

Metamaterial-scanning acoustic microscopes should lead to deeply-sub-wavelength resolution imaging of textiles or skin texture, with broad application in industry and biomedicine. New metasurfaces should lead to wide-band response and applications in efficient acoustic transduction. We should also be able to develop multiple-resonator-frequency kHz- down to Hz-frequency metapillars and metabeams for total vibration absorption, and acoustic metaplates with double-negative behaviour. In addition, the creation of phoxonic metamaterials should lead to novel "quadruple-negative" metamaterials with application to acoustic-optic modulation and co-focused sub-diffraction-limit acoustic and optic beams.

【Publications Relevant to the Project】

・Q. Xie, S. Mezil, P. H. Otsuka, M. Tomoda, J. Laurent, O. Matsuda, Z. Shen and O. B. Wright, 'Imaging GHz zero-group-velocity Lamb waves', Nat. Comm. **10**, 2228, 2019.
・E. Bok, J. J. Park, H. Choi, C. K. Han, O. B.Wright and S. H. Lee, 'Metasurface for Water-to-Air Sound Transmission', Phys. Rev. Lett. **120**, 044302, 2018.

【Term of Project】

FY2019-2021

【Budget Allocation】

107,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://kino-ap.eng.hokudai.ac.jp
olly@eng.hokudai.ac.jp

Title of Project：Development of a Wideband Microwave Absorber – Contributing to the Internet of Things Society Through Dual-phase Engineering

SUGIMOTO Satoshi
(Tohoku University, Graduate School of Engineering, Professor)

Research Project Number: 19H05620　Researcher Number: 10171175
Keywords: microwave absorber, powder, composite, reflection loss, permeability

【Purpose and Background of the Research】

In the Internet of Things (IoT) era, in which devices and appliances are now connected to the Internet, the number of information and communication technology (ICT) devices is expected to rapidly increase. To accommodate the transmission of large amounts of information at high speeds, the frequency band will be shifted from the current ultra-high frequency band to the higher super-high frequency band (0.7–6.0 GHz), which is called the early 5G band. However, as the noise emitted from many ICT devices affects communications using this band, reduction of this noise is vital.

Although electromagnetic wave absorbers absorb noise and are used to mitigate against this problem, conventional electromagnetic wave absorbers using soft magnetic materials, such as spinel ferrite and Fe-based materials, are not used in this frequency range because of the decrease in the imaginary part of their relative permeability (μ_r"). In addition, because ICT devices emit noise at many different frequencies, electromagnetic wave absorbers should function over a wide frequency range.

Therefore, in this research, modified dual-phase powders consisting of hard magnetic and soft magnetic phases will be prepared. The hard magnetic phase will increase the frequency range because of its high magnetic anisotropy and the soft magnetic phase will generate high permeability. By controlling the microstructure of the modified dual-phase powder, we will develop broadband electromagnetic wave absorbers that can function in the early 5G band.

【Research Methods】

The modified dual-phase powder will be based on a composite powder consisting of hard and soft magnetic phases (Table 1). This design is based on the difference in resonannce frequencies between the two phases. The powder will be prepared by heat treatment (e.g., hydrogen reduction), followed by mixing using a mechanofusion reaction or a coating method (e.g., arc plasma deposition). Furthermore, to obtain electromagnetic wave absorption over a wide frequency range, μ_r' and μ_r" must be within a certain range (matching region), as shown in Fig. 1. To achieve this, the two-phase microstructure will be controlled by methods including the distribution of the two phases in the powders and the volume fraction of the powders in resin composites.

Table 1 Schematic illustration of modified dual-phase powders.

Method	Hard Magnetic Particles		Soft Magnetic Particles		Modified Dual Phase Particles	
Mixing	Coprecipi-tation	◯	Hydrogen Reduction Hydrogen Plasma Metal Reaction (HPMR)	●	Mechanofusion	◎
Coating	–	–		●	Metal Organic Decomposition	◎
	Coprecipi-tation	◯	–	–	Arc Plasma Deposition (APD)	◎
Heat Treat.	Coprecipi-tation	◯	–	–	Hydrogen Reduction (Partial reduction)	◎

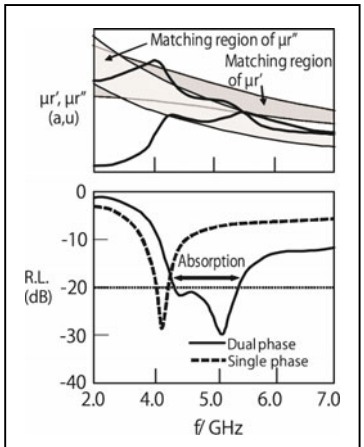


Fig. 1 Matching regions and reflection loss (RL).

【Expected Research Achievements and Scientific Significance】

In this research, a new type of microwave absorption material will be developed for use in microwave absorbers. The material will be based on a modified powder composed of a hard and soft magnetic phase. The results will contribute to the development of ICT devices and to the establishment of IoT and sustainable societies.

【Publications Relevant to the Project】

・S. Sugimoto, S. Kondo, K. Okayama, et al., "M-type ferrite composite as a microwave absorber with wide bandwidth in the GHz range", *IEEE. Trans. Magn.*, **35**(5), 3154-3156, (1999).
・T. Maeda, S. Sugimoto, T. Kagotani, et al., "Effect of the soft/hard exchange interaction on natural resonance frequency and electromagnetic wave absorption of the rare earth-iron-boron compounds", *J. Magn. Magn. Mater.*, **281**, 195-205, (2004).

【Term of Project】

FY2019-2023

【Budget Allocation】

122,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.material.tohoku.ac.jp/~jisei/index.html
sugimots@material.tohoku.ac.jp

Title of Project：Development of Spin Coherent Microscopy with Time and Space Resolutions Dedicated for Quantum Information Processes

KOMEDA Tadahiro
(Tohoku University, Institute of Multidisciplinary Research for Advanced Materials, Professor)

Research Project Number：19H05621　Researcher Number：30312234
Keyword：Nano microscope technique, Spintronics, Quantum Information Process

【Purpose and Background of the Research】

The development of the quantum computing (QC) attracts much attention, which is expected to play the crucial role in the quantum information process. Compared to the rapid progress of the software, the construction of the hardware faces technical difficulties.

In the QC system, the element of the information is called quantum bit (qubit) and the superposition of the assembly of the qubits is the core of QC. It is required to tune the interaction between qubits with a high precision, which is one of the technical barriers for the hardware construction. In terms of the precise placement of the qubit, the use of the molecule spin as the qubit has a large advantage due to the precision of the molecule structure. Combined with the use of the high-resolution spin detection system of ESR/NMR, the assembly of the molecules served as the platform of the Shor algorithm in the early stage of the QC development. However, ESR/NMR techniques require a large amount of molecules due to the sensitivity. This suggests that a new spin detection system for the nano-device composed of a small number of molecules has to be developed. In addition such a system can be used for the analysis of each qubit to judge whether it can be qualified for the qubit.

【Research Methods】

This project is dedicated to the development of the spin microscope, which can detect a spin of an atom/molecule with the atomic-scale space resolution. In addition, combined with the pulse RF application, the time evolution of the spin can be examined.

We pay special attentions for molecules, which is partially because the qubit with multiple states, which is called a qudit, is studied extensively to reduce the number of qubits. This can be realized with using bis(phthalocyaninato)terbium(III) complex ($TbPc_2$). The 4*f* spin of this molecule possesses a large magnetic anisotropy, the class of the molecules is called single molecule magnet (SMM).

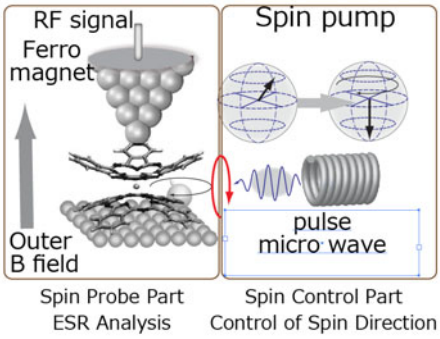


Figure 1. Skematics of the spin microscope. Spin probe part (left) detects the direction of the spin with ESR chemical analysis. Spin manipulation part (right) control the direction of the spin.

We employ the tunneling magnetic resistance (TMR) to detect the spin direction of the molecule. (see Fig. 1) The 4f electron of the TbPc2 molecule has a large spin of $J=6$. Depending on whether the spins of the tunneling electrons and the 4f spins are parallel or anti-parallel, we see the increase/decrease of the tunneling conductance due to the TMR and the information of the nuclear spin state appears as the hyper structure in the conductance change of the TMR. In addition to the detection of the spin state of the electron/nucleus, we place coils to generate pulse magnet to manipulate the spin direction and observe it time-evolution to examine the dynamic.

【Expected Research Achievements and Scientific Significance】

The techniques that will be developed in this project enable the detection of a single spin together with the analysis of its dynamics and coherence. The new spin microscope can provide a similar chemical analysis currently produced by ESR/NMR techniques for a nano system which will play an important role in the characterization of the qubit and qudit of the quantum computer.

【Publications Relevant to the Project】

○Observation and electric current control of a local spin in a single-molecule magnet, T. Komeda, H. Isshiki, J. Liu, Y.-F. Zhang, N. S. Lorente, K. Katoh, B. K. Breedlove, M. Yamashita: Nat. Comm. 2, (2011) 217.
○Spatially Resolved Magnetic Anisotropy of Cobalt Nanostructures on the Au(111) Surface, P. Mishra, Z. K. Qi, H. Oka, K. Nakamura, T. Komeda: Nano Lett. 17, (2017) 5843-5847.

【Term of Project】

FY2019-2023

【Budget Allocation】

147,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://db.tagen.tohoku.ac.jp/php/forweb/outline.php?lang=ja&no=1020

Title of Project：Non-collinear spintronics

FUKAMI Shunsuke
(Tohoku University, Research Institute of Electrical Communication, Associate Professor)

Research Project Number：19H05622　Researcher Number：60704492
Keyword：Spintronics, Non-collinear magnetic structure

【Purpose and Background of the Research】

Spintronics, where two characters of electron – charge and spin – are utilized simultaneously, allows electrical control of collective magnetic ordering of magnetic materials. This has been a central topic of the spintronics research for the past two decades and various opportunities that classical magnetic engineering cannot achieve has been unraveled. Direct electrical manipulation of magnetization through the spin-transfer torque (STT) was demonstrated in 1999 and is utilized nowadays in STT-MRAM, a nonvolatile magnetic memory utilizing the STT-induced magnetization switching. In 2011, spin-orbit torque (SOT) was found as an alternative driving force to control the magnetization of ferromagnets and high-speed magnetization switching, which is not readily achieved by the STT, has been demonstrated. In addition, in 2016, SOT was found to allow electrical control of Néel vector of collinear antiferromagnets, which has not been considered to offer technological benefits, gathering great attentions recently. As described above, new horizons have been opened by appearance of new magnetic ordering and driving force.

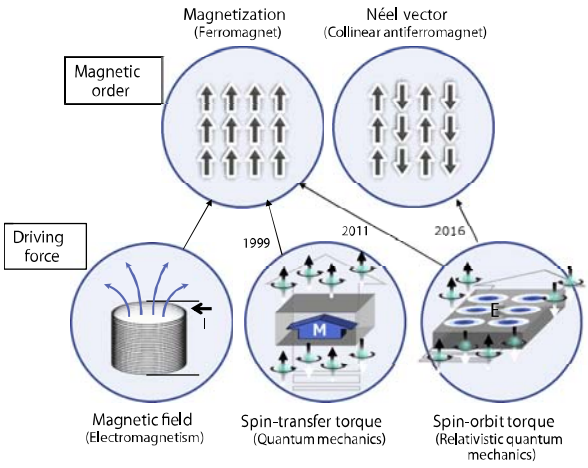


Figure 1 Electrical control of magnetic ordering

Figure 1 shows an overview of the electrical control of collective magnetic ordering described above. In this project, we aim to offer a new opportunity in the electrical control of magnetic ordering and to this end we focus on non-collinear magnetic structures which have not been explored in this field so far.

【Research Methods】

This field has mainly dealt with collinear magnetic ordering till now. Our project will explore a new paradigm "non-collinear spintronics" that should be spread beyond the conventional "collinear spintronics" paradigm. Several recent studies have revealed various interesting phenomena observed in non-collinear magnetic structures, which are realized as a consequence of frustration of several magnetic interactions. We will carry out experimental investigation where advanced stack-structure deposition, microfabrication, and measurement technique will be utilized, together with theoretical studies, and clarify the capability and functionality of the novel physical properties of the non-collinear magnetic structures.

【Expected Research Achievements and Scientific Significance】

The electrical control of magnetic ordering is not only a critical building block of nonvolatile magnetic memory, but also a promising ingredient for unconventional, e.g., neuromorphic, computing. "Non-collinear spintronics" explored in this project is expected to push out the frontier of spintronics, as well as forming a new basis for such low-power, intelligent integrated circuits and information devices.

【Publications Relevant to the Project】

· S. Fukami *et al.*, "Magnetization switching by spin–orbit torque in an antiferromagnet– ferromagnet bilayer system," *Nature Materials*, vol. 15, pp. 535-541 (2016).
· S. Fukami *et al.*, "A spin–orbit torque switching scheme with collinear magnetic easy axis and current configuration," *Nature Nanotechnology*, vol. 11, pp. 621-625 (2016).

【Term of Project】

FY2019-2023

【Budget Allocation】

155,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.spin.riec.tohoku.ac.jp/en/

【Grant-in-Aid for Scientific Research (S)】

Broad Section D

Title of Project：Development of a new upgrade recycling technology for titanium

OKABE Toru
(The University of Tokyo, Institute of Industrial Science, Professor)

Research Project Number：19H05623　Researcher Number：00280884
Keyword：Titanium, Recycling, Deoxidation, Rare earth element, Pyrometallurgical process

【Purpose and Background of the Research】

Titanium is an attractive metal because of its abundance and excellent properties such as high specific strength and corrosion resistance. However, no process can produce Ti from its ore at a low cost. Furthermore, during the fabrication of Ti, a large amount of scrap is generated due to its poor workability (Fig. 1). Therefore, Ti products are expensive and not used widely.

The oxygen concentration in Ti scrap is high and the price of such scraps is between one-tenth and half of that of virgin metal (Ti sponge). In this study, we developed a novel method to directly remove oxygen from Ti scrap to use it for producing high-purity Ti ingots. With this new "upgrade recycling method," we aim to establish a new recycling scheme for Ti scrap to decrease the cost of Ti products.

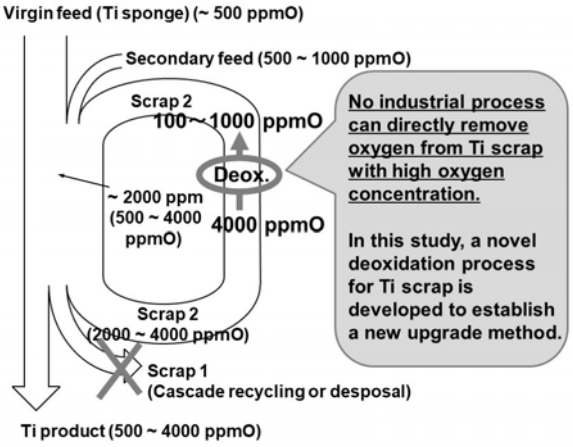


Fig. 1 Material flow of Ti scrap and oxygen concentration in Ti scraps.

【Research Methods】

If Mg can be used as a deoxidizing agent for Ti deoxidation in molten $MgCl_2$, vacuum separation of Mg and $MgCl_2$ and electrolysis of $MgCl_2$ for Mg regeneration—employed in the conventional Ti production process (the Kroll process)—can be utilized. However, as Ti has a high affinity for oxygen, it is considered impossible to remove the oxygen dissolved in Ti ($O_{in\ Ti}$) by forming MgO utilizing Mg deoxidation ($O_{in\ Ti} + Mg \rightarrow MgO$) due to the low deoxidation ability of Mg.

In our recent studies, a novel method for decreasing the activity of MgO in MgX_2 (X: F, Cl) by adding a rare earth halide (REX_3) was proposed, based on thermodynamic assessment. $O_{in\ Ti}$ reacts with Mg and the REX_3 to form a rare earth oxyhalide REOX ($O_{in\ Ti} + Mg + REX_3 \rightarrow REOX + MgX_2$). It was found that this novel method decreases the oxygen concentration in Ti to levels below 100 ppm O (relevant literatures has been cited below).

However, thermodynamic data available on rare earth compounds involve large errors and are unreliable. Therefore, in this study, we will experimentally investigate the reliability of the thermodynamic data available on rare earth compounds. During the course of the experiments, we will evaluate the errors in the thermodynamic data, investigate the effect of the formation of rare earth oxyhalides on the deoxidation of Ti, and develop a novel deoxidation method. Furthermore, a method for the recovery of rare earth oxyhalides will be developed to establish a process with no consumption of rare earth. Moreover, new removal techniques or mitigation techniques for contaminants in Ti ores, such as iron, will also be developed.

【Expected Research Achievements and Scientific Significance】

The material flow of Ti will change when the cost of Ti production process using upgraded Ti scrap becomes comparable to that of the conventional Ti production process from ores (the Kroll process). If it becomes possible to export highly valuable Ti products produced from imported low-cost Ti scrap, global business concerning Ti metal production will face a paradigm shift.

【Publications Relevant to the Project】

・T. H. Okabe, C. Zheng, and Y. Taninouchi: 'Thermodynamic Considerations of Direct Oxygen Removal from Titanium by Utilizing the Deoxidation Capability of Rare-Earth Metals', Metall. Mater. Trans. B, vol. 49, no. 3, (2018) pp.1056–1066. (DOI: 10.1007/s11663-018-1172-4)
・T. H. Okabe, Y. Taninouchi, and C. Zheng: 'Thermodynamic Analysis of Deoxidation of Titanium Through the Formation of Rare-Earth Oxyfluorides', Metall. Mater. Trans. B, vol. 49, no. 6, (2018) pp. 3107–3117. (DOI: 10.1007/s11663-018-1386-5)

【Term of Project】FY2019-2023

【Budget Allocation】155,300 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.okabe.iis.u-tokyo.ac.jp/
okabe@iis.u-tokyo.ac.jp

Title of Project：Dynamic femtoliter reactor technology for next generation digital bioassays

NOJI Hiroyuki
(The University of Tokyo, School of Engineering, Professor)

Research Project Number：19H05624　Researcher Number：00343111
Keyword：Single molecule digital counting, Dynamic nano reactor technology

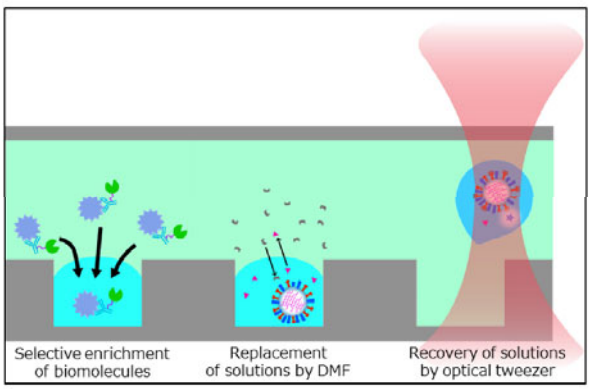
【Purpose and Background of the Research】

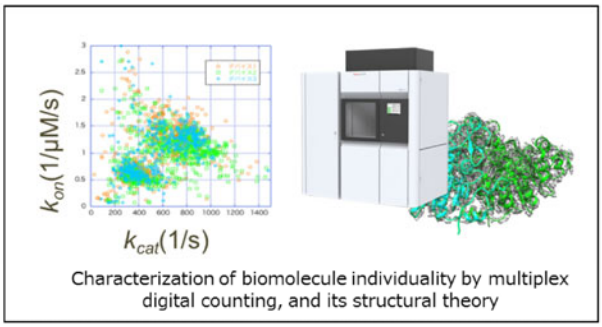
We have developed femtoliter reactor (fL reactor) array technology and lead the research of single molecule digital bioassays. However, conventional fL reactor arrays are not capable to actively condense and encapsulate target molecules, that is a bottleneck for further expansion of the research field and applications of digital bioassay. This project aims to develop new key technologies to confer "dynamic" functions on fL reactor array: active uptake and condensation of molecules, control of solution composition, and release of molecules from reactors or release of reactors themselves from array devices. Such technologies will enable the on-chip integration of conventional off-chip processes such as solutions exchange and sample condensation. These innovations will realize on-site single molecule digital diagnostics. These technologies will also pave a way for multidimensional digital bioassays that will reveal the molecular mechanisms of the polymorphism of activities of enzyme molecules and virus particles.

【Research Methods】

Firstly, we will develop"dynamic" fL reactor technologies which allow condensation of solutes, solution exchange, volume control, and release of solutes or reactors themselves. For this purposes, we will attempt to incorpotare unieque solution phenomena (eg, excluded volume effect) as well as dielectricphoresis (DEP) and digital microfluidic (DMF) with fL reactor array devices.

Next, based on this technological development, we will establish novel single molecule digital counting methods, and develop on-chip integrated digital bioassay technology (mainly ELISA). Moreover, we will develop multidimensional digital bioassay methods that quantitatively analyze the activity of individual molecules under various conditions in order to characterize their activity in multiple parameter space. These multidimensional digital bioassays will provide deep insights on how polymorphism among enzyme molecule or virus particles emerges.





Characterization of biomolecule individuality by multiplex digital counting, and its structural theory

【Expected Research Achievements and Scientific Significance】

Digital ELISA is regarded as one of the most promising bioassays for next generation clinical diagnosis. However, current system requires off-chip processes that hamper the realization of on-site high sensitive diagnostic tests. Once such off-chip processes are integrated on-chip digital ELISA, the total size of the assay system should be remarkably downsized, offering an avenue for on-site diagnosis that is indispensable for a personal medical care in future. In addition, this project will enhance our understanding on "molecular individuality", that will also bring important implications on how evolutional adaptation occurs at molecular level.

【Publications Relevant to the Project】

・Tabata KV, et al., Antibody-free digital influenza virus counting based on neuraminidase activity, *Sci Rep*. 31;9(1):1067 (2019)
・Zhang Y and Noji H, Digital Bioassays: Theory, Applications, and Perspectives, *Anal Chem*., 89, 92-101 (2017)
・Rondelez Y, et al., Microfabricated arrays of femtoliter chambers allow single molecule enzymology, *Nature Biotechnology*, 23, 361-365 (2005)

【Term of Project】

FY2019-2023

【Budget Allocation】

138,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.nojilab.t.u-tokyo.ac.jp/
office@nojilab.t.u-tokyo.ac.jp

Title of Project：Novel Negative Thermal Expansion Materials for Thermal Expansion Control

AZUMA Masaki
(Tokyo Institute of Technology, Institute of Innovative Research, Laboratory for Materials and Structures, Professor)

Research Project Number：19H05625　Researcher Number：40273510
Keyword：Negative Thermal Expansion, Phase Transition, Local Structure Analysis, Composite Materials, Topology Optimization

【Purpose and Background of the Research】

Thermal expansion arising from anharmonicity of lattice vibrations causes serious problems such as: 1. Deviation of positioning, 2. Deformation, breakage, deterioration of shape accuracy and peeling due to thermal stress. These problems are recognized as a pressing issue in advanced electronic devices such as power semiconductors and three-dimensional integrated circuit devices, and energy and environmental technologies such as thermoelectric conversion and fuel cells, and thermal expansion control is essential for technological innovation. Azuma and Takenaka have developed a new generation of negative thermal expansion materials, which are expected to be able to control the thermal expansion coefficient to an arbitrary value by adding to resins. It is the purpose of this research to establish thermal expansion control technology using giant negative thermal expansion material while developing new materials aiming at industrialization.

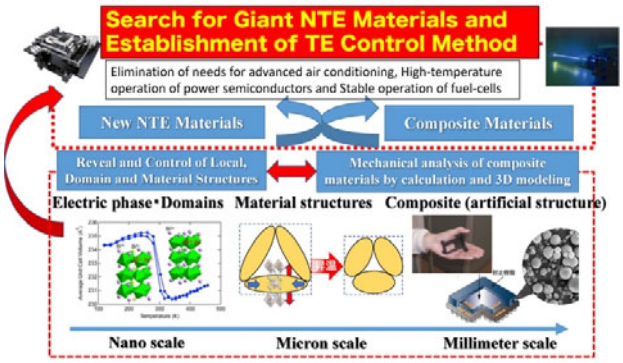


Figure 1 Image of the project

【Research Methods】

Reveal the nanoscale local structure, micron scale domain structure and material structure and structural and mechanical properties of millimeter scale artificial structure fabricated by 3D printing using advanced quantum beams and numerical calculation based on elastic mechanics theory. Furthermore, we will elucidate the phase transition dynamics that is the origin of negative thermal expansion, making full use of first-principles calculations. We will conduct efficient material development by feeding back these results to material design. In addition, a zero thermal expansion composite materials with strong mechanical properties is realized by dispersing the negative expansion material developed in this way into a resin with numerically optimized concentration and arrangement using 3D printing.

【Expected Research Achievements and Scientific Significance】

First, the understanding of the phase transition behavior that influences the negative thermal expansion characteristics will progress, and an efficient material search method can be established. This provides a negative thermal expansion material that can be supplied at a realistic price, followed by a negative thermal expansion of -100×10^{-6} / °C over a temperature range of 300°C. In addition, we construct a method to predict the thermal expansion coefficient of a composite material in which a structural material having positive thermal expansion and a negative thermal expansion material are mixed at an arbitrary ratio. Furthermore, by optimizing the placement of the negative thermal expansion material by 3D printing, a structural material with high mechanical strength and an arbitrary coefficient of thermal expansion is realized.

By these, the theory of the negative thermal expansion material and its usage will be constructed, and the problem of the thermal expansion which is socially required is solved, contributing to the further development of precision processing, energy and environmental technology.

【Publications Relevant to the Project】

・K. Takenaka, Y. Okamoto, T. Shinoda, N. Katayama, and Y. Sakai, “Colossal negative thermal expansion in reduced layered ruthenate”, *Nature Commun.*, **8**, 14102/1–7 (2017).
・M. Azuma, W-T Chen, H. Seki, M. Czapsli, S. Olga, K. Oka, M. Mizumaki, T. Watanuki, N. Ishimatsu, N. Kawamura, S. Ishiwata, M. G. Tucker, Y. Shimakawa, and J. P. Attfield, “Colossal negative thermal expansion in $BiNiO_3$ induced by intermetallic charge transfer”, *Nature Commun.*, **2**, 347/1–5 (2011).

【Term of Project】

FY2019-2023

【Budget Allocation】

155,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.msl.titech.ac.jp/~azumalab/

Title of Project：High performance microbial cell factories development by model based metabolic design and adaptive laboratory evolution

SHIMIZU Hiroshi
(Osaka University, Graduate School of Information Science and Technology, Professor)

Research Project Number：19H05626　Researcher Number：00226250
Keyword：Metabolic Engineering, Bioprocess

【Purpose and Background of the Research】

To establish sustainable society, microbial production of chemicals and fuels from bio-resources has attracted great attention. It is not easy to systematically improve metabolic pathways of microorganisms to optimize productivity of the target product because microorganisms involve many metabolic reactions with complicated interactions in the cells. Development of *in silico* platform to understand metabolic activity at the whole cell level and rational design method of metabolic pathway modification are highly desired.

In this study, we plan to develop the integration method of *in silico* metabolic pathway design of growth coupled production of target chemicals and adaptive laboratory evolution to obtain evolved strains with superior phenotype. Rate limiting steps of the metabolic pathways would be eliminated in the evolved strain. Based on the elucidation information of inherent control mechanism, novel metabolic engineering method to rationally optimize target productivity is established in this research.

【Research Methods】

Novel metabolic engineering principle and methods to understand microbial metabolism and rationally design metabolic pathway modification are established. An industrially important microorganism, *Escherichia coli*, is used as a host cell for bio-production in this study.

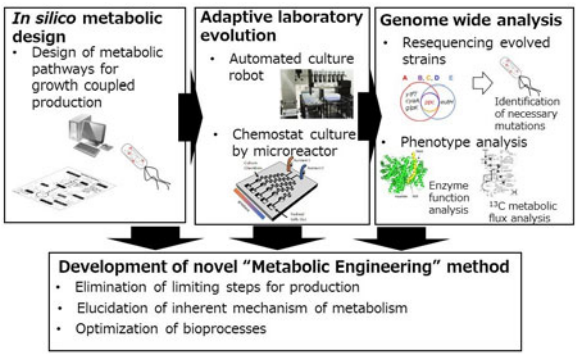


Fig. Plan of Research

To achieve the objectives, we plan to perform this research as following steps. 1) *in silico* design of metabolic pathways as growth coupled production for ten chemicals from different substrates, 2) adaptive laboratory evolution of the chemical producing strains by independent culture series by the automated culture robot, 3) multiple chemostat cultures by microfluidic technology, 4) elucidation of metabolic transition mechanisms by genome and metabolomics analyses, and 5) molecular breeding for superior performance cells with high productivity.

【Expected Research Achievements and Scientific Significance】

In this study, we plan to integrate *in silico* design of metabolic pathways and adaptive laboratory evolution engineering. By comparative genome and metabolic states analyses of the parental and evolved strains, rate limiting steps and inherent control mechanisms in metabolism are revealed. The final goal of the study is establishment of rational modification strategy method to optimize target product. The results provide us a novel understanding of microorganisms and new discipline of construct high performance cell factories in bioprocesses.

【Publications Relevant to the Project】

・Tokuyama, K, Toya, Y, Horinouchi, T, Furusawa, C, Matsuda, F, Shimizu, H. Application of adaptive laboratory evolution to overcome a flux limitation in an *Escherichia coli* production strain, ***Biotechnol Bioeng,*** **115**, 1542-1551 (2018)
・Toya, Y, Shimizu, H. Flux analysis and metabolomics for systematic metabolic engineering of microorganisms, ***Biotechnol Adv***, **31**, 818-826 (2013)

【Term of Project】

FY2019-2023

【Budget Allocation】

144,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www-shimizu.ist.osaka-u.ac.jp/hp/index.html
shimizu@ist.osaka-u.ac.jp

Title of Project：Super-resolution live-cell imaging of cell-attached nanointerface using LSPR sheets

TAMADA Kaoru
(Kyushu University, Institute for Materials Chemistry and Engineering, Professor)

Research Project Number：19H05627　Researcher Number：80357483
Keyword：Localized surface plasmon resonance, Self-assembly, Live-cell imaging, Super-resolution

【Purpose and Background of the Research】

A breakthrough in image analysis technology using AI is causing a paradigm shift in the field of biomedical diagnostics. When enormous number of images can be processed at high speed, what is needed next is cutting-edge, high-quality image information that matches advanced information processing technology. Our original technique, 'Localized plasmon resonance (LSPR) sheet' composed of self- assembled metal nanoparticles, realizes super-resolution, high-speed imaging of molecular dynamics at the buried nanointerface due to the optical confinement and fluorescence enhancement effect of LSPR. In this study, the LSPR sheet is used to reveal complex molecular level of reactions at the cell attached nanointerface in super-resolution. We challenge to build up new methodology to solve important biomedical issues such as differentiation and reprogramming of stem cells and canceration by use of the LSPR sheet.

【Research Methods】

Our previous study revealed that the LSPR sheets composed of spherical nanoparticles provide the world thinnest fluorescence images in the Z-axis direction due to the light confinement effect by LSPR (Figure 1, Figure 2) [1, 2]. In this new project, we will fabricate new self-assembled sheet composed of different shape of particles in order to realize more stable and stronger optical electric field for super-resolution high-speed 'live-cell' imaging. We will build up system to process large amounts of high-resolution, high-speed images and track and analyze the molecular dynamics of living cells in real time. We will also develop fast diagnosis methods of cell characteristics by use of biochemical and physical stimulation. The Z-position of focal adhesion such as "push in" or "pull up" on a soft gel will be evaluated in nano-sensitivity by the brightness change of focal adhesion spots.

【Expected Research Achievements and Scientific Significance】

One of our goal is to bring new discoveries in the life science field by use of our unique LSPR sheet. Another goal is to complete our LSPR sheet as a global standard technology, and contribute to the society by the development of "high-throughput diagnostic system of cellular activity and tumors".

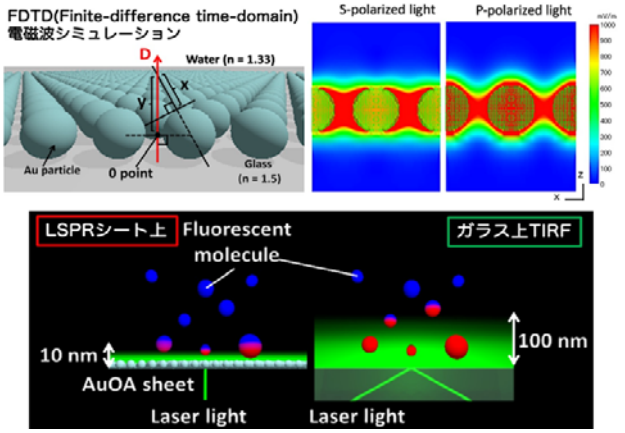


Fig.1 Electric field excited by self-assembled spherical metal nanoparticles.

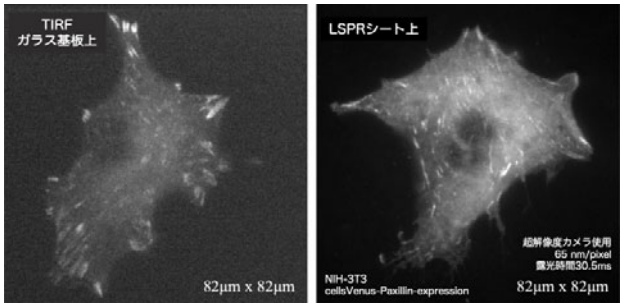


Fig.2 Image of immobilized cell on LSPR sheet in comparison with regular TIRF image.

【Publications Relevant to the Project】

1. Masuda, S.; Yanase, Y.; Usukura, E.; Ryuzaki, S.; Wang P.; Okamoto, K.; Kuboki, T.; Kudoaki, S.; Tamada, K.*, High-resolution imaging of a cell- attached nanointerface using a gold-nanoparticle two dimensional sheet, **Sci. Rep.** 7, 3720 (2017).
2. Usukura, E.; Yanase, Y.; Ishijima, A.; Kunoki, T.; Kidoaki, S.; Okamoto, K.; Tamada, K.*, LSPR mediated high axial-resolution fluorescence imaging on a silver nanoparticle sheet, **PLoS ONE**, 12, e0189708 (2017).

【Term of Project】

FY2019-2023

【Budget Allocation】

149,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.cm.kyushu-u.ac.jp/ktamada/
tamada@ms.ifoc.kyushu-u.ac.jp

Title of Project：Attosecond Science in the sub-keV region

MIDORIKAWA Katsumi
(RIKEN, Center for Advanced Photonics, Director)

Research Project Number：19H05628　Researcher Number：40166070
Keyword：Quantum Electronics, Attosecond Science, Ultrafast Optics, Nonlinear Optics, Laser Engineering

【Purpose and Background of the Research】

Attosecond science has carved out one important research branch of ultrafast optics for the last two decades. The success had given us many important knowledges for fundamental science of the interaction between electrons and photons. However, an output energy of isolated attosecond pulses above 100 eV is still not sufficient, though the pulse duration attained is sub-100 as. Thus, applications of attosecond pulses has been limited to a photon energy region of less than 100 eV and the extension of available photon energy of an isolated attosecond pulse to the sub-keV region is desired eagerly.

In this research, in order to bring a breakthrough in attosecond science, we will extend the cut-off wavelength of an isolated attosecond pulse to the sub-keV region and develop a novel method to control polarization of attosecond pulses by combining a high energy mid-infrared pulse source and a loose focusing method.

【Research Methods】

(1) Compression of high energy 3μm pulses
A 2.5 μm idler pulse generated with optical parametric amplifier (OPA) pumped by a fs Ti:S laser is introduced to a gas cell filled with rare gases to increase the bandwidth to 1.8 – 4.0 μm by self-phase modulation. This broadband pulse is used as a seed of dual-chirped pulse OPA (DC-OPA). Then, the chirp and pulse duration are adjusted with a AOPDF to suppress spectral narrowing during amplification. After the amplification, the 3 μm pulse is compress to a few cycle duration with a combination of bulk silica glasses and chip mirrors.

(2) Generation of sub-keV attosecond high harmonics
The continuum harmonics having a cutoff energy near keV is generated by focusing a few cycle 3 μm high energy pulse to a rare gas cell. Although generation efficiency of high harmonics is rapidly decreasing with increasing the pump wavelength, an efficiency of 10^{-7} is expected by compensating absorption loss and phase mismatch in the sub-keV region.

(3) Observation of sub-femtosecond structural dynamics by x-ray transient absorption spectroscopy
A 50 nm thick graphite on a Al thin film is irradiated with 25 fs Ti:S pulses to induce its structural change. Then, ultrafast transient x-ray absorption spectrum is measured to obtain an information of the rearrangement of C atoms with attosecond harmonics covering the C K-edge to 700 eV.

(4) Generation of circularly polarized high harmonics
Novel two-stage co-axial pumping geometry which can generate circularly polarized high harmonics is investigated. The polarization of high harmonics is arbitrary controlled by precisely adjusting the delay between two orthogonally polarized harmonics with linear polarization which are generated two different position and propagated colinearly.

【Expected Research Achievements and Scientific Significance】

Since the demonstration of “water window” high harmonics generation by using fs 1.6 μm pulses, a pumping source of attosecond pulses is being changed to from a conventional 800 nm Ti:S laser to mid-infrared OPA. An intense attosecond pulse in the sub-keV region which is generated with DC-OPA developed in my laboratory will provide attosecond temporal resolution in x-ray absorption spectroscopy. Circularly polarized attosecond pulses also would revolutionize x-ray magnetic circular dichroism measurements. Those new attosecond pulse technologies are expected to bring the remarkable progress in materials and chemical science. Furthermore, the advent of fs high-energy mid-infrared lasers has a potential to explore the horizon of strong field physics as well as attosecond science.

【Publications Relevant to the Project】

・Y. Fu, K. Midorikawa, and E. J. Takahashi, “Towards a petawatt-class few cycle infrared laser system via dual-chirped optical parametric amplification,” Sci. Reports. 8, 7629 (2018).
・E. J. Takahashi, T. Kanai, K. L. Ishikawa, Y. Nabekawa, and K. Midorikawa, “Coherent water window x-ray by phase-matched high-order harmonics,” Phys. Rev. Lett. 101, 253901 (2008).

【Term of Project】FY2019-2023

【Budget Allocation】152,400 Thousand Yen

【Homepage Address and Other Contact Information】

https://rap.riken.jp/en/labs/eprg/asrt/

Title of Project：Efficient spin current generation based on coherent magnetoelastic strong coupling state

OTANI Yoshichika
(RIKEN Center for Emergent Matter Science, Professor)

Research Project Number：19H05629　Researcher Number：60245610
Keyword：magnon-phonon coupling, acoustic cavities, spin current, strong coupling

【Purpose and Background of the Research】

One of the most fundamental forms of magnon-phonon interaction is an intrinsic property of magnetic materials, i.e. “magnetoelastic coupling”. This particular form of magnon-phonon interaction has been known for more than a century and has important consequences for fundamental descriptions of the physics of magnetic materials and applications; where elastic excitation produces changes of effective magnetic fields or vice versa. More recently, magnon-phonon coupling was employed for the generation and investigation of pure spin currents (flows of angular momentum) in nonmagnetic materials. The proposed research project aims to clarify the effect of magnon-phonon interactions on spin current generation in both the weak and strong magnon-phonon coupling regimes. Enhancement of the magnon-phonon interaction, via implementation of acoustic wave reflectors, would directly improve the efficiency of spin current generation by minimizing energy losses, and thus enable us to explore the strong coupling regime.

【Research Methods】

In our experiments, we generate surface acoustic waves (SAWs) by injecting AC-voltage to interdigital transducers (IDTs). The SAWs then propagate over the surface and couple to a magnetic layer. However, this method is limited by the bi-directionality of the SAWs, which travel in opposite directions from IDTs, therefore only imparting half of the total phonon energy into the magnetic layer. Thus, it is crucial to minimize the losses of phononic energy in our transfer mechanism. However, we can completely overcome this limitation by adding acoustic reflectors to the ends of our IDTs as shown Fig. 1. If the distance between reflectors and IDTs is properly engineered, we can obtain constructive wave interference and hence increase the phonon coupling to our magnetic layer. By collecting the waves travelling in the opposite direction to our magnetic film, and directing them back towards the film, we can expect enhancements of the coupling strength by two to four times. The resulting structure is an acoustic analogue of an optical resonator formed between adjacent Bragg mirrors, and consequently allows us to enter the strong magnon-phonon coupling regime.

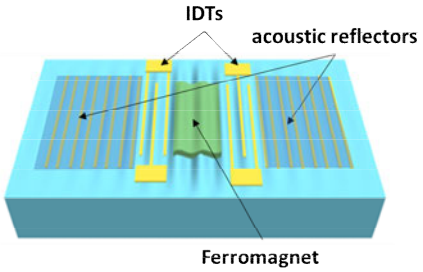


Fig. 1 Cavity device structure for strong magnon-phonon coupling

【Expected Research Achievements and Scientific Significance】

The minimization of energy losses in the magnon-phonon coupling would directly result in enhancement of spin current generation. We plan to extend our study and elucidate the level of spin current generation we can achieve when we are in the strong coupling regime of magnon-phonon interactions. In this regime, the spin current generation is predicted to depend not only on the minimization of energy losses, but also on the ultra-efficient cyclical transfer of energy within the magnon-phonon composite quasiparticle state, potentially leading to as-yet unknown regimes of spin current generation. Furthermore, we may take advantage of the strong magnon-phonon coupling regime to explore emergent quantum phenomena associated with the superposition state. Under the right conditions it could be possible to transfer information from the magnon to the phonon state and vice versa, in an encrypted system, representing a new paradigm of quantum information based on magnon-phonon coupling phenomena.

【Publications Relevant to the Project】

M. Xu, J. Puebla, F. Auvray, B. Rana, K. Kondou, and Y. Otani, “Inverse Edelstein effect induced by magnon-phonon coupling”, Phys. Rev. B **97**, 180301(R) (2018).

【Term of Project】

FY2019-2023

【Budget Allocation】

137,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www2.riken.jp/lab-www/nanomag/

Title of Project：Practical synthesis of rare and structurally complex natural products and the development of the molecules with better biological functions

HAYASHI Yujiro
(Tohoku University, Graduate School of Science, Professor)

Research Project Number：19H05630　Researcher Number：00198863
Keyword：organocatalyst, one-pot reaction, total synthesis, asymmetric synthesis

【Purpose and Background of the Research】

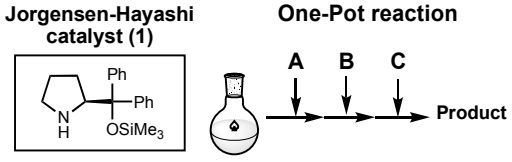
Natural products have a treasure trove of functions. Excellent medicines have been developed based on natural products. However, the science of rare natural products with complex backbones remains unexplored, because of their scarcity. If rare and biologically active natural products with complex skeletons can be synthesized in a short time with an enough quantity, they could open the door to a new science.

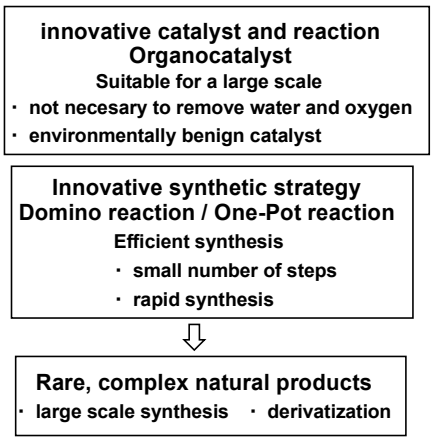
Efficient synthesis is one of the current trends in natural product synthesis, but it is a challenge to synthesize the complex natural products on a large scale. I have developed an innovative "Jorgensen-Hayashi catalyst (**1**)", and found many practical asymmetric reactions with excellent enantioselectivity. I also developed the new concept of pot economy, where multiple reactions are carried out in the same reaction vessel. Therefore, it would be possible to synthesize unexplored, rare natural products efficiently on a large scale by combining the organocatalyst mediated asymmetric reactions with pot economy. Moreover, if the synthetic method of the natural products can be accomplished, the creation of derivatives with better biological properties can be possible.

【Research Methods】

Organocatalysts are practical catalysts, because it is not necessary to remove water and oxygen from them completely, and there is no fear of metal contamination in the final compounds. Moreover, oragocatalysts are usually inexpensive. I have developed "Jorgensen-Hayashi catalyst **1**", which is an effective catalyst for many asymmetric reactions.

On the other hand, I proposed the concept of pot economy in the synthesis of molecules. One-pot operations serve as effective method for both carrying out several transformations and forming several bonds in a single-pot, while at the same time cutting out several purifications, minimizing chemical waste generation, and saving time.





Organic natural products with strong biological activity will be synthesized using the combination of organocatalyst and the concept of pot economy. Target molecules include amphotericin B, amphdinolide, prostaglandin, and steroids.

【Expected Research Achievements and Scientific Significance】

Natural products, which are difficult to obtain from natural sources and are difficult to synthesize because of their complex structure, can not to be investigated for their biological functions due to their scarcity. The practical synthesis of these natural products on a large scale will make a new science. Moreover, it can also provide derivatives with better biological functions.

【Publications Relevant to the Project】

・Pot economy and one-pot synthesis, Y. Hayashi, *Chem. Sci.*, **2016**, *7*, 866-880.
・Time Economical Total Synthesis of (−)-Oseltamivir, Y. Hayashi, S. Ogasawara, *Org. Lett.*, **2016**, *18*, 3426-3429.

【Term of Project】

FY2019-2023

【Budget Allocation】

133,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ykbsc.chem.tohoku.ac.jp/

Title of Project：Innovative Functions Originating from Unexploited Electronic States in Nanowire Metal Complexes

YAMASHITA Masahiro
(Tohoku University, Advanced Institute for Materials Research, Professor)

Research Project Number：19H05631　Researcher Number：60167707
Keyword：Nanowire complex, Electronic property, Strongly correlated electron system, Coordination polymer

【Purpose and Background of the Research】

Discovery of new electronic states in solids often develops new functions and research fields. For instance, conductive organic polymers, superconducting copper oxides, carbon nanotubes and graphene have been widely investigated because of their unique electronic states. Thus, it is important to develop the materials which have multistability of electronic states.

One-dimensional (1D) electron system intrinsically provides various electronic states and characteristic electronic properties based on the strong correlation between electrons and lattice. Therefore, the 1D electron system is key to create a platform for exploring new electronic states and properties. In this research, we especially focus on quasi-1D halogen-bridged metal complexes (MX chains), which have high tunability and rich electronic properties derived from organic and inorganic components, respectively. We believe that the development of new electronic states in MX chains will give us the unprecedented innovative electronic functions.

【Research Methods】

[1] Creation of innovative electronic functions based on Pt(III) averaged valence state

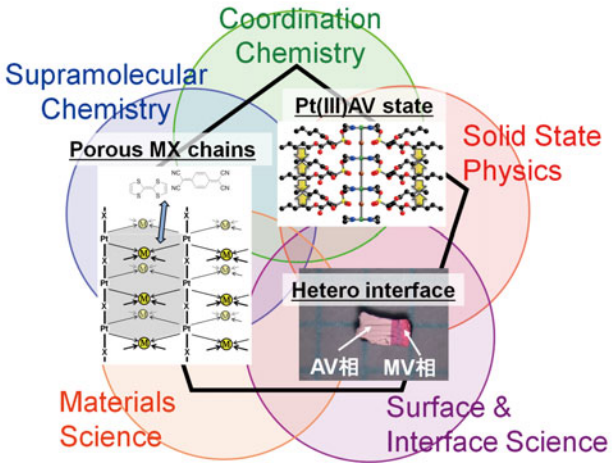
MX chains have the bistability of electronic states (i.e. M(III) averaged valence (AV) state and M(II/IV) mixed valence (MV) state). Although Pt complexes are most promising for achieving the high functionalities, all Pt complexes reported so far form MV state. In this subject, the techniques which successfully stabilized AV state in Pd complexes will be applied to Pt complexes (e.g. attractive force between alkyl chains and multiple hydrogen-bond networks).

[2] Development of new electronic structures in nano and hetero interface

Heterojunction crystals and superstructures will be fabricated by epitaxial crystal growth from solution by using electrocrystallization. The electronic structure around the interface will be detected by STM and Raman spectroscopy. Moreover, we fabricate the heterojuction of p-type and n-type semiconducting MX chains to study the characteristics of the single-crystalline device.

[3] Modulating band filling by chemical doping in porous MX chains

In contrast to inorganic materials, it is quite difficult to achieve chemical doping in molecular crystals by ion substitution or defect, because the molecules have a certain size. To overcome this problem, we introduce porosity to MX chains and conduct carrier injection by the redox reaction with guest molecules.



【Expected Research Achievements and Scientific Significance】

In addition to the enhancement of gigantic third-order nonlinear optical susceptibility, various novel properties such as metallic conduction, diode characteristic, molecular-responsible switching will be developed. Moreover, the control of band filling should enhance the understanding of molecule-based materials with 1D electron system.

【Publications Relevant to the Project】

1) M. R. Mian, H. Iguchi, S. Takaishi, M. Yamashita et al., Multiple-Hydrogen-Bond Approach to Uncommon Pd(III) Oxidation State: A Pd−Br Chain with High Conductivity and Thermal Stability. *J. Am. Chem. Soc.* **139**, 6562–6565 (2017).

2) S. Kumagai, S. Takaishi, H. Iguchi, M. Yamashita, Charge-bistable Pd(III)/Pd(II,IV) coordination polymers: phase transitions and their applications to optical properties. *Dalton Trans.*, **44**, 8590–8599 (2015).

【Term of Project】

FY2019-2023

【Budget Allocation】

152,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://coord.chem.tohoku.ac.jp/~sakutai/

Title of Project：Comprehensive search of cancer specific enzymatic activities and creation of innovative neutron capture therapy probe

URANO Yasuteru
(The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor)

Research Project Number：19H05632　Researcher Number：20292956
Keyword：Fluorogenic probes, BNCT, Quantum chemical calculation, Cancer, Biomarker

【Purpose and Background of the Research】

The establishment of a treatment for refractory diseases such as cancer is an extremely important issue in present-day Japan, and various basic analysis techniques including imaging are developed worldwide. Under these circumstances, this research representatives have developed a completely new diagnostic and therapeutic technology based on "live imaging of clinical specimens" using the "chemical fluorogenic probes" to realize the advanced precision fluorescence guided surgery etc.

On the other hand, there are still many types of cancer that cannot be visualized by the probes developed so far, and optical methods cannot be applied to deep imaging and treatment. Therefore, in order to solve these problems, in the present application we will carry out the projects listed in the next section to find out specific biomarker enzymes of cancer types that cannot be visualized using conventional methods, to achieve rapid fluorescence imaging, and to develop innovative Boron Neutron Capture Therapy (BNCT) probes for treatment and discovery of deeply located cancer.

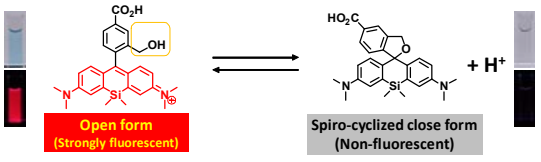
This research subject was carried out with the participation of clinical surgeons and neutron beam irradiation equipment development researchers as research co-workers, centering on the research representative who had advanced probe development technology.

【Research Methods】

The research method of this subject is as follows.

(1) Logical design of fluorogenic probes based on quantum chemical calculation, finding out novel biomarkers, and developing new intraoperative rapid imaging technology

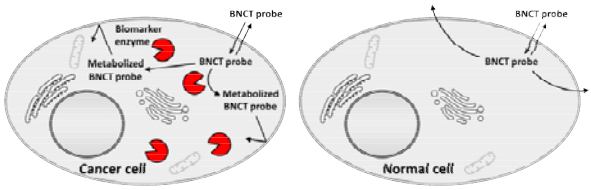
Using quantum chemical calculation, we aim to establish a system that accurately predicts the equilibrium constant of intramolecular spiro-cyclization equilibrium (see below), which is a fluorescence ON / OFF control mechanism that has been uniquely established by the research representative, to realize the development of novel probes for oxidases and reductases. By applying these probes to various cancer clinical specimens, new biomarker enzymatic activities are discovered, and new intraoperative imaging techniques are established.



Nat. Chem., 2014, 6, 681–689.

(2) Development and verification of BNCT probes for treatment and visualization of deeply located microtumors

BNCT is a therapeutic method for killing cancer cells using α particles and Li ions generated by the nuclear reaction of boron (^{10}B) and neutrons, and has attracted great attention as an innovative therapeutic method with less damage to normal cells. In this research, we aim to develop BNCT probes based on a new principle by utilizing specific biomarker enzymatic activity of cancer cells. Specifically, we develop probes that turn into highly retained products due to specific enzyme activity of cancer cells, but quickly leaks from normal cells, to realize BNCT treatment with a high T/N ratio. (Below)



【Expected Research Achievements and Scientific Significance】

The establishment of a method to design and develop highly practical fluorescent probes using quantum chemical calculation non-empirically is the world's first achievement, which provides breakthrough benefits to live cell and clinical imaging. Furthermore, a novel BNCT probe that utilizes biomarker enzymatic activity is a novel cancer medical technology that realizes selective treatment and detection of deeply located microtumors whose social significance is extremely high.

【Publications Relevant to the Project】

・Uno S, et al., ***Nat. Chem.*** 2014, 6, 681-689.
・Umezawa K, et al., ***Nat. Chem.*** 2017, 9, 279-286.

【Term of Project】 FY2019-2023

【Budget Allocation】 154,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.f.u-tokyo.ac.jp/~taisha
http://cbmi.m.u-tokyo.ac.jp
uranokun@m.u-tokyo.ac.jp

Title of Project：Directed Evolution of a Palette of Optogenetic and Chemi-Optogenetic Indicators for Multiplexed Imaging of Cellular Metabolism

Robert E. Campbell
(The University of Tokyo, School of Science, Professor)

Research Project Number：19H05633　Researcher Number：40831318
Keyword：Protein Engineering, Fluorescence, Microscopy, Cell Biology, Metabolites, Neuroscience, Cancer

【Purpose and Background of the Research】

A healthy cell is like a well-organized city which runs smoothly due to a steady supply of input energy (e.g., food, petrol, and electricity) and reliable lines of communication (e.g., phones, internet, and newspapers). If one of these energy inputs or lines of communication is interrupted, the organization of the city is grossly affected and its productive contributions to the country are disrupted. Similarly, growing evidence indicates that many important human diseases have causes, or consequences, that relate to changes in the way cells (the cities) of the body (the country) acquire or use biological energy. One example is that cancer cells consume sugars very differently than healthy tissues. Another example is that many neurodegenerative diseases involve detrimental changes in brain energy metabolism. The aim of this research is to develop tools for multiparameter visualization of the full metabolism of a cell. These tools will provide insight into numerous diseases by enabling us to visualize how individual cells are generating and using biological energy.

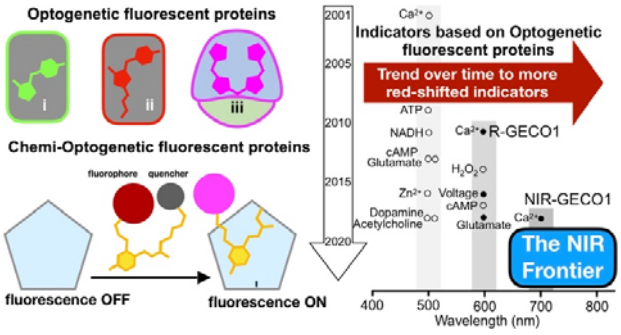


Figure 1. Optogenetic (i. green FP; ii. red FP; and iii. near-infrared FP) and chemi-optogenetic fluorophores.

【Research Methods】

The most powerful tools for visualizing dynamic processes in cells are optogenetic fluorescent proteins (FPs) that absorb one color of light and emit (fluoresce) a different color of light. We have extensive expertise at converting optogenetic FPs into indicators for the visualization of neuronal signalling. In this work we propose to build upon this foundation and develop metabolite indicators in a variety of colors, including near-infrared (NIR). NIR is very safe and very low energy, and therefore enables the imaging of indicators deeper into tissue than is possible using visible wavelengths of light. To create NIR indicators we will use both optogenetic FPs as well as chemi-optogenetic FPs based on proteins that bind to designed NIR fluorophore ligands.

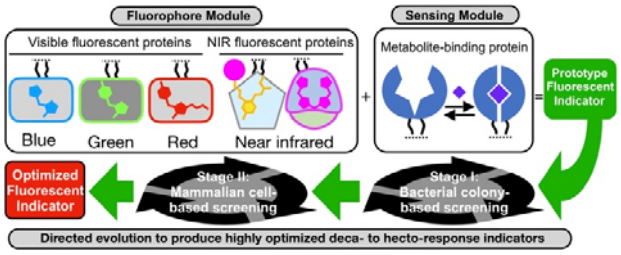


Figure 2. An innovative work flow for the design and optimization of modular, multicolor indicators.

【Expected Research Achievements and Scientific Significance】

By the conclusion of this project, we will have developed an improved toolbox of indicators that can will enable future insights into the mechanisms of debilitating neural and metabolic disorders. We will distribute these tools freely and broadly to accelerate research in as many countries and health areas as possible.

【Publications Relevant to the Project】

- Y. Qian *et al.,* "A genetically encoded near-infrared fluorescent calcium ion indicator", *Nat. Methods*, **2019**, 16, 171–174.
- Y. Shen *et al.,* "Genetically encoded fluorescent indicators for imaging intracellular potassium ions", *Commun. Biol.*, **2019**, 2, 18.
- J. Wu *et al.,* "Genetically Encoded Glutamate Indicators with Altered Color and Topology", *ACS Chem. Biol.*, **2018**, 13, 1832–1837.

【Term of Project】

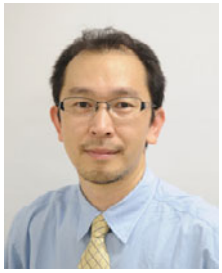
FY2019-2023

【Budget Allocation】

155,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.chem.s.u-tokyo.ac.jp/campbell/
campbell@chem.s.u-tokyo.ac.jp



Title of Project：Nanoscale Element Replacement Science: Structural Transformation of Nanocrystalline Phases and Development of Novel Functions

TERANISHI Toshiharu
(Kyoto University, Institute for Chemical Research, Professor)

Research Project Number：19H05634　Researcher Number：50262598
Keyword：Nanoparticle-related Chemistry, Colloid, Material Conversion and Catalyst, Energy Conversion Materials

【Purpose and Background of the Research】

Noble metal nanoparticles (NPs) are excellent functional materials based on the band structures that the d band centers are a few eV lower than the Fermi levels. Therefore, it seems difficult to replace the noble metal NPs with other NPs.

In this study, a series of novel NPs that surpass the performance of noble metal NPs will be generated from theoretical and experimental points of view as follows.

(1) The electronic structures of NPs are largely modulated by the introduction of p-block elements into d-block metal NPs and the alloying by element replacement (galvanic replacement) with base metal ions to achieve the superior physical and chemical properties.

(2) The crystal and electronic structures are modulated by the partial element replacement (ion exchange) to form the ionic crystalline heterostructured NPs, which can convert the whole near infrared light energy.

Through these studies, novel material science called "nanoscale element replacement science" on the basis of the new concept "ground-state electronic structure modulation" will be developed.

【Research Methods】

In this study, two kinds of novel NPs, unprecedented metal NPs and ionic crystalline heterostructured NPs, are designed and synthesized to achieve the superior properties, compared with the noble metal NPs (Fig. 1).

• Synthesis and novel functions of metal compound NPs and unprecedented alloy NPs

A series of metal compound NPs composed of d-block metals and p-block elements are converted into the unprecedented alloy NPs by the pseudo-galvanic replacement of p-block elements with base metal ions. Then, novel physical and chemical properties of these NPs based on the ground-state electronic structure modulation are developed.

• Synthesis of ionic crystalline heterostructured NPs for near-infrared light energy conversion

Ionic crystalline heterostructured NPs are synthesized by ion exchange of heavily doped semiconductor NPs ($Cu_{2-x}S$, ITO, etc.) exhibiting localized surface plasmon resonance in near-infrared region, and used as near-infrared light energy conversion materials.

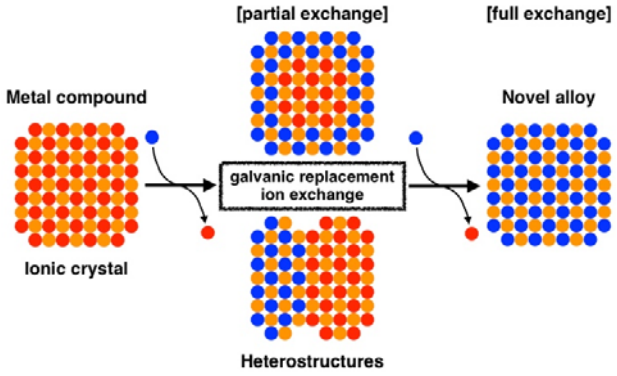


Fig. 1　Formation of novel alloy NPs and heterostructured NPs by using element replacement reactions

【Expected Research Achievements and Scientific Significance】

If the crystal structures and electronic structures of inorganic crystal phases could be freely modulated by simple element replacement reactions, rare noble metals would be completely replaced. For example, if the Pt NPs used in the polymer electrolyte fuel cell could be replaced with NiP_x NPs having comparable catalytic ability, the cost of the catalysts would be simply reduced to 1/3000 or less. In addition, if the rod-like Au NPs, which absorb near-infrared light, could be substituted for heavily-doped semiconductor NPs, whole near-infrared light energy would be utilized, which is a great contribution to energy problems.

【Publications Relevant to the Project】

• Z. Lian, T. Teranishi et al., "Plasmonic p-n Junction for Infrared Light to Chemical Energy Conversion", *J. Am. Chem. Soc.*, **141**, 2446–2450 (2019).
• H.-L. Wu, T. Teranishi et al., "Formation of Pseudomorphic Nanocages from Cu_2O Nanocrystals through Anion Exchange Reactions", *Science*, **351**, 1306–1310 (2016).

【Term of Project】FY2019-2023

【Budget Allocation】155,100 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.scl.kyoto-u.ac.jp/~teranisi/index_E.html
teranisi@scl.kyoto-u.ac.jp

Title of Project：New Main Group Element Chemistry and Materials Science Based on Heavy Aryl Anions

TOKITOH Norihiro
(Kyoto University, Institute for Chemical Research, Professor)

Research Project Number：19H05635　Researcher Number：90197864
Keyword：aryl anion, high periodic main group element, aromatic compound

【Purpose and Background of the Research】

Multiple-bond compounds of high periodic main group elements, *that is* "heavy main group elements," have characteristic properties such as their small HOMO-LUMO energy difference. However, they are generally very reactive and readily polymerize. In order to stabilize such compounds, steric protection with bulky substituents and/or electronic perturbations with heteroatom substituents or ligands are required. The necessity of introducing such special substituents has restricted the further application of the excellent properties of "heavy multiple bonds".

We have recently succeeded in the synthesis and isolation of "heavy phenyl anions," in which the anion carbon of the phenyl anion is replaced with Ge or Sn. While they have sufficient properties as aromatic compounds, *i.e.* Ge/Sn-containing multiple bonds, they are able to exist as thermally stable compounds without bulky substituents due to their charge repulsion. We will further develop this discovery as "heavy aryl anion chemistry", extract the difference from carbon analogues, and design and synthesize novel conjugated molecules containing heavy elements. As an ultimate goal, the construction of "heavy graphene" in which some skeletal carbons of graphene are replaced with heavy group 14 elements will be investigated.

【Research Methods】

In this research, we will carry out the studies mainly from the following three viewpoints.

(a) Design of "heavy aryl anion" building blocks having various electronic states and structures: We will develop a new methodology that enables efficient and systematic synthesis of derivatives having (1) various heavy group 14 elements (Si, Ge, Sn, Pb), (2) fused and linked polycyclic rings, (3) heterocycles, and complex systems of (1) to (3).

(b) Determination of the properties of "heavy aryl anions": In "heavy phenyl anions", we have found the divalent character of the central heavy element. This unique property, negligible for the parent phenyl anion, indicates the possibility of molecular transformation different from carbon chemistry, and it is considered to be largely variable depending on the type of substitution elements and ring structures. By systematic understanding based on the results of various spectroscopies, structural analysis, verification of reactivities, and theoretical calculations of the compounds obtained in (a), it leads to molecular design according to desired physical properties and reactivity.

(c) Creation of novel high-order conjugated molecules: By combining the "heavy element chemistry" approach obtained in (a) and (b) with the widely accumulated "carbon chemistry" approach, we will expand the research into higher-order conjugated systems such as "heavy PPV (*p*-phenylene vinylene)" or "heavy aryl anion polymer".

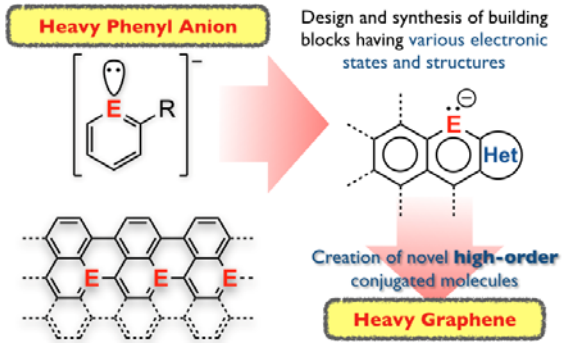


Figure 1. Summary of this research

【Expected Research Achievements and Scientific Significance】

The stabilization methods for highly reactive species of heavy elements have been limited to kinetic stabilization and thermodynamic stabilization. The system in this research may give us a new concept of stabilization, which should be termed as "the third stabilization", completely different from those mentioned above. If this system has generality, great impact and influence will be expected on the development of element chemistry.

【Publications Relevant to the Project】

・"Germabenzenylpotassium: A Germanium Analogue of a Phenyl Anion", Y. Mizuhata, S. Fujimori, T. Sasamori, N. Tokitoh, *Angew. Chem. Int. Ed.* **2017**, *56*, 4588.
・"Stannabenzenylpotassium: The First Isolable Tin-Containing Benzene Derivative", S. Fujimori, Y. Mizuhata, N. Tokitoh, *Chem. Eur. J.* **2018**, *24*, 17039.

【Term of Project】

FY2019-2023

【Budget Allocation】

154,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://oec.kuicr.kyoto-u.ac.jp/~tokitohlab/
tokitoh@boc.kuicr.kyoto-u.ac.jp

Title of Project：Efficiency and durability enhancement of solar cells using lead-free high dimensional halide perovskite materials

MIYASAKA Tsutomu
(Toin University of Yokohama, Project Professor)

Research Project Number：19H05636　Researcher Number：00350687
Keyword：perovskite, photovoltaic, solar cell, conversion efficiency, lead-free

【Purpose and Background of the Research】

Although "lead" leads in terms of high efficiency of perovskite solar cells up to 24%, toxicity and stability of lead-based perovskites is the most formidable challenges for real use. Especially in the consumer electronics for which the perovskite device exhibits superior performance keeping high voltage output under weak indoor light, use of lead is strictly regulated or prohibited. This project aims at synthesis and application of lead-free all-inorganic halide perovskite and perovskite-like materials as photovoltaic absorbers through compositional development of metal halide hybrid compounds formed by morphological refinement for formation of defect-free polycrystalline absorber layer. The goal of the project is to achieve high performance and robust stability of non-lead perovskite-based solar cells with conversion efficiency comparable with lead perovskite-based cells (up to 20%).

【Research Methods】

Lead-free halide perovskite materials composed of metal cations of Sn/Ge, Bi, Ag, and Ti will be designed and synthesized so as to form three dimensional structure of crystals which are favorable for isotropic movement of the photo-generated carriers. In the perovskite lattice structure represented by ABX_3 (Fig. 1), the A site cation is replaced with an inorganic ion such as Cs, Ag, Rb and the B site is replaced by Sn, Ge, Bi, In, Ti, etc. The crystal structure is stabilized by tuning a mixed halide system of Cl/Br/I.

Lead-free materials are selected to have broad and strong absorption at low bandgap energy (<1.6eV), the latter enabling high theoretical efficiency (Fig. 2). Physical and photophysical properties will be investigated in terms of defect density, carrier mobility, etc. based on photo-luminescence measurement to assess carrier recombination rate as a main cause of intrinsic energy loss. For compositional engineering, in the case of Ag and Bi-based perovskites, Bi is doped with In or other metal cation in combination with use of mixed halogen as anion. For Sn-based perovskites, doping effect of divalent and trivalent cations such as Ge will be studied to stabilize Sn (II) in the atmosphere. For Ti-based perovskites, synthetic approach is focused on a method to stabilize Ti (IV) and to minimize impurities and defects for formation of a high quality polycrystalline film for photovoltaic applications.

In addition to solution process, vacuum deposition method will be also employed for preparation of high purity defect-free perovskite films by controlling thermodynamically non-equilibrium growth for kinds of lead-free perovskite compositions that had been difficult to form by solution processes. Here, multi-source vacuum deposition system is used for precise deposition (Fig. 1).

In fabrication of photovoltaic cell (Fig. 2), we will optimize the kinds of carrier (hole and electro) transport materials for efficiency (especially voltage) and thermal stability enhancement.

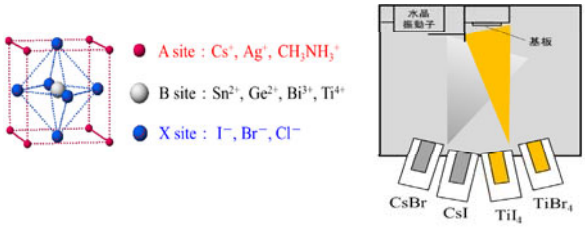


Fig. 1 Lattice structure of metal halide perovskites and vacuum deposition-based film preparation

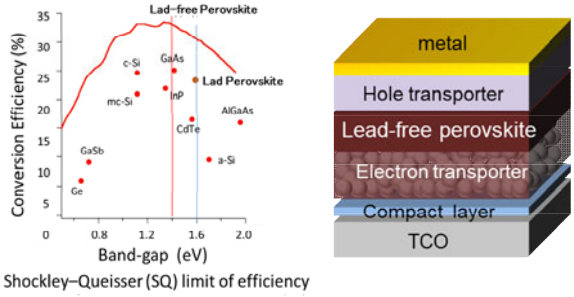


Fig. 2 Theoretical limit of efficiency for lead-free perovskite photovoltaic cells and device structure

【Expected Research Achievements and Scientific Significance】

Design of lead-free perovskites leads to explore new field of halide perovskite science and its inexpensive and high efficiency devices will accelerate industrial applications of perovskite power devices backed by high environmental compatibility.

【Publications Relevant to the Project】

・A. K. Jena, A. Kulkarni, and T. Miyasaka, "Halide Perovskite Photovoltaics: Background, Status, and Future Prospects", *Chem. Rev.*, **2019**, 119, 3036-3103.
・N. -G. Park, M. Gratzel, and T. Miyasaka, "Organic-Inorganic Halide Perovskite Photovoltaics", Springer International Publishing, **2016**. (DOI: 10.1007/978-3-319-35114-8)

【Term of Project】

FY2019-2023

【Budget Allocation】

151,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.cc.toin.ac.jp/sc/miyasaka/en/index.html

【Grant-in-Aid for Scientific Research (S)】

Broad Section F

Title of Project：Study on the mechanism of nutrient recognition and coordination of nutrient response in plants

FUJIWARA Toru
(The University of Tokyo, Graduate School of Agricultural and Life Sciences, Professor)

Research Project Number：19H05637　Researcher Number：80242163
Keywords：ribosome, plasma membrane, cell wall, mineral nutrients, growth analysis, modeling

【Purpose and Background of the Research】

Historically, fertilization contributed greatly to global food production and is also necessary in modern agriculture to achieve high yields. Fertilization, on the other hand, faces problem of eutrophication and limitation of resources. Importance of fertilization is based on the limited ability of plants to absorb nutrients from soils.

Plants evolved in the natural soil with mostly nutrient poor soils and carries ability to adapt low-nutrient environments. This ability, however, has a certain limitation, and if we can improve this ability, it contributes realization of "Low input agriculture." For this, it is important to understand plant mechanisms to adapt low-nutrient environments.

To respond to nutritional conditions, it is essential to sense the nutrient levels in cells and in the environments. Based on the sensing, multiple processes including nutrient transport, metabolism and growth are regulated in a coordinated manner to achieve response as an organism. Our previous study identified mechanism to sense nutrients in cytoplasm which induce regulation of gene expression. Nutrient sensing can also happen in plasma membrane and cell walls. In this project we study mechanisms of nutrient sensing in different cellular compartments and describe multiple phenomena that associates with sensing. Such observation will lead us to comprehensively understand plant responses to low nutrient environments.

【Research Methods】

We previously demonstrated that nutrient sensing occurs in the process of translation of *NIP5;1*, a gene encoding boron transporter (Figure 1, Tanaka et al 2016).

In this project, details of the nutrient sensing mechanisms including structural analysis of ribosome and biochemical analysis will be conducted to elucidate molecular basis of recognition.

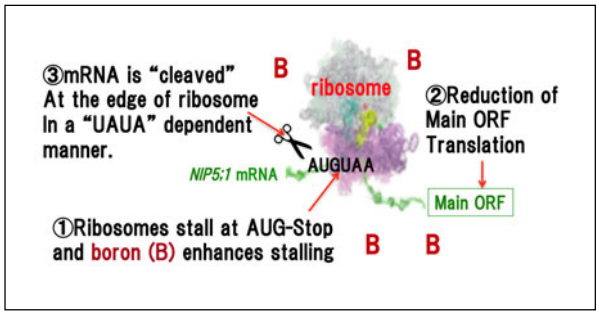


Figure 1 Regulation of boron dependent *NIP5;1* expression

Plasma membrane and cell wall are also the subcellular locations where nutrients are recognized. Transporters and polysaccharides chemically interact with nutrients and possibly function for nutrient recognition. Effects of mutations on transporters and/or genes affecting polysaccharides accumulation will be used to examine their effects on transporter expression, nutrient distribution, growth and gene expression. Such analysis will leads to comprehensive understanding of nutrient response in plants.

【Expected Research Achievements and Scientific Significance】

Our study is unique in that nutrient recognition is studied in three different compartments in plants and expected to lead to comprehensive understanding of nutrient response in plants. The outcome of our project will provide useful information for sustainable agriculture in the future.

【Publications Relevant to the Project】

-Tanaka, M., Sotta, N., Yamazumi, Y., Yamashita, Y., Miwa, K., Murota, K., Chiba, Y., Hirai, MY., Akiyama, T., Onouchi, H., Naito, S. & Fujiwara, T "The Minimum Open Reading Frame, AUG-Stop, Induces Boron-Dependent Ribosome Stalling and mRNA Degradation" Plant Cell 28: 2830–2849 (2016) doi: org/10.1105/tpc.16.00481.

-Sotta, N., Duncan, S., Tanaka, M., Sato, T., Marée, A. F.,Fujiwara, T., & Grieneisen, V. A. "Rapid transporter regulation prevents substrate flow traffic jams in boron transport." eLife 6:e27038 (2017) doi: 10.7554/eLife.27038

【Term of Project】FY2019-2023

【Budget Allocation】153,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://park.itc.u-tokyo.ac.jp/syokuei/index_e.html

Title of Project：Molecular basis of bulk transport machinery playing key roles in lipid secretion in plant cells

YAZAKI Kazufumi
(Kyoto University, Research Institute for Sustainable Humanosphere, Professor)

Research Project Number：19H05638　Researcher Number：00191099
Keyword：Lipid secretion, Plant cell, Bulk transport, Secondary metabolism, Shikonin

【Purpose and Background of the Research】

Plants secrete a large number of lipophilic metabolites, both polymers and low molecular weight substances, such as wax/suberins and terpenoid compounds, respectively. The latter includes many biologically active compounds like taxol and shikonin, which are mostly accumulated outside the cells after biosynthesis, i.e.: in apoplastic spaces. However, it is not well known how such lipophilic compounds are accumulated in oil droplets surrounded by the lipid monolayer like oil bodies, how they recognize the plasma membrane, or how they can go across the plasma membrane to be largely accumulated in the apoplast.

In this study, we utilize a model system to characterize the molecular mechanism of lipid secretion, i.e.: the shikonin production system by *Lithospermum erythrorhizon*. This is an herbal medicinal plant, from which a high shikonin-producing cell line was established. This line produces more than 10% of shikonin derivatives. There are several advantages in utilizing these plant cell cultures, for instance the visibility of the lipid (shikonin) as a red pigment, the strict regulation of shikonin production and the availability of cell mass due to the cultured cells. Using this system, we aim to elucidate the molecular basis of lipid secretion from plant cells.

【Research Methods】

To uncover the molecular mechanism of lipid secretion, we first listed genes, which were selectively expressed in shikonin-producing conditions, as being relevant for shikonin production. Among them, subcellular localization was analyzed to narrow down the candidate genes putatively involved in lipid secretion from *L. erythrorhizon* cells. The involvement of individual genes/proteins in the production and secretion of shikonin, will be evaluated by virus-induced gene silencing (VIGS), which will take advantage of the high throughput, despite the transient expression. The strong candidates will be then subjected to genome editing to produce knockout hairy roots, which will then be analyzed by transparent electron microscopy. Fluorescence tag for candidate proteins will also be used to trace the subcellular movement of these proteins accompanied with shikonin molecules. Protein-protein interaction will then be evaluated to figure out the entire bulk transport machinery.

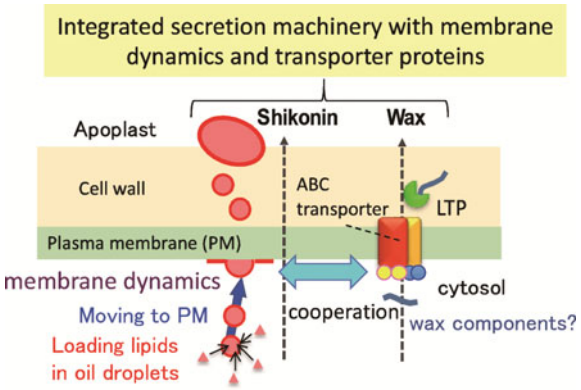


Figure 1　Bulk transport of lipid molecules

【Expected Research Achievements and Scientific Significance】

Plants accumulate many valuable lipophilic natural compounds in apoplastic spaces, like subcuticular cavities of glandular trichomes and resin ducts, whilst the secretion mechanisms are largely unknown. Elucidation of the molecular mechanism of lipid secretion from plant cells, will enable us to understand the survival strategy of land plants that prevents dryness and is also expected to provide the technical basis for the production of valuable secondary metabolites, e.g.: monoterpenoids as fragrances, as well as vincristine and paclitaxel as anticancer drugs.

【Publications Relevant to the Project】

・Bowman JL, et al., Insights into land plant evolution garnered from the *Marchantia polymorpha* genome, ***Cell***, 171(2): 287-304.e15 (2017).
・Tatsumi, K., et al., Characterization of shikonin secretion in *Lithospermum erythrorhizon* hairy roots as a model of lipid-soluble metabolite secretion from plants, ***Frontiers Plant Sci.*** 7, 1066 (2016).
・Morita, M., et al., Vacuolar transport of nicotine is mediated by a novel multidrug and toxic compound extrusion (MATE) transporter in *Nicotiana tabacum*. ***Proc. Natl. Acad. Sci. USA***, 106, 2447-2452 (2009).

【Term of Project】

FY2019-2023

【Budget Allocation】

127,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.rish.kyoto-u.ac.jp/lpge/index.html
yazaki@rish.kyoto-u.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section F

Title of Project：Integrated understanding of nitric oxide in yeasts and fungi and its application to microbial breeding and drug development

TAKAGI Hiroshi
(Nara Institute of Science and Technology, Graduate School of Science and Technology, Professor)

Research Project Number：19H05639　Researcher Number：50275088
Keyword：Nitric oxide, Yeast, Fungi, Synthetic regulation, Physiological function

【Purpose and Background of the Research】

Nitric oxide (NO) is a signaling molecule involved in the regulation of many biological processes and NO is produced by NO synthase (NOS) in mammals. Research on NO in the yeast *Saccharomyces cerevisiae*, which is important as a model for higher eukaryotes and in fermentation industry, do not make progress due to the lack of mammalian NOS orthologues in the genome.

We found that NO is synthesized through the flavoprotein Tah18-dependent NOS activity in yeast and that NO confers high-temperature tolerance on yeast via the transcription factor Mac1-mediated activation of the Cu,Zn-superoxide dismutase Sod1. We also proposed a novel regulatory mechanism of NO synthesis mediated by the Tah18-Dre2 complex. Furthermore, it was shown that he dual functions (cell protection vs. cell death) of NO found in higher eukaryotes also occur in yeast (Figure 1).

In this study, for understanding of molecular functions of NO in yeasts and fungi, we will analyze the synthetic mechanisms and the physiological roles of NO. The effects of NO on fermentation ability of yeasts and on growth, infection and biologically active substances production in fungi will be investigated for contribution to breeding of industrial yeasts and development of antifungal agent.

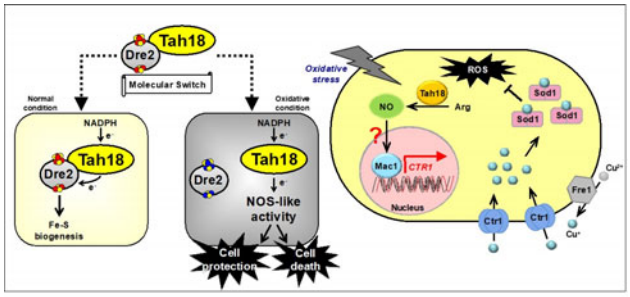


Figure 1 Model of NO synthesis (left) and stress tolerance by NO (right) in yeast

【Research Methods】

1) Elucidation of molecular functions of NO in yeast: We will analyze the expression of Tah18-dependent NOS-like activity, including identification of the oxygenase-like protein, and the function of the mammalian Ndor1 and Ciapin1, which are homologous to Tah18 and Dre2, respectively. We will also identify the NO-targeted proteins with *S*-nitrosylation and nitration using the biotin switch and western blotting methods combined with LC-MS. Furthermore, we will understand the molecular mechanism and physiological significance of the dual functions of NO.

2) Functional analysis of NO in industrial yeasts and its application to fermentative production: We will construct industrial yeast strains with modified expression of NO-related genes (overexpression, knockout), examine the effect of NO on fermentation ability, and challenge the breeding of strains with increased fermentation ability.

3) Functional analysis of NO in fungi and search for drug target molecules: We will focus on the molecular functions of NO, particularly NO-related genes, secondary metabolism and NO tolerance, examine the effect of NO on growth, infection and biologically active substances production and identify target genes for antifungal drug in both model and pathogenic fungi.

【Expected Research Achievements and Scientific Significance】

1) Accumulation of basic knowledge on NO: Our study will contribute to understanding of molecular functions of NO acquired by yeasts and fungi as a survival strategy under various environments. In addition, a series of the studies on yeasts and fungi as a model for higher eukaryotes may lead to the discovery of mechanisms of NO-mediated pathogenesis and NO generation in plants.

2) Applications to industrial yeasts and fungi: By regulating intracellular NO synthesis, improvement of fermentative production will be promising in industrial yeasts. Moreover, elucidation of molecular functions of NO and regulatory mechanisms of secondary metabolism in pathogenic fungi will lead to development of antifungal agent and discovery of biologically active substances.

【Publications Relevant to the Project】

・Yoshikawa Y, *et al*. Regulatory mechanism of the flavoprotein Tah18-dependent nitric oxide synthesis and cell death in yeast. *Nitric Oxide*, **57**, 85-91 (2016).
・Nasuno R, *et al*. Nitric oxide-mediated antioxidative mechanism in yeast through the activation of the transcription factor Mac1. *PLoS One*, **9**, e113788 (2014).
・Zhou S, *et al*. NO-inducible nitrosothionein mediates NO removal in tandem with thioredoxin/ *Nat. Chem. Biol.*, **9**, 657-663 (2013).

【Term of Project】FY2019-2023

【Budget Allocation】153,800 Thousand Yen

【Homepage Address and Other Contact Information】

https://bsw3.naist.jp/takagi/?cate=183
hiro@bs.naist.jp

Title of Project：Innovative chemical genetics on novel function of endogenous metabolites

YOSHIDA Minoru
(RIKEN, Center for Sustainable Resource Science, Group Director)

Research Project Number：19H05640　Researcher Number：80191617
Keyword：Endogenous metabolite, Chemical genetics, Drug target, Posttranslational modification, Metabolic pheromone

【Purpose and Background of the Research】

Many metabolites have cellular function independent of their metabolic roles by acting as cofactors or inhibitors for posttranslational modification enzymes (Fig. 1). Therefore, it seems possible that metabolites in common metabolic pathways possess unexpected activity, and that their dynamic fluctuation upon environmental changes greatly affects the destiny of life through affecting their adaptation and homeostasis. Although fluctuation of metabolites can be analyzed by metabolome, their biological function has been poorly understood because of difficulties in activity measurements. This study aims at elucidating novel function of metabolites by molecular and chemical genetics.

【Research Methods】

In this research, we will uncover new function of metabolites using fission yeast and animal cells with our original screening systems. To this end, we will expand our metabolite compound library.

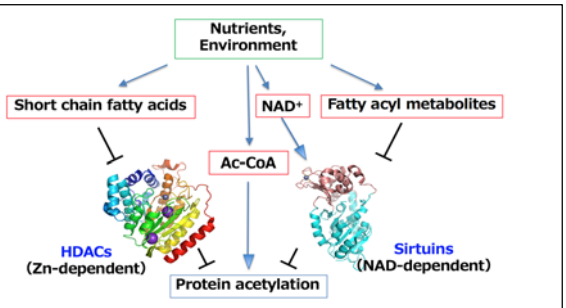


Fig. 1. Protein acetylation regulated by metabolites

(1) Chemical genetics for energy metabolism
We previously showed that SIRT2 has defatty-acylase activity, which requires formation of a large hydrophobic pocket to accommodate the substrate fatty-acyl lysine. However, once the defatty-acylation reaction occurs, it loses deacetylase activity. This is probably because *O*-acyl-ADP ribose, the product of defatty-acylation, binds the hydrophobic pocket thereby inhibiting deacetylase activity. On the other hand, the fatty-acyl lysine substrate may kick it out from the pocket, allowing the next cycle of catalysis. Here we will elucidate the molecular mechanism for the conversion of enzyme activity from deacetylation to defatty-acylation by using synthetic derivatives of *O*-acyl-ADP ribose. In addition, we will analyze the mode of action of a natural product derivative named TLAM, which activates mitochondria respiration and suppresses the Warburg effect in cancer cells.

(2) Chemical genetics for hypoxia response
The eukaryotic translation factor eIF5A is subject to hypusination, a unique posttranslational modification. Hypothesis that hypusination of eIF5A acts as a sensor of hypoxia at the translation level will be examined. Furthermore, we will investigate why defective hypusination under the hypoxic conditions downregulates mitochondrial protein synthesis by ribosome profiling.
(3) Chemical genetics for amino acid metabolism
Based on our previous discovery of a fission yeast pheromone that induces cancellation of nitrogen catabolite repression, we will identify novel signaling small molecules by searching for mutants whose growth can be recovered in the vicinity of the wild-type cell colony.
(4) Chemical genetics for lipid metabolism
We will elucidate the mechanism of cell growth inhibition by fatty acids with odd number carbons or marine microbial lipids by identifying genes that alter their sensitivity.

【Expected Research Achievements and Scientific Significance】

Fluctuation of metabolites upon environmental changes regulates homeostasis through altered posttranslational modification such as acetylation. Uncovering of hidden function of metabolites will lead to the development of novel medical or material production technologies.

【Publications Relevant to the Project】

- Sun *et al.* Identification of novel secreted fatty acids that regulate nitrogen catabolite repression in fission yeast. *Sci. Rep*. 6: 20856, 2016.
- Ito *et al.* The subcellular localization and activity of cortactin is regulated by acetylation and interaction with Keap1. *Sci. Signal.* 8: ra120, 2015.
- Nishimura *et al.* Marine antifungal theonellamides target 3beta-hydroxysterol to activate Rho1 signaling. *Nat. Chem. Biol.* 6: 519-526, 2010.

【Term of Project】

FY2019-2023

【Budget Allocation】

154,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.riken.jp/research/labs/csrs/chem_genom/
http://www2.riken.jp/SPD/CG/index.html

【Grant-in-Aid for Scientific Research (S)】

Broad Section G

Title of Project：Regime shifts in coastal marine ecosystems: an empirical approach based on advanced monitoring and nonlinear dynamical theory

KONDOH Michio
(Tohoku University, Graduate School of Science, Professor)

Research Project Number：19H05641　Researcher Number：30388160
Keyword：environmental DNA, biodiversity, resilience, coastal ecosystem, data-driven science

【Purpose and Background of the Research】

Anthropogenic disturbances and global changes may cause a dramatic shift in species composition and degradation of ecosystem services. Such an abrupt change in ecosystems is called “regime shift”, which is, according to theory, caused by a change in dynamical property of ecosystems. However, there are few direct empirical evidences from real nature. How to forecast a regime shift is another question that has not been fully answered.

There are two major difficulties to overcome to advance the empirical study of regime shift. First, we are lacking of good monitoring data of regime shift happening in nature. Ecological monitoring is usually effort-demanding and therefore it is not straight forward to capture a regime shift of many-species communities in the field. Second, we are lacking of effective methods that enable evaluating the dynamical property of ecological systems. Consequently, the link between regime shift and dynamical properties is left unanswered.

In the present project we are to give a better empirical understanding of, and to develop a method to forecast, ecological regime shifts by combining the advanced ecological monitoring method and data analytical tools, which allow us overcoming the two abovementioned difficulties.

【Research Methods】

Environmental DNA, the recently monitoring method for biodiversity, forms the basis of present project. The eDNA technique allows one to make a list of biological species from the DNA fragments organisms shed into the environmental water (Fig. 1). We conduct weekly to monthly eDNA monitoring at dozens of monitoring sites located along Japanese coast and obtain a highly-resolved monitoring data that captures the spatio-temporal dynamics of several hundreds to thousands of fish species. Using this massive data, we are to depict when and where ecological regime shifts take place along Japanese coast.

The eDNA monitoring data would be further analyzed by using a modeling tool based on non-linear dynamical theory to test the hypothesis that an ecological regime shift is caused by a change in dynamical property of ecological systems. Furthermore, by using the modeling technique to evaluate system’s stability from time-series data, we are to develop a method with which one can forecast the ecological regime shift either earlier, more correctly or more sensitively.

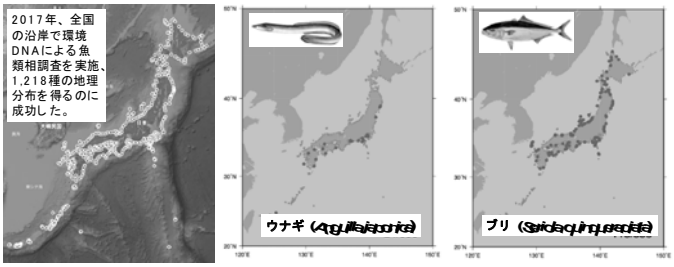


Fig. 1 One can get an advanced data of fish community along Japanese coast by using eDNA.

【Expected Research Achievements and Scientific Significance】

There are four expected achievements from the present project. We would (1) identify the spatio-temporal patterns of ecological regime along Japanese coast and (2) demonstrate if ecological regime shifts are related to changes in dynamical properties of ecological systems. We also develop methods (3) to judge if there is an on-going regime shift or (4) to forecast the future regime shift by using ecological monitoring data,

【Publications Relevant to the Project】

Miya et al. (2015) MiFish, a set of universal primers for metabarcoding environmental DNA from fishes: detection of > 230 species from aquarium tanks and coral reefs in the subtropical western North Pacific. Roy Soc Open Sci 2: 150088.
Ushio et al. (2018) Fluctuating interaction network and time-varying stability of a natural fish community. Nature 554: 360-363.

【Term of Project】 FY2019-2023

【Budget Allocation】 153,700 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.lifesci.tohoku.ac.jp/research/teacher/detail---id-45517.html
michio.kondo.b8@tohoku.ac.jp

Title of Project：Elucidation of cognitive and learning mechanism of cerebral cortex by multiscale optogenetics

OHKI Kenichi
(The University of Tokyo, Graduate School of Medicine, Professor)

Research Project Number：19H05642　Researcher Number：50332622
Keyword：cerebral cortex, visual cortex, imaging, optogenetics, neural circuits, information processing

【Purpose and Background of the Research】

How does the brain perform complex information processing? How does the brain alter neural circuits through learning and acquire complex functions? Our first goal is to elucidate what kind of information each neuron receives and combines it to output complex information, as an elementary process of information processing in the brain. Our second goal is to elucidate how the information input to each synapse changes, as an elementary process of learning and memory. We will further elucidate the learning rules of synaptic plasticity from the viewpoint of information, and how the learning rules relate to the changes in the function of the cell.

In order to achieve both goals, we will develop a spine level functional imaging method using optogenetics, visualize the information input to each synapse, observe the change continuously, and elucidate the elementary processes of information processing and learning and memory at synapse level. Furthermore, in combination with cell population imaging, we will elucidate how these elementary processes contribute to learning as a whole network. Finally, we will activate the cell population artificially using optogenetics, and examine whether the activity of the cell population has a causal relationship with perception and learning. As described above, in multiscale from the synapse level to the whole brain level, we will elucidate the principles of information processing and learning rules of the brain.

【Research Methods】

(1) Develop functional imaging method of spine level using optogenetics
We will develop a method to comprehensively examine what kind of information is input to thousands of synapses of each neuron.
(2) Elucidate the elementary processes of information processing in the brain
We will develop a method to systematically investigate nonlinear complex receptive fields of neurons in higher visual area using deep learning. By combining the method of item (1), we will elucidate what kind of information each neuron in higher visual cortex receives and combines it to output complex information such as the shape of an object.
(3) Elucidate elementary processes of learning in the brain and learning rules
While the animal learns a new figure over time, we will observe changes in the selectivity of neurons in the higher visual cortex, and observe changes in the information input to the individual spines of the cells over time. We will clarify the learning rules of synapse from the viewpoint of information.
(4) Elucidate changes in information representation by cell population associated with learning and memory
In (3), we will clarify how the information input to individual neurons changes with learning. Here, we will further clarify how it contributes to learning as a whole network.
(5) Develop methods of photo-suppression at the area level and photo-activation of cell populations
In order to examine the causal relationship between the activity of the cell population and perception and learning, we will develop methods of photo-suppression and photo-activation.
(6) Verify causality between cell population activity in higher visual cortex and perception and learning
Using the methods developed in (5), we will examine the causal relationship between cell population activity and perception and learning.

【Expected Research Achievements and Scientific Significance】

We will clarify what kind of information each neural cell in the higher visual area receives and combines it to output complex information, and the learning rules of synaptic plasticity from the view point of information. We expect that the elucidation of the principle of information processing and the learning rule about the information will lead to the development of a new algorithm of artificial intelligence.

【Publications Relevant to the Project】

・Ukita J, Yoshida T, Ohki K. Characterisation of nonlinear receptive fields of visual neurons by convolutional neural network. Sci Rep. 2019 Mar 7;9(1):3791.

【Term of Project】

FY2019-2023

【Budget Allocation】

156,200 Thousand Yen

【Homepage Address and Other Contact Information】

https://physiol1.m.u-tokyo.ac.jp/ern24596/

Title of Project：Understanding the seasonal adaptation mechanism and its application

YOSHIMURA Takashi
(Nagoya University, Graduate School of Bioagricultural Sciences, Professor)

Research Project Number：19H05643　Researcher Number：40291413
Keyword：photoperiodism, seasonal adaptation, medaka, chemical genomics

【Purpose and Background of the Research】

Organisms exposed to seasonal changes in the environment, such as daylength, temperature, and precipitation, are known to adapt their physiology and behavior, including reproduction, hibernation, migration and molting accordingly. How these organisms sense these seasonal changes, remains unknown. In addition, the mechanistic nature that drives the seasonally regulated physiology remains unclear. Furthermore, morbidity in humans, owing to cardiac, cerebrovascular, infectious, and psychiatric diseases, is seasonal, and peaks in winter. At high latitudes, about 10% of population suffer from winter depression, and high suicide rates are a serious social issue. However, the underlying mechanism is yet to be determined.

Medaka is an excellent model because of its robust responses to seasonal changes in daylength and temperature, as well as the availability of genome-editing techniques. The difficulties in manipulating genes in some species (e.g., quail and sheep) and the unclear seasonal responses in other species (e.g., zebrafish and mouse), presents medaka as an ideal system for these studies (Fig. 1). Furthermore, small teleosts, such as zebrafish and medaka, are emerging models for the study of complex disorders and are becoming powerful models in pharmacogenetic studies.

In this study, we aim to investigate the genetic basis of the seasonal sensing mechanism by using the medaka fish. We will also investigate the molecular basis of seasonally regulated physiology by assessing gene expression on a genome-wide scale in tissue samples collected every month over a period of two years. Furthermore, compounds that rescue the winter phenotype will be developed using a chemical genomics approach.

【Research Methods】

Medaka populations captured at higher latitudes show more robust responses to daylength and temperature alterations than do the populations found at lower latitudes. Our genetic analysis of this fish has already detected significant quantitative trait loci. The candidate genes will be evaluated to understand the genetic basis of the seasonal sensing mechanism.

The RNA-seq analysis of the two-year time-series samples identified seasonally oscillating genes in the medaka fish. We plan to elucidate the molecular basis of the seasonally regulated physiology and behavior.

A multi-omics analyses, together with a chemical screening of the winter medaka to understand and rescue the winter phenotype, will also be performed.

【Expected Research Achievements and Scientific Significance】

Living organisms adapt to seasonal alterations on earth. Although this phenomenon has attracted great interest, the underlying mechanism remains unknown and this is a fundamental question in biology. This study is expected to uncover the genetic and molecular bases of these mechanisms in vertebrates and develop compounds that could regulate the seasonal adaptation mechanisms in animals.

【Publications Relevant to the Project】

- Shimmura T, et al., Dynamic plasticity in phototransduction regulates seasonal changes in color perception. *Nature Communications* 8, 412 (2017)
- Tamai TK, et al., Identification of circadian clock modulators from existing drugs. *EMBO Molecular Medicine* 10, e8724 (2018)
- Nakayama T et al., Seasonal regulation of the lncRNA *LDAIR* modulates self-protective behaviors during the breeding season. *Nature Ecology & Evolution* 3, 845-852 (2019)

【Term of Project】

FY2019-2023

【Budget Allocation】

153,500 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.agr.nagoya-u.ac.jp/~aphysiol/

Figure 1 Medaka shows clear seasonality.

Title of Project：Dissecting the mechanism underlying behavioral regulation through real-time spatiotemporal manipulation of neural circuits

MORI Ikue
(Nagoya University, Graduate School of Science, Professor)

Research Project Number：19H05644　Researcher Number：90219999
Keyword：Neurobiology, Variability, Information Processing, Behavior

【Purpose and Background of the Research】

In contrast to computers, brain computation seems far more variable and complex. Intriguingly, the brain enables to generate variable yet distinct behavioral outputs even when the same sensory stimuli are presented to the animal. Such probabilistic feature of animal behaviors is thought to be important for the survival and reproduction of the animal in ever-changing environments. Despite how brain generates variable behavioral outputs is a fundamental question in neuroscience, the logics behind such variable feature are still elusive. The compact nervous system of *C. elegans* provides an excellent opportunity to dissect the neural mechanisms underlying variability in brain function.

We recently observed that optogenetic activation of a single *C. elegans* sensory neuron evoked multiple behavioral responses. A brain-wide single neuron ablation coupled with high-throughput behavioral analysis revealed that distinct behavioral responses induced by this single neuron activation required recruiting different neural circuits, each of which is composed of unique combination of neurons. Further, some neurons among the components of these neural circuits showed apparent spontaneous activities even when the sensory neurons were silent.

These observations suggested the possible basis of variability in brain function, where the changes in the activity of the sensory neuron can be interpreted differently depending on the internal state of the nervous system, and hence generate distinct behavioral outputs. In this study, we aim to investigate this possibility and identify the neural principle of variability in brain function.

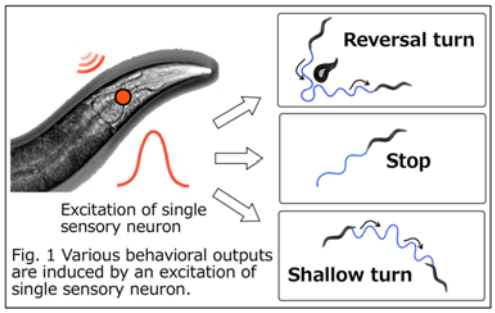


Fig. 1 Various behavioral outputs are induced by an excitation of single sensory neuron.

【Research Methods】

We will develop a new custom microscope system with real-time feedback system, in which timing of optogenetic manipulation of the sensory neuron can be determined by real-time monitoring of neural states of freely-moving animals. With this system, we plan to perform real-time analysis of the following components: 1) tracking the animal movement; 2) identifying neurons in the moving animals; 3) detecting the calcium signals from the neurons; and 4) analyzing the neural activity and determine the timing of optogenetic manipulation of the sensory neuron.

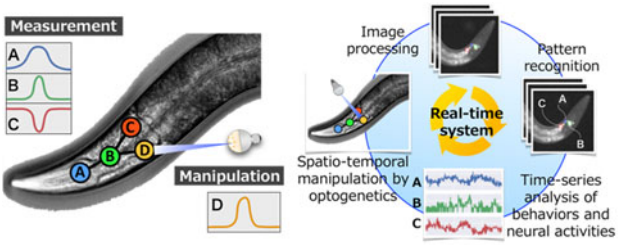


Fig. 2 Real-time optogenetic system to be established

【Expected Research Achievements and Scientific Significance】

Variability in behaviors is a unique feature of living organisms that distinguish them from computers. This study aims to understand the neural logics of information processing that confers variability in brain function. Understanding the principle of variability will be a milestone of neuroscience and also provide a platform for the development of new algorithms for soft computing.

【Publications Relevant to the Project】

Ikeda M., Nakano S., Giles A.C., Costa W.S., Gottschalk A., and Mori I.
Circuit Degeneracy Facilitates Robustness and Flexibility of Navigation Behavior in *C. elegans*. bioRxiv (2018)
https://doi.org/10.1101/385468

【Term of Project】

FY2019-2023

【Budget Allocation】

121,700 Thousand Yen

【Homepage Address and Other Contact Information】

https://nsi.bio.nagoya-u.ac.jp/en/
http://elegans.bio.nagoya-u.ac.jp/~lab/index.html

【Grant-in-Aid for Scientific Research (S)】

Broad Section G

Title of Project：Multi-scale molecular dynamics simulation on biomolecular dynamics in crowded cellular environments

SUGITA Yuji
(RIKEN, Cluster for Pioneering Research, Chief Scientist)

Research Project Number：19H05645　Researcher Number：80311190
Keyword：Multi-scale simulation, crowded cellular environment, liquid-liquid phase separation, protein conformational flexibility, enzyme reaction

【Purpose and Background of the Research】

Proteins or other biomacromolecules are crowded at high concentration in a living cell. Recently, the role of non-specific molecular interaction in the environments is found to be essential for various cellular functions.

In this research, we study both specific and non-specific molecular interactions and biomolecular dynamics in crowded cellular environments. For this purpose, we develop multi-scale molecular dynamics simulation methods combining coarse-grained models, atomistic models, and hybrid quantum mechanics/molecular mechanics (QM/MM) models. Simulations using different molecular models are connected by informatics approach.

【Research Methods】

The multi-scale simulation methods are developed and implemented into GENESIS molecular dynamics software. This software has been developed in RIKEN for large-scale atomistic simulations on K computer or post-K (Fugaku) computer.

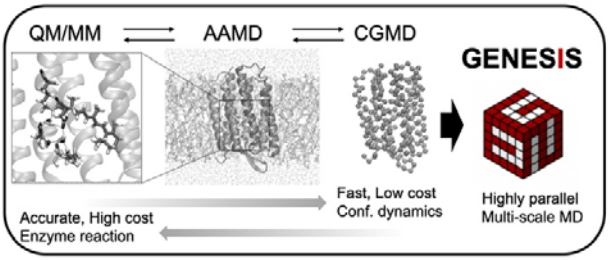


Figure 1　Multi-scale simulation method

In this research, we mainly develop coarse-grained simulations as well as QM/MM calculations. We also develop new methods to connect simulations with different molecular models by using informatics approaches, such as machine learning or Bayesian theory.

The developed methods are applied to two biological phenomena. One is liquid-liquid phase separation caused by proteins in signal transduction pathways. We examine the role of protein conformational flexibility and stability on the formation of liquid-liquid phase separation by performing multi-scale molecular dynamics simulations, solution NMR, and in-cell NMR spectroscopy. Simulation results are, thus, examined experimentally for improving the reliability of computational models and methods.

Second one is the role of cellular environments in enzymatic reactions. Enzymes can catalyze chemical reactions in a living cell. Before conducting the enzyme catalysis, substrate binding is required for enzyme, which can be affected by the surrounding environments. We study the substrate channeling in tryptophan synthase by computer simulations, such as atomistic molecular dynamics and hybrid QM/MM simulations. The simulation results are compared to the existing experimental results.

【Expected Research Achievements and Scientific Significance】

We can develop unique and useful multi-scale simulation modules in GENESIS. Since GENESIS is freeware under GPLv2 license, the developed methodologies will be released in future version of GENESIS. The multi-scale simulation will be available on Fugaku computer as well as PC-clusters with/without GPUs.

To understand molecular function in crowded cellular environments, substrate binding, protein-protein or protein-substrate interaction, and enzyme catalysis are the essential components. In this research, we will study molecular mechanisms underlying these essential functions and propose new insights as well as research strategies combining simulations with experiments.

【Publications Relevant to the Project】

・Yu, I. et al., Biomolecular interactions modulate macromolecular structure and dynamics in atomistic model of a bacterial cytoplasm. *eLife* **5**, e19274 (2016).
・Sakakibara, D. et al., Protein structure determination in living cells by in-cell NMR spectroscopy. *Nature* **458**, 102-105 (2009).

【Term of Project】

FY2019-2023

【Budget Allocation】

152,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://www2.riken.jp/TMS2012/tms/ja/index.html
sugita@riken.jp

Title of Project：Elucidating the Dynamics of Memory

Thomas McHugh
(RIKEN, Center for Brain Science, Team Leader)

Research Project Number：19H05646　Researcher Number：50553731
Keyword：hippocampus, cortex, memory, oscillations

【Purpose and Background of the Research】

Information in the brain is conveyed by the spiking of neurons and the computations underlying memory require these spikes be organized, both spatially and temporally. This is achieved through rhythmic oscillations, a fundamental mechanism of communication and organization throughout the brain. Here we will build on our work in the control and decoding of the physiology of memory to investigate how oscillations in hippocampal/cortical circuits organize the information required for memory and how temporally organized information is altered by dysfunction and disease. Combining novel optogenetic techniques with *in vivo* physiology and computational and analytical approaches we will address several fundamental questions:

•What determines which of a brain's millions of neurons contribute to a given memory trace?
•How are those neurons interconnected, and how does that trace evolve with time and experience?
•How are those neurons engaged during memory consolidation and recall?
•Can memory loss due to aging and disease be treated by intervention to improve synchronous activity?

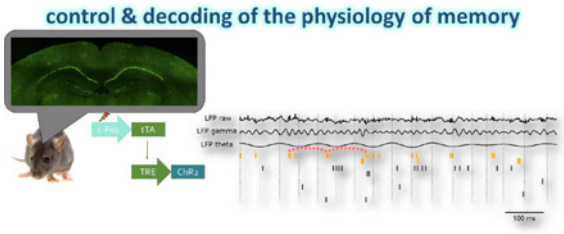


Fig. 1

【Research Methods】

We have recently combined our expertise in physiology with the emerging technology of memory engram labeling, based on the combination of immediate early gene expression and optogenetics, to functionally tag, identify & manipulate neurons involved in the encoding of a specific memory (Fig. 1). Building on this we will collect and analyze high-density recording of neuronal activity in the other regions of the hippocampus and cortex, allowing us to examine the interactions of neurons across brain regions during memory consolidation and recall. Further, the identification of a general signature of neurons engaged by memory will allow us to train algorithms with data from the high density recording to permit the identification of engram neurons based on physiology alone, without the need for optogenetic identification. These efforts will allow us to create models to classify memory age and quality based on physiology (Fig. 2) and better understand how temporal and spatial organization of activity can improve memory and brain health in cases of disease.

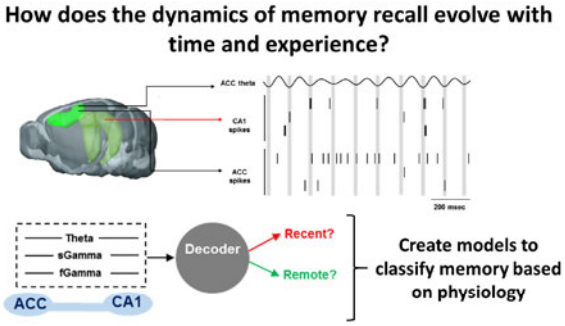


Fig. 2

【Expected Research Achievements and Scientific Significance】

This research will build on our ability to disambiguate information (spiking) and oscillations in the encoding, consolidation and recall of a specific memory. These advances leave us in a unique positon to investigate the mechanisms of integration of information and oscillations across regions of the brain and reveal their individual roles in memory, as well as yield insight to treatments of disorders involving aberrant neural dynamics.

【Publications Relevant to the Project】

Tanaka et al (2018) The hippocampal engram maps experience but not place. Science, 361(6400):392-397.
Middleton et al (2018) Altered hippocampal replay is associated with memory impairment in mice heterozygous for the SCN2A gene. Nature Neuroscience, 21(7):996-1003.
Middleton and McHugh (2016) Silencing CA3 disrupts temporal coding in the CA1 Ensemble. Nature Neuroscience, 19(7): 945-951.

【Term of Project】 FY2019-2023

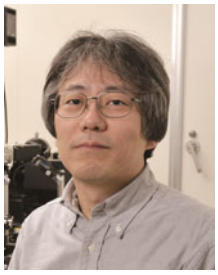
【Budget Allocation】 127,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://cbs.riken.jp/en/faculty/t.mchugh/

【Grant-in-Aid for Scientific Research (S)】

Broad Section G



Title of Project：Comprehensive approach toward understanding cell surface receptor functions coupled with membrane structure and lipid composition

SAKO Yasushi
(RIKEN, Cluster for Pioneering Research, Chief Scientist)

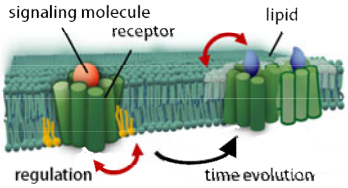
Research Project Number：19H05647　Researcher Number：20215700
Keyword：Receptor, Cell membrane, Cell signaling, Single-molecule measurement

【Purpose and Background of the Research】

The cell membrane, which is the boundary of cells and environment, has the fundamental structure of lipid bilayer. Receptor proteins embedded in the cell membrane are responsible for the acceptance, processing and transduction of extracellular information into the cells.

Lipid bilayer is a two-dimensional fluid, in which several hundred species of lipid molecules inhomogeneously distributed dynamically changing their assembly. Interactions with membrane domain structure and specific lipids regulate functions of membrane receptors. Vice versa, activities of membrane receptor affect compositions of boundary lipids and membrane structure. Such interactive communications produce self-organization of cell membrane for signal processing and transduction.

In this research, by applying cutting edge single-molecule technologies, we study behavior-function relationships of the most species of the major human membrane receptors to elucidate general mechanism of regulation of membrane receptor functions by the self-organization of membrane structures.



【Research Methods】

We have developed method of single-fluorescent molecule measurement of membrane proteins. This method allows quantification of molecular movements, dimerization, oligomerization, and interaction with extra- and intra-cellular proteins of membrane proteins on the living cell surface. It also allows measurements of structural dynamics and reactions of purified receptor molecules in artificial membranes. This project will use this method for the study of membrane receptors.

G protein-coupled receptors (GPCRs) and receptor tyrosine kinases (RTKs) are the targets of this study. We will compare the single molecule behaviors and functions about 300 species of GPCRs (excluding odorant receptors) and 60 species of RTKs in human cells to obtain general mechanism of signal processing and transduction of membrane receptors. We will focus on the diversification of the signaling pathways, signal bias, and crosstalk between different species of receptors.

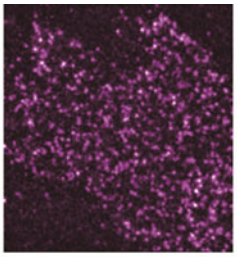
We also study dynamics of membrane domain structure and composition of boundary lipids of receptors. By using protein probe for specific lipid molecules, we can achieve super resolution imaging of 10~100 nm-scale lipid domains. Biochemical analysis of the boundary lipids of membrane receptors will be done in nanodiscs.

Major items of our project are as follows:

1. Comprehensive single-molecule measurement of membrane receptors
2. Super-localization imaging of membrane receptors and lipids
3. Analysis of the boundary lipids of membrane receptors
4. Measurement of molecular dynamics and lipid regulation in artificial membrane

【Expected Research Achievements and Scientific Significance】

In this study, we wish to understand meanings of the transient spatiotemporal dynamics of membrane structure and lipid compositions in the expression of signal processing and transduction functions of membrane receptors. Comprehensive single-molecule measurement is first enabled by our recent development of the automated imaging system. Since GPCRs and RTKs are the major targets medical drugs, this study will contribute to medical science and pharmacology.


Single-molecule imaging of membrane receptors

【Publications Relevant to the Project】

・Yanagawa M, Hiroshima M, Togashi Y, Yamashita T, Shichida Y, Murata M, Ueda M, Sako Y. Single-molecule diffusion-based estimation of GPCR activity. Sci. Sig. 11, eaaao1917 (1-16) (2018)
・Hiroshima M, Pack C-g, Kaizu K, Takahashi K, Ueda M, Sako Y. Transient acceleration of epidermal growth factor receptor dynamics produces higher-order signaling clusters. J. Mol. Biol. 430, 1386-1401 (2018)

【Term of Project】 FY2019-2023

【Budget Allocation】 117,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www2.riken.jp/cell-info/
sako-lab@riken.jp

Title of Project：Biology of sugar-alcohol modification in glycan

ENDO Tamao
(Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology, Senior Fellow)

Research Project Number：19H05648　Researcher Number：30168827
Keyword：glycosylation, sugar-alcohol, post-translational modification

【Purpose and Background of the Research】

Glycosylation is an important post-translational modification of cell surface and intercellular molecules, regulating various physiological processes, such as molecular interactions and intracellular communications. We have found novel glycan modifications by sugar-alcohol phosphates (ribitol-phosphate and glycerol-phosphate) in mammals (Ref. 1,3). We also identified several enzymes involved in the sugar-alcohol phosphate modifications and revealed that a defect in ribitol-phosphate modification causes severe disorders such as congenital muscular dystrophy with brain malformation (Ref. 1,2). In the sugar-alcohol phosphate modification, ribitol or glycerol binds to saccharide through phosphodiester linkage, while typical glycans are formed by glycosidic linkage between monosaccharides. The sugar-alcohol phosphates have long been known as a component of bacterial cell wall, teichoic acid, but they have never been found in mammals. Interestingly, the mammalian sugar-alcohol phosphates are conserved as molecules with a function disinct from that in bacteria and are related to diseases. However, details of the metabolic pathway of mammalian sugar-alcohol phosphates are poorly understood. Additionally, the advantage of the usage of phosphodiester linkage in glycosylation is also unclear. In this study, we aim to elucidate the biological significance of sugar-alcohol phosphates modification in glycan formation.

【Research Methods】

In this study, we will focus on the following subject areas to elucidate the biological significance of sugar-alcohol phosphate modification:

1. Physicochemical characteristics: we will synthesize a series of glycans containing sugar-alcohol phosphate and examine their physicochemical properties.
2. Molecular basis of sugar-alcohol phosphate modification: the mechanism of modification will be elucidated by studies on the structural biology of related enzymes.
3. Metabolic pathway of sugar-alcohol phosphate modification: the enzymes responsible for synthesis and metabolism of sugar-alcohol phosphate will be elucidated by biochemical assays.
4. Target molecules of sugar-alcohol phosphate modification: specific detection methods for the modified glycans will be developed using chemical biology and antibodies or lectin-like molecules.
5. Biological function: the effects of sugar-alcohol phosphate deficiency on biological functions will be examined using genetically modified cells/animals.

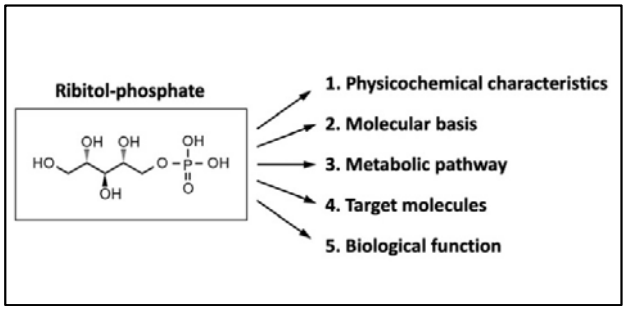


Figure 1. Research methods

【Expected Research Achievements and Scientific Significance】

The underlying molecular mechanism of sugar-alcohol modification and its biological significance will be elucidated by this study. Furthermore, the results will provide a pathomechanism of congenital muscular dystrophy and aid in the development of therapies.

【Publications Relevant to the Project】

1. Kanagawa M. et al. (2016) Identification of a post-translational modification with ribitol-phosphate and its defect in muscular dystrophy. *Cell Rep.*, 14, 2209-2223
2. Kuwabara N. et al. (2016) Carbohydrate-binding domain of the POMGnT1 stem region modulates *O*-mannosylation sites of α-dystroglycan. *Proc. Natl. Acad. Sci. USA*, 113, 9280-9285
3. Imae R. et al. (2018) CDP-glycerol inhibits the synthesis of the functional *O*-mannosyl glycan of α-dystroglycan. *J. Biol. Chem.*, 293, 12186-12198

【Term of Project】FY2019-2023

【Budget Allocation】135,000 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.tmghig.jp/research/

【Grant-in-Aid for Scientific Research (S)】

Broad Section H

Title of Project：Deciphering Molecular Basis for the Anti-Oxidative Stress Response and Application of the Basis for Disease Prevention and Therapy

YAMAMOTO Masayuki
(Tohoku University, Graduate School of Medicine, Professor)

Research Project Number：19H05649　Researcher Number：50166823
Keyword：Stress response, KEAP1-NRF2 system

【Purpose and Background of the Research】

Environmental factors such as dietary poison, ultraviolet, and air pollution often cause redox disturbance and leads to irreversible changes of biomolecules that might explain many types of disorder. The KEAP1-NRF2 system is one of the most important defense mechanisms against the redox disturbance. In addition to the anti-oxidant function of NRF2, we recently clarified that NRF2 has a potent anti-inflammatory function, which is likely to result from direct inhibition of pro-inflammatory cytokine production by NRF2. Considering recent studies describing the increased oxidative stress and smoldering chronic inflammation in the pathological basis of many disorders, including Alzheimer's disease, arthritis and type 2 diabetes, we can expect that NRF2 activation is effective for prevention and treatment of the chronic diseases and achievement of healthy aging. The goal of this research is to clarify new mechanisms of the KEAP1-NRF2 system and to explore the effectiveness of NRF2 activation for anti-disease strategy toward health and longevity. In this research proposal, we will clarify basic molecular mechanisms how the KEAP1-NRF2 system is regulated, contributions of NRF2 to the prevention of stress-related disorders, and relation among the functionality of the KEAP1-NRF2 system and organismal redox balance and health.

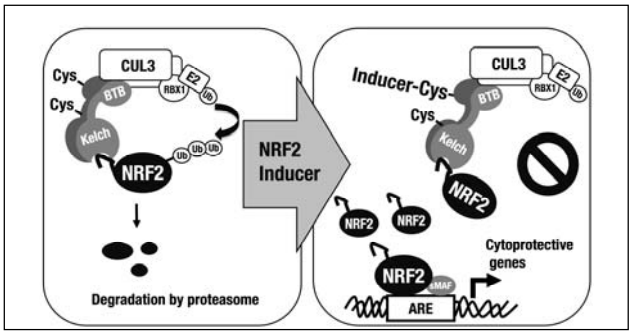


Figure 1 KEAP1-NRF2

【Research Methods】

We will clarify basic molecular mechanisms how the KEAP1-NRF2 system is regulated, contributions of NRF2 to the prevention of various disorders, and relation among the functionality of the KEAP1-NRF2 system and organismal redox balance and health.

1) ROS sensor(s) of KEAP1. To clarify the function of the oxidative stress sensor *in vivo*, we are planning to generate KEAP1 mutant knock-in lines of mice that will be unable to response to hydrogen peroxide.

2) Structure analysis of NRF2-KEAP1-CUL3 complex. To understand this mechanism how KEAP1's structure changes in response to stress to regulate NRF2's activity, structural analysis of full-length KEAP1 must be undertaken. We will endeavor to reveal the structure and function of KEAP1 in complex with NRF2 and CUL3 by combining X-ray crystallography, cryo-EM and NMR spectroscopy analyses.

3) Physiological analysis of NRF2 in prevention of aging related disease. We have developed several lines of mice for targeting KEAP1 or NRF2, and also obtained disease model animal for Alzheimer's disease, arthritis and type 2 diabetes. To clarify contribution of NRF2, we are generating compound mice having loss- or gain-of-NRF2 function in these disease model mice.

【Expected Research Achievements and Scientific Significance】

As an outcome of this research, we will consolidate an idea that NRF2 activation is a general target for an anti-disease strategy. Extension of health span is an urgent need in the current super-aging society. To this end, long-term and preventive intervention with low costs is required. A good thing about the KEAP1-NRF2 system is that NRF2 can be appropriately activated by naturally occurring phytochemicals contained in vegetables and other food. From these social perspectives, we believe that NRF2 is a perfect target for anti-aging strategy with sufficient practicality.

【Publications Relevant to the Project】

- **Yamamoto M**, Kensler TW, and Motohashi H. The Keap1-Nrf2 System: a thiol-based sensor-effector apparatus for the maintenance of redox homeostasis. ***Physiol Rev*** 98, 1169-1203. (2018)
- Suzuki T, **Yamamoto M**. et al, Molecular mechanism of cellular oxidative stress sensing by Keap1. ***Cell Reports*** *in press* (2019)

【Term of Project】 FY2019-2023

【Budget Allocation】 153,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.dmbc.med.tohoku.ac.jp/official/index.html
masiyamamoto@med.tohoku.jp

Title of Project：Elucidation of pathogenic immunological memory to understand the pathogenesis of intractable inflammatory diseases

NAKAYAMA Toshinori
(Chiba University, Graduate School of Medicine, Professor)

Research Project Number：19H05650　Researcher Number：50237468
Keyword：Immune systems, Airway inflammation, Allergy, Pathogenic immunological memory

【Purpose and Background of the Research】

The main purpose of our research is to investigate the mechanisms that control the differentiation of memory helper T cells and their induction of allergic airway inflammation (asthma). “Immunological memory” is a major issue in the field of immunology research. Recently, we identified two pathogenic memory Th2 cell populations (IL-5-high-producing and fibrosis-inducing memory Th2 cells) that are harmful to humans (Figure 1).

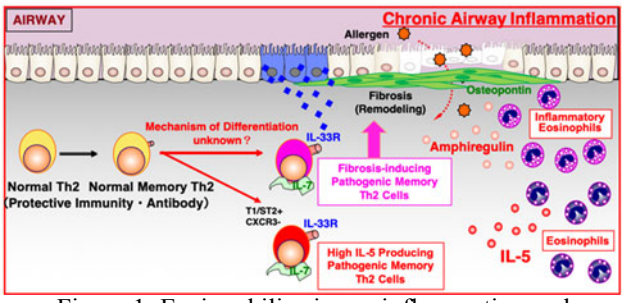


Figure 1: Eosinophilic airway inflammation and fibrosis induced by pathogenic memory Th2 cells

Based on these findings, we proposed a “pathogenic memory Th population disease induction model” in which pathogenic subpopulations induce and control the pathogenesis of various inflammatory diseases (Figure 2). We intend to explore the mechanisms underlying how pathogenic immunological memory T cells differentiate and are maintained in mouse models or human patients for a long time at the molecular and cellular levels.

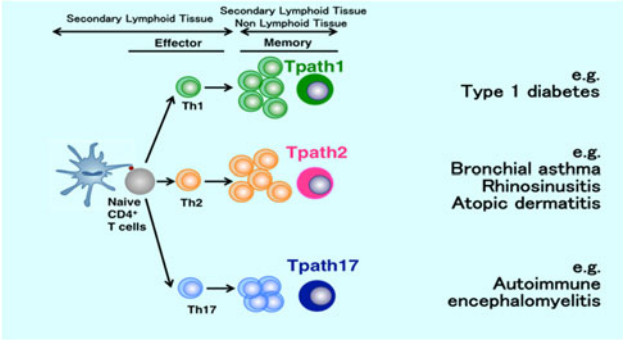


Figure 2: Pathogenic memory Th cells and inflammatory diseases

【Research Methods】

(1) To identify novel functional molecules regulating the pathogenesis and differentiation of "Pathogenic Memory Th2 (Tpath2) cells", we will conduct integrative analyses of Tpath2 cells using single-cell RNA-Seq, ChIP-Seq, or ATAC-Seq. We will also analyze the mechanism underlying the functional transformation and maintenance of Tpath2 cells regulated by Polycomb and Trithorax groups at the chromatin level. (2) In the spatio-temporal mapping of microenvironments responsible for the differentiation and maintenance of Tpath2 cells, we will examine immunohistological and pathological changes of inducible bronchus-associated lymphoid tissue (iBALT) and fibrosis of localized inflammation. (3) To promote research in support of a proof of concept, we will perform analyses using samples of human patients with chronic eosinophilic sinusitis, chronic hypersensitivity pneumonitis, eosinophilic esophagitis, and other diseases.

【Expected Research Achievements and Scientific Significance】

This research aims to clarify the nature of “pathogenic immunological memory”, both at the molecular and cellular levels, and to define the regulation of pathogenesis by immunological memory *in vivo*. These points of view are unique and scientifically significant. We will also focus on human immunology: we plan to analyze the inflamed tissues of several patients as well as human cells in almost all experiments. We additionally intend to examine the concepts derived from animal experiments to see if they can be applied to humans. Once we have determined how to control the number or function of immunological memory cells, this research may help contribute to the development of new treatment strategies for intractable inflammatory diseases.

【Publications Relevant to the Project】

・Morimoto Y, Nakayama T, et al., Amphiregulin-producing pathogenic memory T helper-2 cells instruct eosinophils to secrete Osteopontin and facilitate airway fibrosis. *Immunity* 49:134-150 (2018).
・Nakayama T, et al., Th2 Cells in Health and Disease. *Annu. Rev. Immunol.* 35:53-84 (2017).

【Term of Project】

FY2019-2023

【Budget Allocation】

155,400 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.m.chiba-u.ac.jp/class/meneki/english/index.html

Title of Project：Comprehensive analysis of molecular machineries for mitotic spindle formation in human cells and its application to development of next generation anti-cancer drug.

KITAGAWA Daiju
(The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor)

Research Project Number：19H05651　Researcher Number：80605725
Keyword：cell division, centrosome, centriole, mitotic spindle, mitotic inhibitor

【Purpose and Background of the Research】

The centrosome is an evolutionarily conserved organelle in eukaryotes, and is important for formation of mitotic spindles, and thus is deeply involved in proper chromosome segregation and maintenance of genome stability. On the other hand, in human cancer cells, it has been reported that cell division proceeds by a centrosome-independent spindle formation mechanism even if the centrosome is physically removed. Recently, we found that in different cancer cell types, the contribution of centrosomes in spindle formation is significantly different. Therefore, in this study, we will identify various spindle formation machineries by performing comparative analysis using many types of human cancer cells as a model. Furthermore, we analyze the molecular basis that controls mitotic spindle formation in an integrated manner, and elucidate the mechanisms of centrosome-dependent and independent mitotic spindle formation in various types of human cancer cells. In addition, by combining the latest cytogenetics, cell biology and chemical biology, it is possible to develop mitotic-phase specific anti-cancer drug.

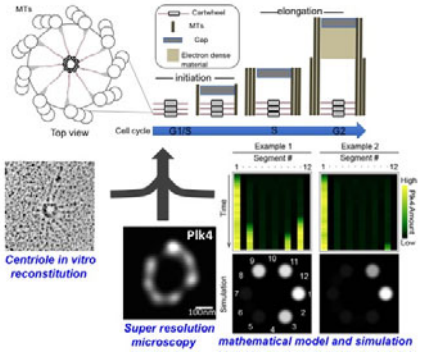


Figure 1　Mechanisms of centriole duplication

【Research Methods】

1) Elucidation of centrosome duplication mechanisms by a combination of super resolution microscopy and *in vitro* reconstruction system. 2) Comprehensive identification and functional analysis of centrosome-independent spindle formation machineries using cytogenetic methods in various human cancer cell types. 3) Develop small molecule compounds that specifically inhibit mitotic spindle formation. 4) Elucidation of the spindle formation mechanism in blood cancer cells.

【Expected Research Achievements and Scientific Significance】

In this research, we use super resolution microscopy technology, simulation, structural biological analysis, etc., and clarify the basic principles that mediate centriole duplication and mitotic spindle formation. Also, we will establish an accurate duplication model of centrosomes using mathematical models and simulations based on raw data. Furthermore, the findings obtained from this study are expected to lead not only to a better understanding of the cell division processes of various cancer cell types but also to the development of new anti-cancer strategies.

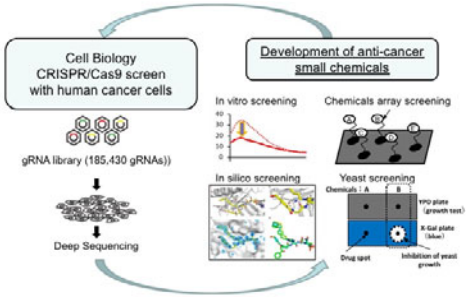


Figure 2　Combination of CRISPR screen and chemical biology

【Publications Relevant to the Project】

・Ohta M., Watanabe K., Ashikawa T., Nozaki Y., Yoshiba S., Kimura A. and Kitagawa D. (2018) Bimodal Binding of STIL to Plk4 Controls Proper Centriole Copy Number. *Cell Reports*, 23, 3160-3169, doi: 10.1016/j.celrep.2018.05.030.
・Tsuchiya Y., Yoshiba S., Gupta A., Watanabe K. and Kitagawa D. (2016) Cep295 is a conserved scaffold protein required for generation of a bona fide mother centriole. *Nature Communications*, doi: 10.1038/ncomms12567.

【Term of Project】

FY2019-2023

【Budget Allocation】

153,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.f.u-tokyo.ac.jp/~seiri/index.html

Title of Project：Genomic origin of chemodiversity in medicinal plants

SAITO Kazuki
(RIKEN, Center for Sustainable Resource Science, Deputy Center Director)

Research Project Number：19H05652　Researcher Number：00146705
Keyword：medicinal plants, genome, metabolome

【Purpose and Background of the Research】

The diversity of the plant metabolome, which is the source of medicine, far surpasses animals and so on, but its genomic origin is an unknown subject and is a fundamental issue. In addition, 90% of physicians still prescribe Kampo, and expectations for botanical medicine are high for extension of healthy lifespan in the aging society. While many herbal medicines depend on imports, the Nagoya Protocol came to seek fair profit distribution, but it is rather a great opportunity for genomic elucidation and intellectual property defense of domestically grown medicinal plants. In addition, in the “Sustainable Development Goals” SDGs (Sustainable Development Goals) adopted by the United Nations in 2015, conservation of biodiversity resources and its sustainable use are issues of global concern. In addition, there is a rapid development of genomic science related technology as a technical background.

In this study, we decipher the genome and metabolome of medicinal resource plants, clarify the origin of their chemical diversity, and apply their findings to the sustainable use of plant resources.

【Research Methods】

Regarding licorice most important as a herbal medicine, which is most frequently used for Kampo prescriptions and so on, we determined high-quality genome sequences of plant species containing and not containing glycyrrhizin, its main active ingredient. Variant strains with different component patterns are resequenced to obtain mutational information. Next, transcriptome and metabolome data are also acquired, and genes, genome regions and mutations that determine component patterns are identified by co-occurrence network analysis or genome wide association study (GWAS) of these. Next, along with functional identification of these genes, biotechnologies such as genome editing and synthetic biology are applied to molecular breeding of licorice and production of active ingredients. At the same time, we will extend this basic method to functional genomics of important medicinal plants other than licorice.

【Expected Research Achievements and Scientific Significance】

It is possible to decipher genomes and metabolomes and clarify the origin of their chemical diversity in medicinal plants of increasing importance in the fields of medicines and medical field. This can be applied to the sustainable use of plant resources that contributes to "Sustainable Development Goals" SDGs, and at the same time, it can extend the horizon of human knowledge. Furthermore, it will open up a new path to medicinal plant resource development in the next 10 to 20 years.

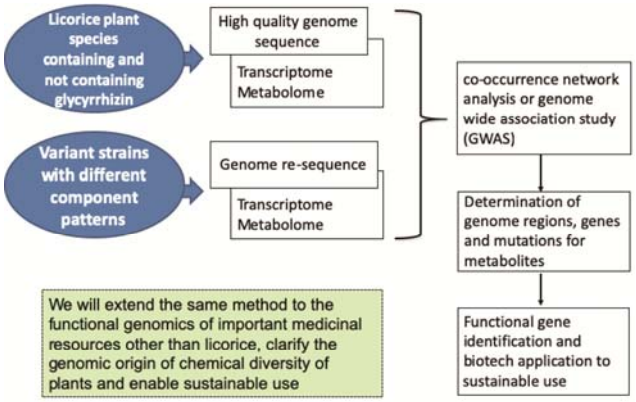


Figure 1 Outline of research

【Publications Relevant to the Project】

・Mochida, K., *et al.*: Draft genome assembly and annotation of *Glycyrrhiza uralensis*, a medicinal legume. *Plant J.*, **89**, 181–194, (2017)
・Rai, A., Saito, K., Yamazaki, M.: Integrated omics analysis of specialized metabolism in medicinal plants. *Plant J.*, **90**, 764-787 (2017)
・Knoch, E., *et al.*: The third DWF1 paralog in Solanaceae, sterol Δ^{24}-isomerase, branching withanolide biosynthesis from the general phytosterol pathway. *Proc. Natl. Acad. Sci. USA*, **115**, E8096-E8103 (2018)
・Tsugawa, H., Nakabayashi, R., *et al.*: A cheminformatics approach to characterize metabolomes in stable-isotope-labeled organisms. *Nature Methods*, **16**, 295–298 (2019)

【Term of Project】

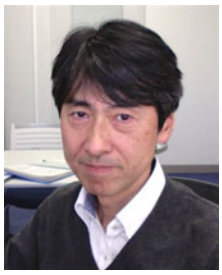
FY2019-2023

【Budget Allocation】

154,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.riken.jp/research/labs/csrs/metabolom/
http://metabolomics.riken.jp/



Title of Project：Deciphering of the epigenetic machinery that determines the hallmarks of hematopoietic stem cell aging

IWAMA Atsushi
(The University of Tokyo, The Institute of Medical Science, Professor)

Research Project Number：19H05653　Researcher Number：70244126
Keyword：Hematopoietic stem cell, aging, epigenetics

【Purpose and Background of the Research】

Hematopoietic cells represent the cell type with the greatest numbers in the body. They circulate throughout the body or stay in the organs and exert various functions such as supply of oxygen, hemostasis, and immune reactions. Hematopoietic stem cells (HSCs) are exposed to various stresses and show functional decline during aging.

Dysfunction of hematopoietic stem cells results in disorganized hematopoietic system, including anemia and immune dysfunction, thereby causing functional decline in various organs, eventually leading to the individual's functional impairment. Aged HSCs are also predisposed to transformation (Figure 1). Therefore, functional impairment of HSCs is tightly associated with individual's functional impairment. Understanding of the mechanisms regulating HSC function over the entire life course thus promotes understanding of the mechanisms underlying individual's functional impairment.

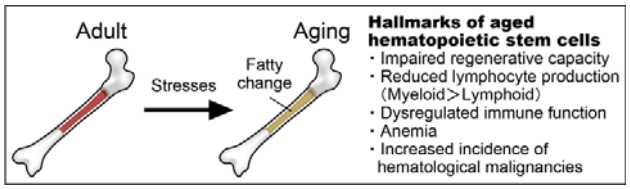


Figure 1. Hallmarks of aged hematopoietic stem cells

【Research Methods】

We will take bioinformatic comprehensive approaches to decipher the changes in epigenetic properties of HSCs over the entire life course: (1) maintenance phase in adult bone marrow and (2) functional impairment phase during aging. We will clarify how various stresses to which mice are exposed alter epigenetic patterns in HSCs and impair individual's function over the entire life course. We have already obtained a part of the epigenetic data of HSCs and identified unique chromatin properties that may account for functional impairment of HSCs with aging. We also take an advantage of single HSC profiling by RNA-seq and ATAC-seq analysis to decipher the alterations in heterogeneities in HSC populations with age (Figure 2).

Because the quality of bone marrow niche holds key to the functional maintenance of HSCs, we will also analyze the alterations in the quality of niche over the entire life course. Furthermore, we will clarify the epigenetic abnormalities responsible for the impaired differentiation of HSCs, which leads to abnormal production of differentiated progenies and transformation into age-associated hematological malignancies.

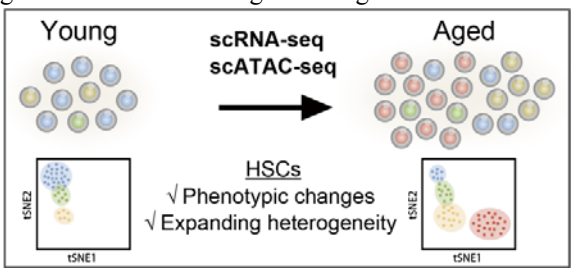


Figure 2. Single cell assays of HSCs

【Expected Research Achievements and Scientific Significance】

Through a series of analyses, we hope to identify factors responsible for the functional impairment of HSCs and their niche, which eventually affect individual's function over the entire life course. By manipulating those factors, we will develop the modalities to control the individual's functional impairment through reactivating HSCs

【Publications Relevant to the Project】

・Tara S, Isshiki Y, Nakajima-Takagi Y, Oshima M, Aoyama K, Tanaka T, Shinoda D, Koide S, Saraya A, Miyagi S, Manabe I, Matsui H, Koseki H, Bardwell VJ, Iwama A. *Bcor* insufficiency promotes initiation and progression of myelodysplastic syndrome. ***Blood*** 132(23):2470-2483, 2018.
・Sashida G, Harada H, Matsui H, Oshima M, Yui M, Harada Y, Tanaka S, Mochizuki-Kashio M, Wang C, Saraya A, Muto T, Inaba T, Koseki H, Huang G, Kitamura T, and Iwama A. Ezh2 loss promotes development of myelodysplastic syndrome but attenuates its predisposition to leukemic transformation. ***Nat Commun*** 5:4177, 2014.

【Term of Project】

FY2019-2023

【Budget Allocation】

153,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ims.u-tokyo.ac.jp/molmed/
03aiwama@ims.u-tokyo.ac.jp

Title of Project：Establishment of an integrated locomotive science including dynamics of bone-articular cells and regulation by immune system

TANAKA Sakae
(The University of Tokyo, The University of Tokyo Hospital, Professor)

Research Project Number：19H05654　Researcher Number：50282661
Keyword：Integrated Locomotive Science, Locomotive Disease, Single-cell Analysis

【Purpose and Background of the Research】

Locomotion is an essential activity to maintain homeostasis of the body. Representative locomotive diseases such as osteoarthritis (OA), osteoporosis and rheumatoid arthritis severely restrict patient's activities of daily living and thus lead to social problems. The difficulty in overcoming those diseases is caused by the diversity and the heterogeneity of the cellular complex associated with bone and articular cartilage. The purpose of this project is to analyze the underlying mechanism of bone and cartilage homeostasis. Using technology for molecular and cellular analysis, transgenic mouse analysis, we elucidate the mechanisms for maintaining the locomotive homeostasis, especially focusing on the regulation by immune system such as innate lymphoid cells (ILC).

【Research Methods】

We collect synovium, bone marrow, and articular cartilage from naïve mouse and OA model mouse, and we analyze comprehensively the proportion and the transition of synovial fibroblast, macrophage, other immune cells such as ILC, osteoblast, osteoclast, osteocyte, and chondrocyte, by using immunohistochemistry assay and mouse genetic modification technology. Furthermore, we perform single-cell RNA sequences (scRNAseq) to analyze the heterogeneity of those cells and the subsets related to each cell type.

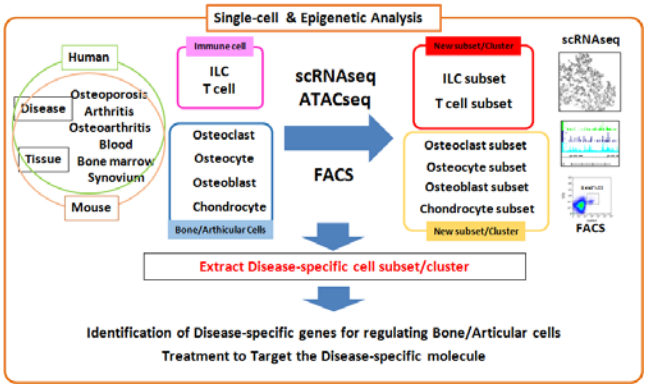


Figure. Integrated Locomotive Science.

We investigate the difference and the overlap between mouse and human about the phenomenon which were observed in those specific mice with OA.

【Expected Research Achievements and Scientific Significance】

This project focuses on the elucidation of heterogeneity of the cells associated with bone and cartilage by understanding the molecular changing in a single cell.From these insights, we could unveil the mechanisms for the locomotive system. Understanding of the mechanism by investigating the effect of immune cells such as ILC, it will be expected that those insights would discover the regulation of the diseases and lead to establishing treatment by targeting molecules associated.

【Publications Relevant to the Project】

- Komatsu N, Okamoto K, Sawa S, Nakashima T, Oh-hora M, Kodama T, Tanaka S, Bluestone JA, Takayanagi H., Pathogenic conversion of Foxp3+ T cells into TH17 cells in autoimmune arthritis, ***Nat Med***. 2014 Jan;20(1):62-8.
- Kobayashi H, Chang SH, Mori D, Itoh S, Hirata M, Hosaka Y, Taniguchi Y, Okada K, Mori Y, Yano F, Chung UI, Akiyama H, Kawaguchi H, Tanaka S, Saito T., Biphasic regulation of chondrocytes by Rela through induction of anti-apoptotic and catabolic target genes, ***Nat Commun***. 2016 Nov 10;7:13336.
- Omata Y, Frech M, Primbs T, Lucas S, Andreev D, Scholtysek C, Sarter K, Kindermann M, Yeremenko N, Baeten DL, Andreas N, Kamradt T, Bozec A, Ramming A, Krönke G, Wirtz S, Schett G, Zaiss MM.,Group 2 Innate Lymphoid Cells Attenuate Inflammatory Arthritis and Protect from Bone Destruction in Mice, ***Cell Rep***. 2018 Jul 3;24(1):169-180.

【Term of Project】

FY2019-2023

【Budget Allocation】

154,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.u-tokyo-ortho.jp/

Title of Project：Anti-cancer therapies aiming for cure through inhibiting tumor-specific responses to environmental fluctuation

ISHIKAWA Fuyuki
(Kyoto University, Graduate School of Biostudies, Professor)

Research Project Number：19H05655　Researcher Number：30184493
Keyword：Stress Response, Cancer Progression

【Purpose and Background of the Research】

Precision medicine based on molecularly targeting anti-cancer drugs has been revolutionized the strategy in cancer therapeutics. One drawback is, however, relapse of cancer cells resistant to the cognate medicine is not infrequent. Molecular targeting inhibits specific signaling molecules, activated by mutations (driver mutations, Fig 1a and b), thereby halt the autonomous cell proliferation (Fig 1c). However, cancer cells show genetic instability, which generates numerous random mutations in the genome. Accordingly, cells possessing a second driver mutation that bypasses the molecular targeting drug arises in time, leading to relapse (Fig 1d).

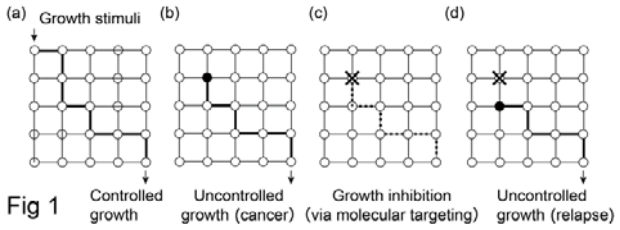


Fig 1

This argument led to a conclusion that to achieve cure without relapse in treating cancer patients, we need to target the system that uniquely enables cancer cells to undergo malignant progression, in addition to the molecular targeting towards driver genes.

【Research Methods】

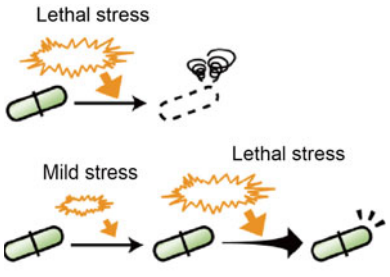


Fig 2　Acquired Tolerance

We have previously investigated how cells respond to non-lethal mild stress. Specifically, we have revealed molecular mechanisms of acquired tolerance (Fig 2), a widely observed phenomenon where a preceding mild stress equips cells with resistance to a following lethal stress, using genetic screening in fission yeast. We will investigate to test whether tumors depend on acquired tolerance for their progression. If yes, we will exploit the dependence to develop novel cancer therapeutics.

【Expected Research Achievements and Scientific Significance】

Normal tissues in organisms are maintained under constant environment thanks to homeostasis. However, tumors are not benefitted by it, and accordingly are exposed to constant environmental fluctuation, such as those of oxygen and nutrient concentrations. As such, responses to non-lethal stresses are vital to tumors in maintaining their viability. This research will give a basic framework in targeting acquired tolerance as a novel strategy to develop cancer treatment aiming at cure.

【Publications Relevant to the Project】

・Chujo, M., Tarumoto, Y., Miyatake, K., Nishida, E., and Ishikawa, F. (2012). ***J Biol Chem*** 287(28), 23440-23450.

【Term of Project】

FY2019-2022

【Budget Allocation】

128,100 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.fish.lif.kyoto-u.ac.jp/en/home_en.html

Title of Projec： Comprehensive studies on the molecular basis of early development and clonal evolution in cancer using advanced genomics.

OGAWA Seishi
(Kyoto University, Graduate School of Medicine, Professor)

Research Project Number：19H05656　Researcher Number：60292900
Keywords: Genome biology, Oncology

【Purpose and Background of the Research】

Whole spectrum of genetic mutations has been clarified in most of the common cancers. However, it remains unclear how heterogeneity in cancer is acquired during initial development and clonal selection in the clinical course. To address these issues, combinations of multiple mutations, cryptic noncoding genomic lesions, and their functional implication should be elucidated. By single-cell sequencing, micro-scale sampling, whole genome sequencing, long-read sequencing, we will elucidate the molecular basis of early development and clonal evolution in cancer. We will also analyze large cohort of cancer patients to establish novel disease classification, to stratify patients according to prognosis, and to identify therapeutic molecular targets, which will be validated for functional implication in mouse models.

【Research Methods (Figure 1)】

1) Sequencing of high-density micro-scale samples, organoid, and laser microdissection tissues will demonstrate the process of clonal expansion in pre-cancer lesions of pancreatic, colon, and breast cancers. Serial sampling of multiple lesions will allow for clonal evolution from primary to aggressive, metastatic, and recurrent cancers.
2) The in-house single-cell sequencing method will simultaneously provide both information of genetic mutations and gene expression levels from a single cell, which will make it possible to display expression profile in each mutated cell from heterogenous fractions.
3) Whole genome and long-read sequencing will identify structural variants in noncoding regions whose significance will be validated by mouse model.
4) Large scale study of cancer patients will reveal association of genetic lesions with disease phenotype, therapeutic response, and prognosis. Coincidence and mutual exclusiveness of genetic mutations will be investigated to elucidate mechanism of stepwise acquisition of heterogeneity in cancer.

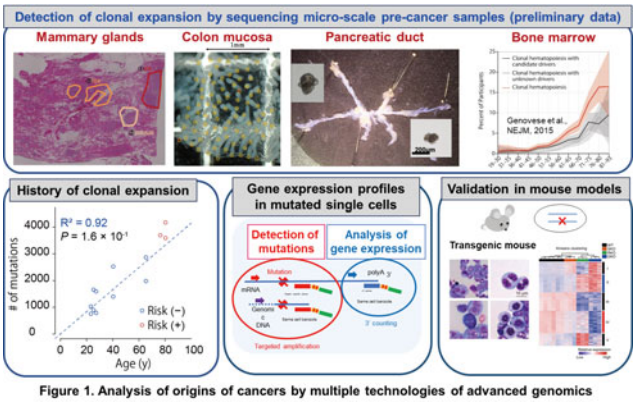


Figure 1. Analysis of origins of cancers by multiple technologies of advanced genomics

【Expected Research Achievements and Scientific Significance】

We will comprehensively demonstrate the process of age-related clonal expansion and remodeling in pre-cancer tissues using single-cell sequencing and micro-scale sampling and clarify their adaptive response to environmental stress and association with initial process in cancer development. We will also identify implication of noncoding lesions by whole genome / long-read sequencing (Figure 2). Moreover, we will conduct such studies in large cohort of patients for achievement of precision medicine on the basis of 'personality of each case' which will be defined by establishment of novel disease classification, prognostic stratification of patients, and identification of therapeutic molecular targets.

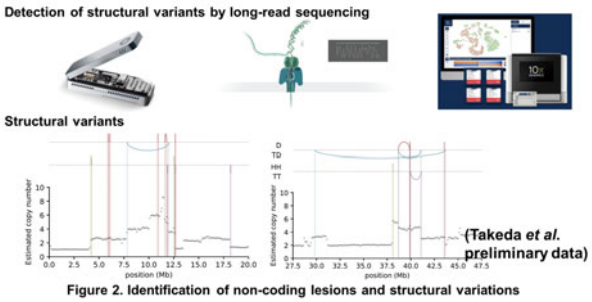


Figure 2. Identification of non-coding lesions and structural variations

【Publication Relevant to the Project】

・Yokoyama A, Ogawa S, *et al*., Age-related remodelling of oesophageal epithelia by mutated cancer drivers. ***Nature.*** 565:312-317, 2019
・Yoshizato T, Ogawa S, *et al*., Somatic mutations and clonal hematopoiesis in aplastic anemia. ***N Engl J Med.*** 373:35-47, 2015

【Term of Project】

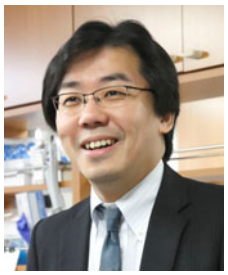
FY2019-2023

【Budget Allocation】

153,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://plaza.umin.ac.jp/kyoto_tumorpatho/
sogawa-tky@umin.ac.jp



Title of Project： Identification and control of pathogenic osteoclasts

ISHII Masaru
(Osaka University, Graduate School of Frontier Biosciences, Professor)

Research Project Number：19H05657　Researcher Number：10324758
Keyword：medicine and welfare, immunology

【Purpose and Background of the Research】

Osteoclasts play a key role in maintaining skeletal homeostasis by supporting steady-state bone remodelling in the bone marrow (BM). However, in contrast to this physiological role, osteoclasts are also involved in pathological arthritic bone erosion in patients with rheumatoid arthritis (RA), which occurs where the hypertrophied synovium (called “pannus”) invades the outer surface of the articular bone. Extensive studies have been performed to identify the osteoclast precursor (OP) population in BM. Nevertheless, precise analysis of OPs in inflammatory conditions has not yet been performed, especially in “inflamed synovium”, the actual site of bone erosion in arthritis, mainly due to technical difficulties associated with approaching and isolating tiny synovial tissues. Thus, whether the two osteoclast populations in the BM and synovial tissue settings have a similar pathway of differentiation and arise from similar precursor states remains unknown (Figure 1). The objectives of the current study are, (1) to identify the osteoclast precursor (OP) population in the inflamed synovium and elucidate the molecular mechanisms responsible for regulating this population, and (2) to elucidate the functional characteristics of osteoclasts in the pannus-bone interface compared with conventional osteoclasts in BM.

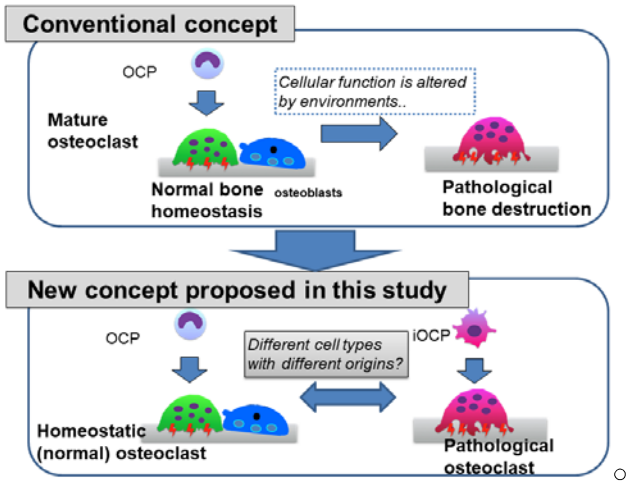


Figure 1. Conventional and novel concepts on osteoclasts in inflammatory conditions. Are they just different in terms of their activation status, or they are essentially different cell types from respectively distinct precursors?

【Research Methods】

Using the original protocol to isolate the inflamed synovium, we identify the OP population in the synovium and then characterize the molecular mechanisms as well as the predicted critical regulator for differentiation of these cell types, by using exhaustive expression analyses, such as RNA sequencing. For analyzing their origins, cellular tracing and intravital imaging with photo-convertible fluorophore will be conducted. Furthermore, by targeting the molecule(s) which we identify specifically expressed in inflammatory OP fractions, we plan to develop novel therapeutics against inflammatory bone destructions. We also further analyze the possible involvement of this novel line of osteoclasts in another pathological conditions such as bone-metastatic tumors. For such analyses, direct visualization of osteoclasts will clarify the differences and characteristics, which may lead to the development of optimized treatment for bone diseases.

【Expected Research Achievements and Scientific Significance】

This work, with its identification and characterization of a novel OPs specifically involved in arthritic bone destruction, and with elucidation of the functional differences between osteoclasts in the BM and pannus-bone interface, will lead to pathogenic-osteoclast specific treatment in patients with rheumatoid arthritis (RA).

【Publications Relevant to the Project】

Furuya, et al., Direct cell-cell contact between mature osteoblasts and osteoclasts dynamically controls their functions in vivo. Nat. Commun., 9: 300, 2018.
Matsuura et al. In vivo visualization of different modes of action of biologic DMARDs inhibiting osteoclastic bone resorption. Ann. Rheum. Dis., 77 :1219-1225, 2018.

【Term of Project】

FY2019-2023

【Budget Allocation】

153,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.icb.med.osaka-u.ac.jp/
mishii@icb.med.osaka-u.ac.jp

Title of Project：Elucidation of abnormal functioning of neuronal circuits underlying neuropathic pain and its application for drug discovery

TSUDA Makoto
(Kyushu University, Graduate School of Pharmaceutical Sciences, Professor)

Research Project Number：19H05658　Researcher Number：40373394
Keyword：Neuropathic allodynia, primary afferent Aβ fiber, optogenetics, spinal dorsal horn neuronal circuit

【Purpose and Background of the Research】

Damage to the nervous system causes neuropathic pain, a highly debilitating chronic pain condition that is frequently resistant to morphine. A cardinal symptom of neuropathic pain is mechanical allodynia, pain that is produced by innocuous mechanical stimulus, such as light touch. A major question is where and how touch information is pathologically converted to pain in the context of nerve damage.

We have previously discovered an essential role of glial cells in the spinal cord in the pathogenesis of neuropathic pain (Nature 2003) and indicated a strong ability of glial cells to alter the function of neuronal cells in the nervous system (Nat Rev Neurosci 2018). In this proposed research program, by using our developed research skills and scientific knowledge in the field of pain and glia combined with a new approach for investigating neuropathic allodynia and a technique for visualization and functional operation of neuronal subsets, we will identify neuronal circuits that are required for neuropathic allodynia. Furthermore, we will determine a cause of functional abnormality of the circuits after nerve injury by focusing on the role of glial cells and top-down signaling from the brain to the spinal dorsal horn. In addition, we will explore drugs that act on neurons and glia implicated in neuropathic allodynia by performing a screening of small-molecule chemical libraries (mainly clinically approved drugs).

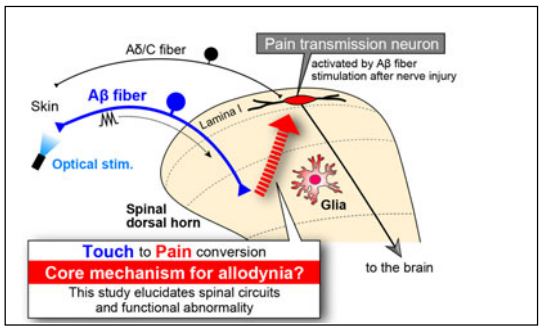


Figure 1　Proposal

【Research Methods】

In our proposed research program, experiments will be performed by using a new approach for investigating morphine-resistant neuropathic allodynia by optogenetics that enable a selective stimulation of touch-sensing primary afferent Aβ fibers and a technique for functional operation of neuronal subsets combined with histology, electrophysiology and imaging. First, we will examine the role of neuronal subsets in the spinal dorsal horn in Aβ fiber-derived neuropathic allodynia. Furthermore, the role of these subsets in Aβ fiber-derived information signal to lamina I SDH neurons after nerve injury will be analyzed. Abnormal functioning of identified neuronal subsets will be examined by focusing on the role of glia. Because recent studies have shown that top-down signaling from the brain directly affects pain processing in the spinal dorsal horn, we will examine the role of identified subsets of dorsal horn neurons as receiving cells of top-down signaling from the brain. Lastly, we will explore drugs that act on neurons and glia implicated in neuropathic allodynia by screening clinically approved drugs.

【Expected Research Achievements and Scientific Significance】

These findings from our proposed research program will identify neuronal circuits that are required for neuropathic allodynia and determine the role of glia and top-down signaling from the brain, which in turn advances our knowledge of 'how touch-sensing Aβ fiber signals are pathologically converted to pain in the context of nerve damage'. Our findings will not only advance in understanding of the mechanisms that underlie neuropathic pain but also provide new targets for treating this chronic pain.

【Publications Relevant to the Project】

・Tsuda M: New approach for investigating neuropathic allodynia by optogenetics. Pain 160 (Suppl 1): S53-S58 (2019)
・Inoue K, Tsuda M: Microglia in neuropathic pain: cellular and molecular mechanisms and therapeutic potential. Nat Rev Neurosci 19: 138-152 (2018)

【Term of Project】FY2019-2023

【Budget Allocation】153,700 Thousand Yen

【Homepage Address and Other Contact Information】

http:// life-innov.phar.kyushu-u.ac.jp/
tsuda@phar.kyushu-u.ac.jp

Title of Project：Integrative study of brain mechanisms to induce hypertension

NODA Masaharu
(Tokyo Institute of Technology, Institute of Innovative Research, Cell Biology Center, Professor)

Research Project Number：19H05659　Researcher Number：60172798
Keyword：hypertension, leptin, angiotensin II, aldosterone, Na_x channel

【Purpose and Background of the Research】

It is well-known that excess salt intake (HS) induces hypertension; however, the mechanism has not been elucidated until recently. We, for the first time, revealed brain mechanisms for salt-induced elevations of blood pressure (BP) (Fig. 1). Briefly, increases of [Na^+] in body fluids activate Na_x channels in the organum vasculosum lamina terminalis (OVLT). The Na_x signal in glial cells in transferred to the central nuclei [paraventricular nucleus (PVN) and rostral ventrolateral medulla (RVLM)] controlling sympathetic nerve activity (SNA). The increase in SNA leads to BP elevations.

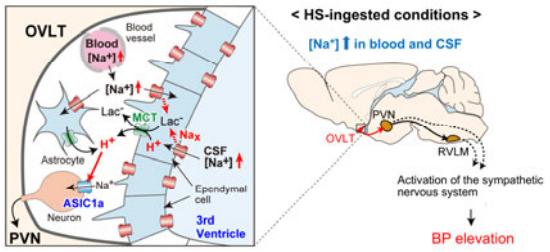


Figure 1　Central mechanisms of salt-induced BP elevations

On the other hand, it is known the obesity and psychological stress elevate BP through activation of SNA. The present study is aimed to elucidate the overall picture of brain mechanisms controlling BP.

【Research Methods】

Under obesity or stress conditions, the level of leptin, angiotensin II, or aldosterone increase in blood. After these factors are received by specific brain loci, the signals are eventually transferred to the central nuclei controlling SNA. We hypothesized that sensing receptive loci of these factors are circumventricular organs (CVOs) that lack blood-brain barrier in the brain.

In the present study, we will promote the following projects: Elucidation of; 1) receptive loci for respective factors, 2) signaling pathways to the PVN or RVLM and, 3) integration mechanism of these signals in some central nuclei. For this purpose, we employ modern research techniques, such as tracing methods by using multiple viral vectors, optogenetics to reveal the function of a specific neural pathway, and Ca^{++} imaging of a nucleus at the single neuronal level.

【Expected Research Achievements and Scientific Significance】

Although the mechanism of salt-induced hypertension has long been studied, the details have not been clarified until recently. The main reasons were that the sensor to detect increases in [Na^+] of body fluids was an enigma, and the mechanisms for sensing and transmitting signal to the center controlling SNA were unknown.

We do not know the sensing loci of leptin, angiotensin II, or aldosterone in the brain, nor the cellular mechanisms of signal transmission. The present study will integratively elucidate brain mechanisms of BP elevations caused by these endogenous pressor factors. This study is of marked academic value and will contribute to the development of a novel strategy to treat hypertension.

【Publications Relevant to the Project】

・Nomura K, Hiyama TY, et al. and Noda M. [Na^+] increases in body fluids sensed by central Na_x induce sympathetically mediated blood pressure elevations via H^+-dependent activation of ASISC1a. **Neuron** *101*, 60-75 (2019).
・Matsuda T, Hiyama TY, et al. and Noda M. Distinct neural mechanisms for the control of thirst and salt appetite in the subfornical organ. **Nature Neurosci.** *20*, 230-241 (2017).
・Noda M, and Sakuta H. Central regulation of body-fluid homeostasis. **Trends Neurosci.** *36*, 661-673 (2013).

【Term of Project】

FY2019-2023

【Budget Allocation】

140,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.rcb.iir.titech.ac.jp/index.html

Title of Project：Developing a translation process model and constructing an integrated translation environment through detailed descriptions of translation norms and competences

KAGEURA Kyo
(The University of Tokyo, Interfaculty Initiative in Information Studies, Professor)

Research Project Number：19H05660　Researcher Number：00211152
Keyword：translation competence, translation norm, machine translation, translation process model

【Purpose and Background of the Research】

We are witnessing an ever-increasing demand for translation. Many graduate-level translation schools have been established. Neural machine translation recently caused a social sensation. Translation theories provide translation norms and competence lists. Quality assurance schemes have been established for industrial translation.

These developments notwithstanding, translation practice as a whole has not advanced as much as expected because these developments have not been fully integrated with one another. One of the most fundamental problems is that the concept of translation has not been shared among different players. This reflects the lack of granularity in the descriptions of translation process, translation competences and norms.

Against this backdrop, our project answers the following questions: (a) what sort of actions to what kind of items by which actors constitute translation process? (b) what sort of norms and competences are related to these actions? By answering these questions, our project defines a translation process model in which each step in the detailed process descriptions is linked to relevant norms and competences.

We define a meta-language set used for describing the model and facilitating communications in translation training and practice. We also automatise what can be automatised among the process steps. The model, the meta-language and the automatic methods are to be evaluated in terms of their effects on translation training and translation practice.

【Research Methods】

The research consists of four main stages: (a) the construction of a translation process model; (b) the development of automatic methods, (c) the development of an integrated translation environment, and (d) the evaluation of models and other elements.

While we put more emphasis on (a) and (b) in the first half of the project period and on (c) and (d) in the second half, these four phases are to be carried out simultaneously throughout the project; we need to construct the model by repeating the cycle of model construction, validation and improvement as the translation process model attains a normative nature.

We use literature review and interviews with qualitative analysis for constructing the translation process model. We describe and model the process while at the same time developing a meta-language. We assign to each step in the translation process due translation norms and competences.

The core tasks to be automatised are identification of constituent elements/items of the source language texts, construction of translation hypotheses and resources, and evaluation and correction of MT results. We use supervised machine learning and knowledge-based methods.

The integrated environment is to be developed based on the systems we have developed so far, i.e. Minna no Hon'yaku and Minna no Hon'yaku for Translator Training.

To evaluate the models and related elements, we use participant-based empirical evaluation. We evaluate the automatic methods by using evaluation data sets and also through participant-based evaluation of their effectiveness in the translation process.

【Expected Research Achievements and Scientific Significance】

This project connects the fruit of translation theories to translation practice and teaching, making the norms and competences objectively sharable among different players involved in translation. It contributes to solving practical problems involved in translation such as the mismatches between clients' requirements and the translation quality.

It also clarifies the role of MT in the real-world translation workflow and takes MT and related technologies out from in vitro to in vivo.

The model, the meta-language, the integrated environment and the data will be made publicly available and/or accessible. This will help further promote research in translation and translation technologies.

【Publications Relevant to the Project】

Kyo Kageura (2019) "Assessing the status of technical documents as textual materials for translation training in terms of technical terms," *Meta* 63(3), pp. 765-784.

Kyo Kageura and Piao Hui (2018) "The status of explanation and the role of meta-language in translation training and translation," *Ewha GTSI Conference*, Seoul, Korea, November 17, 2018. (Keynote Talk)

【Term of Project】

FY2019-2023

【Budget Allocation】

136,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://edu.trans-aid.jp/
kyo@p.u-tokyo.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section J

Title of Project：Psychological foundations of body scheme transformation via co-embodiment in virtual reality and its application

HIROSE Michitaka
(The University of Tokyo, Graduate School of Information Science and Technology, Professor)

Research Project Number：19H05661　Researcher Number：40156716
Keyword：Co-embodiment, Body scheme, Virtual Reality, We-mode, Skill transfer

【Purpose and Background of the Research】

The purpose of this research project is to reveal the mechanism for evoking the sense that the joint action with others is due to one's own contribution (sense of agency) and the mechanism for transforming the latent knowledge necessary for performing the physical action (body scheme) in the virtual environment where two person perform physical action as not only "I" but also "We" by using one embodied avatar (Co-embodiment). Based on them, this project also aims to realize efficient skill transfer methods using virtual reality settings.

【Research Methods】

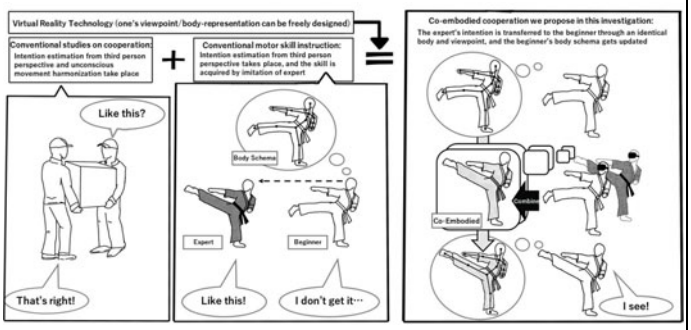


Figure 1　Understanding "We-mode" with Co-embodiment and its application in skill transfer

Interdisciplinary research for understanding "we-mode" and realizing its application in skill transfer will goes on as following;

(A) Realize the basic co-embodiment technology which can establish we-mode during joint action from first person perspective.

(B) Clarify the conditions and mechanisms that cause sharing of intention in action and transferring body scheme between actors under unconscious level.

(C) Develop the method for physical skill transfer using co-embodiment technique, and reveal its performances and limitations.

【Expected Research Achievements and Scientific Significance】

This is a multidisciplinary research project. From the viewpoint of cognitive science, this project propose a new experimental system by utilizing virtual reality which is able to make us use any kind of body to investigate the mechanisms of we-mode and body scheme. From the viewpoint of engineering, this project aims to develop effective skill transfer systems based on the clarified mechanisms of we-mode and body scheme. Expected research Achievements are following;

- Elucidation of the mechanisms of sence of agency in joint action and we-mode with a new experimental method that allows others to intervene their own bodily actions by using virtual reality.

- Elucidation of the mechanisms of action intention sharing and body scheme transformation through experiments which investigate the effectiveness of the learning with the proposed method with controlling parameters of co-embodiment.

- Realizing the novel physical skill transfer system that fully utilizes the characteristics of we-mode by establishing we-mode in a situation where two people work on the same action with the same viewpoint and the same body

【Publications Relevant to the Project】

Ogawa, N., Ban, Y., Sakurai, S., Narumi, T., Tanikawa, T., & Hirose, M. (2016). Metamorphosis hand: dynamically transforming hands. In Proceedings of the 7th Augmented Human International Conference 2016, Article 51, ACM.
Kojima, T., Hiyama, A., Miura, T., & Hirose, M. (2014). Training archived physical skill through immersive virtual environment. In International Conference on Human Interface and the Management of Information, pp. 51-58, Springer, Cham.

【Term of Project】FY2019-2023

【Budget Allocation】154,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://cyber.t.u-tokyo.ac.jp/
hirose@cyber.t.u-tokyo.ac.jp

Title of Project：Innovative Methods for Scientific Computing in the Exascale Era by Integrations of (Simulation+Data+Learning)

NAKAJIMA Kengo
(The University of Tokyo, Information Technology Center, Professor)

Research Project Number：19H05662　Researcher Number：20376528
Keyword：Supercomputing, Data Assimilation, Machine Learning, Integration of (Simulation+Data+Learning)

【Purpose and Background of the Research】

The performance of the fastest supercomputer will reach Exa-FLOPS (10^{18} FLoating point Operations Per Second) in 2021. Towards the end of Moore's law, we need to develop not only new hardware, but also new algorithms and applications. In this study, we propose an innovative method for computational science for sustainable promotion of scientific discovery by supercomputers in the Exascale Era by combining (Simulation + Data + Learning (S+D+L)), where ideas of data science and machine learning are introduced to computational science.

【Research Methods】

The BDEC system (Big Data & Extreme Computing), which is scheduled to be introduced to the Information Technology Center, the Tokyo University in 2021, is a Hierarchical, Hybrid, Heterogeneous (h3) system, which consists of computing nodes for computational science and those for data science/machine learning. In this study, we consider the BDEC as the platform for integration of (S+D+L), develop an innovative software platform "h3-Open-BDEC" for integration of (S+D+L), and evaluate the effects of integration of (S+D+L) on the BDEC. The h3-Open-BDEC (Figure 1) is designed for extracting the maximum performance of the supercomputers with minimum energy consumption focusing on (1) innovative method for numerical analysis with high-performance/high-reliability/power-saving based on the new principle of computing by adaptive precision, accuracy verification and automatic tuning, and (2) Hierarchical Data Driven Approach (hDDA) based on machine learning.

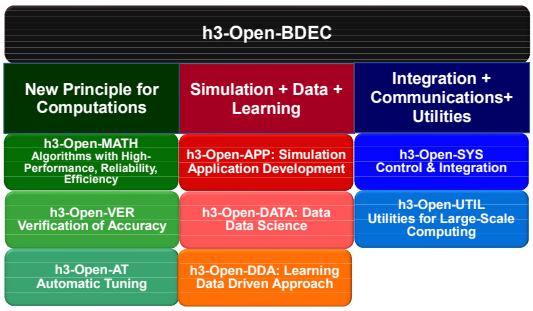


Figure 1 Overview of h3-Open-BDEC

In Data Driven Approach (DDA), technique of machine learning is introduced for predicting the results of simulations with different parameters. DDA generally requires a lot of simulations for generation of teaching data. We propose the hDDA, where simplified models for generating teaching data are constructed automatically by machine learning with Feature Detection, MOR, UQ, Sparse Modeling and AMR (Figure 2)

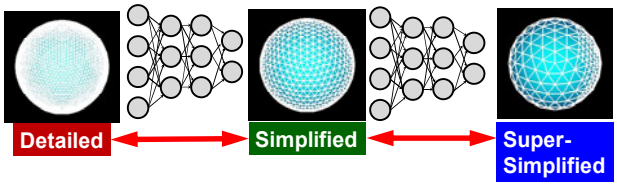


Figure 2 Generation of Simplified Model by Hierarchical DDA (hDDA)

【Expected Research Achievements and Scientific Significance】

The h3-Open-BDEC is the first innovative software platform to realize integration of (S+D+L) on supercomputers in the Exascale Era, where computational scientists can achieve such integration without supports by other experts. Source codes and documents are open to public for various kinds of computational environments. This integration by h3-Open-BDEC enables significant reduction of computations and power consumptions, compared to those by conventional simulations.

【Publications Relevant to the Project】

K. Nakajima, T. Furumura, T. Iwashita, T. Katagiri et al., ppOpen-HPC: Open Source Infrastructure for Development and Execution of Large-Scale Scientific Applications on Post-Peta-Scale Supercomputers with Automatic Tuning (AT), Mathematics for Industry 13, 15-35, Springer, 2015

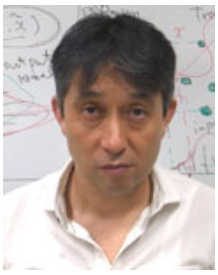
K. Fujita, T. Ichimura, K. Nakajima et al., Wave propagation simulation of complex multi-material problems with fast low-order unstructured finite-element meshing and analysis, ACM Proceedings of HPC Asia 2018, 2018 (Best Paper Award)

【Term of Project】 FY2019-2023

【Budget Allocation】 152,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://nkl.cc.u-tokyo.ac.jp/h3-Open-BDEC
https://github.com/Post-Peta-Crest/ppOpenHPC



Title of Project：Development of e-Testing platform ensuring sustainable reliability

UENO Maomi
(The University of Electro-Communications, Graduate School of Informatics and Engineering, Professor)

Research Project Number：19H05663　Researcher Number：50262316
Keyword：e-Testing, equivalent tests, adaptive test, performance test, automated essay scoring

【Purpose and Background of the Research】

e-Testing, a computer based testing that enables to measure abilities of examinees who take different test forms on the same scale, has been used in various testing organizations, such as the information-technology promotion agency (IPA) and the common achievement tests organization (CATE). e-Testing requires uniform test forms for which each form comprises a different set of items but which still have equivalent accuracy. Our group has developed a uniform test assembly method that maximizes the number of generated test forms with the best measurement accuracy. The proposed method has been used in various testing organizations such as IPA and CATE. However, we found a critical problem that the measurement accuracy deteriorates over time because IRT item parameters with high exposure frequency tend to be changed dynamically. To resolve this problem, this study develops a platform that ensures sustainable high reliability for e-testing which includes performance test such as essay test, practical skill test, and so on. This study also operates the platform on some actual large scale tests to show the effectiveness.

【Research Methods】

Our platform consists of the following four subsystems.

1. Uniform test assembly system that increases the number of assembled equivalent test forms drastically.
2. Item bank management system that predicts the number of deteriorated items and generates uniform test forms efficiently from the item bank after new items are appended.
3. Uniform adaptive testing system with item exposure control using the uniform test assembly system
4. Performance testing system that ensures equivalent and reliable measurement using the item response theory and automated essay scoring methods.

Furthermore, we will operate the developed platform on several actual tests, such as the common achievement tests for medical and dental students, writing tests in the National Center for University Entrance Examinations, and OSCE in the Tokyo Medical and Dental University, to evaluate the effectiveness and to develop the guidelines.

【Expected Research Achievements and Scientific Significance】

Ensuring sustainable reliability is a new important problem that we found through our long experience. Therefore, our research will contribute to technical innovation and widespread use of e-Testing in actual society. Furthermore, our proposed methods are new technologies that integrate various research fields, such as artificial intelligence, computer science, mathematics, and statistics.

ISO standard obliges to evaluate test forms equivalence and the measurement accuracies although the details of the evaluation results have not been reported from the test organizations in the world. However, in Japan, several testing organizations, such as CATE, has reported these indices. Furthermore, almost all test organizations in Japan consider to introduce this CATE e-testing operation.

In the future, we expect that such the Japanese style e-testing will be a world standard. In this study, we will develop a high quality e-Testing system for making a good chance to create a new testing market from Japan.

【Publications Relevant to the Project】

Maomi Ueno, Yoshimitsu Miyazawa (2018) IRT-Based Adaptive Hints to Scaffold Learning in Programming, IEEE Transactions on Learning Technologies, IEEE computer Society, Vol.11, Issue 4, 415-428

Masaki Uto, Duc-Thien Nguyen, Maomi Ueno (in press) Group optimization to maximize peer assessment accuracy using item response theory and integer programming, IEEE Transactions on Learning Technologies, IEEE Computer Society.

【Term of Project】

FY2019-2023

【Budget Allocation】

123,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ai.lab.uec.ac.jp

Title of Project：Muon-induced soft error evaluation platform: future prediction based on measurement and simulation

HASHIMOTO Masanori
(Osaka University, Graduate School of Information Science and Technology, Professor)

Research Project Number：19H05664　Researcher Number：80335207
Keyword：soft error, muon, integrated system, VLSI, reliability

【Purpose and Background of the Research】

Soft error originating from cosmic ray is a serious concern for reliability demanding applications of integrated systems. According to device miniaturization, muon could become a major source of soft error, and the error rate may drastically elevate. This research aims to investigate whether muon would be the dominant error source in the future. For accurate prediction, this research will obtain fundamental physics data of muon-Si nuclear reaction and measure the error rate of state-of-the-art SRAM. With these, we will establish a simulation platform that reproduces physical phenomena and contributes to Society 5.0.

【Research Methods】

This research will establish a word-first simulation platform that accurately understands and evaluates muon-induced soft error and predicts the error rate of future devices. With fundamental physics data, which will be acquired by this research, and verification of hardware-simulation correlation, we will improve the accuracy and reliability of simulation technology.

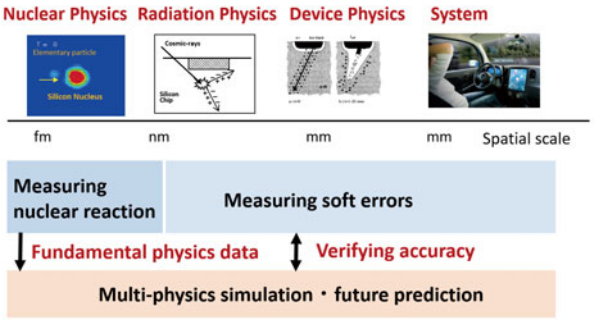


Figure 1 Organization of this research project

Figure 1 shows the organization of this research. Researchers who cover nuclear physics to system work together for this project. For establishing a reliable simulation platform that can be applied to future prediction, we will experimentally obtain muon-Si nuclear reaction data (Task 1: Niikura, Watanabe, Sato) and provide it to simulator developers. We will perform soft error measurement experiments with state-of-the-art SRAM, investigate physical phenomena contributing to soft error, and characterize its soft error rate (Task2: Hashimoto, Sato, Niikura). We will develop a multi-physics simulator that includes nuclear physics, radiation physics and device physics (Task 3: Abe, Kamakura, Niikura). The physics data obtained by Task 1 will be exploited in simulator development, and the hardware-simulation correlation will be verified with the soft error data measured by Task 2. Finally, we will predict soft error rate of future devices using the developed simulation platform and investigate the impact of muon-induced soft error on future information technology (Task 4: Hashimoto, Watanabe, Abe, Kamakura).

【Expected Research Achievements and Scientific Significance】

We will be able to correctly understand the physics of muon-induced soft error and reveal how serious muon-induced soft error would be and how urgent its countermeasure development is. This project develops an error evaluation platform, and distributes it to academia and industry so that countermeasures to muon-induced soft error can be developed.

Overall, this project prevents unexpected reliability degradation due to muon-induced soft error, and eliminates reliability degradation sources that prevent Society 5.0 from being actualized.

【Publications Relevant to the Project】

・W. Liao, M. Hashimoto, S. Manabe, Y. Watanabe, K. Nakano, H. Sato, T. Kin, K. Hamada, M. Tampo, and Y. Miyake, "Measurement and Mechanism Investigation of Negative and Positive Muon-Induced Upsets in 65-nm Bulk SRAMs," *IEEE Transactions on Nuclear Science*, 65(8), pp. 1734-1741, August 2018.
・S. Manabe, Y. Watanabe, W. Liao, M. Hashimoto, K. Nakano, H. Sato, T. Kin, S. Abe, K. Hamada, M. Tampo, and Y. Miyake, "Negative and Positive Muon-Induced Single Event Upsets in 65-nm UTBB SOI SRAMs," *IEEE Transactions on Nuclear Science*, 65(8), pp. 1742-1749, August 2018.

【Term of Project】

FY2019-2023

【Budget Allocation】

156,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www-ise1.ist.osaka-u.ac.jp/
hasimoto@ist.osaka-u.ac.jp

Title of Project：Context Recognition of Humans and Objects by Distributed Zero-Energy IoT Devices

HIGASHINO Teruo
(Osaka University, Graduate School of Information Science and Technology, Professor)

Research Project Number：19H05665　Researcher Number：80173144
Keyword：IoT, Context Recognition, Sensing, Energy harvest, Wireless Communication

【Purpose and Background of the Research】

In recent years, various research and development aiming at the realization of the "super smart society" utilizing IoT, wireless communication, AI and big data have been advanced. In order to realize such super smart society, it is important to spread battery-less, maintenance-free IoT devices (hereafter referred to "zero-energy IoT devices"). Generally, IoT devices consume power for sensing, processing and communication where the power consumption for communication is very high (sensing is on the order of tens of μW, while wireless communication is on the order of mW to hundreds of mW). The key technology for the Internet connection of IoT devices is the spread of ultra-low power communication mechanisms.

In recent years, Wi-Fi based backscatter communication technology (power consumption of about 10 μW) that can transmit and receive at a distance of several tens of meters at several Mbps and RFID communication technology that can transmit and receive data from a distance of several meters have been developed. In addition, IoT devices using only the power obtained by environmental power generation and their sensing technology have been devised. However, many of those existing sensing devices and technology remain in the development of relatively simple context recognition technology such as the presence or movement of humans at the target point.

In this research, by utilizing knowledge of cross layers of the application layer and physical layer in zero-energy IoT device networks, and building machine learning mechanisms using many zero-energy IoT devices, we aim to create advanced context recognition technology.

【Research Methods】

In this research, first, by combining (i)zero-energy IoT devices, (ii)backscatter/RFID communication devices, and (iii)electronic circuits made by 3D printers, we will create zero-energy IoT devices for context recognition of humans and objects. In addition, we will build zero-energy IoT device networks combining these devices in mesh forms and create more advanced context recognition technology such as trajectory estimation and behavior recognition of humans and objects.

Then, using such zero-energy IoT devices applicable to context recognition of humans and objects, we create new context recognition technology for (i)watching over the elderly at the nursing facilities, (ii)understanding the activities of athletes, (iii)trajectory estimation of human and objects, (iv)construction of sociograms for grasping human relations of children, (v)understanding of wind power and ground movement, and (vi)air conditioning management in commercial facilities (Fig.1).

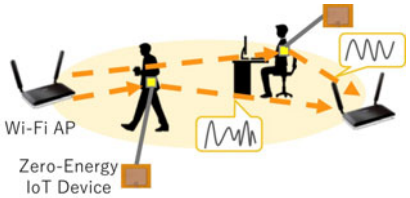


Fig.1 Context recognition using zero-energy IoT devices

【Expected Research Achievements and Scientific Significance】

By developing various context recognition systems using zero-energy IoT device networks as described above, and evaluating and examining their effectiveness, we expect to contribute the design and development of context recognition technology of humans and objects for the realization of the "super smart society" promoted by the government. We think we also contribute to the spread of various context recognition systems by realizing the design development environment of such context recognition systems.

【Publications Relevant to the Project】

[1] T. Higashino, A. Uchiyama, S. Saruwatari, H. Yamaguchi and T. Watanabe: "Context Recognition of Humans and Objects by Distributed Zero-Energy IoT Devices", *Proc. of 39th IEEE Int. Conf. on Distributed Computing Systems (ICDCS 2019)*, pp.1787-1796, 2019.

[2] Y. Fukushima, D. Miura, T. Hamatani, H. Yamaguchi and T. Higashino: "MicroDeep: In-network Deep Learning by Micro-sensor Coordination for Pervasive Computing", *Proc. of 4th IEEE Int. Conf. on Smart Computing (SMARTCOMP 2018)*, pp.163-170, 2018.

【Term of Project】

FY2019-2023

【Budget Allocation】

154,000 Thousand Yen

【Homepage Address and Other Contact Information】

http://www-higashi.ist.osaka-u.ac.jp/kibanS-2019

Title of Project：Effects of land conversion from tropical peat swamp forest to oil palm plantations on ecosystem functions and the atmospheric environment

HIRANO Takashi
(Hokkaido University, Research Faculty of Agriculture, Professor)

Research Project Number：19H05666　Researcher Number：20208838
Keyword: Atmospheric environment, disturbance, greenhouse gases, oil palm plantation, tropical peat

【Purpose and Background of the Research】

Tropical peatlands coexisting peat swamp forest were distributed widely in lowlands in insular Southeast Asia, especially in Indonesia and Malaysia, and have accumulated a huge amount of soil organic carbon (peat).

Recently, however, the peat ecosystems have been disturbed severely through deforestation and drainage to develop oil palm plantations. The land conversion makes peat carbon vulnerable and potentially changes the peatlands from a carbon sink to a large carbon source. Figure 1 shows pictures of recent land conversion from a peat swamp forest to an oil palm plantation in Sarawak, Malaysia. A large amount of carbon dioxide (CO_2) was emitted through the land conversion, including deforestation, drainage and biomass and peat burning.

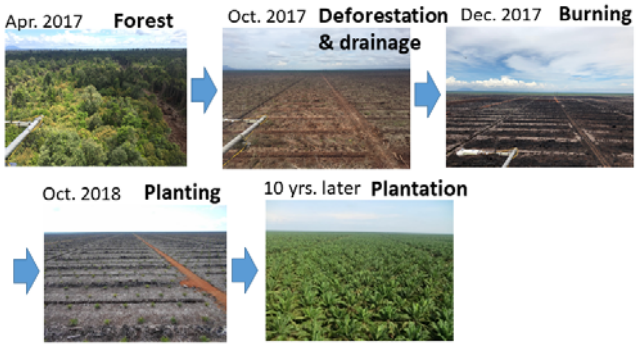


Fig.1 Land conversion in Sarawak, Malaysia.

The objectives of this study are 1) to elucidate the effects of the land conversion and the resultant expansion of oil palm plantations on the carbon pool and the fluxes of greenhouse gases (GHGs), reactive trace gas (BVOC: isoprene) and energy, and 2) to quantify and model the effects of the plantation expansion on the balance of GHGs between the ecosystems and atmosphere and regional climate system.

【Research Methods】

We will establish a tower flux network in tropical peat ecosystems in insular Southeast Asia, including natural and disturbed swamp forests, and oil palm plantations with different ages in collaboration with research institutes in Malaysia, Singapore and Indonesia (Fig. 2). Moreover, we will establish a database, including the fluxes of GHGs (CO_2 and methane (CH_4)), isoprene and energy (sensible and latent heat), meteorological and soil factors, and so on. Using the database, synthesis research will be conducted on the effects of the land conversion on ecosystem functions, such as GHGs balance and energy balance. In addition, we will quantify and model the effects of oil palm expansion on the GHGs balance and climate system in peat areas in Sumatra, Borneo and the Malay Peninsula using satellite remote-sensing, a terrestrial biosphere model (VISIT) and local / regional climate simulation.

Fig.2 Flux tower

【Expected Research Achievements and Scientific Significance】

There were no comprehensive synthesis studies so far on the effects of land conversion to oil palm plantations in tropical peatlands. Therefore, scientifically valuable outcomes on the change of GHGs balance and regional climate is highly expected, including 1) robust emission factors for CO_2 and CH_4, 2) age-averaged GHGs emissions from oil palm plantations by life cycle assessment, and 3) high-resolution land cover mapping using PALSAR data.

【Publications Relevant to the Project】

Hirano T et al., Effects of disturbances on the carbon balance of tropical peat swamp forests. *Global Change Biology*, **18**, 3410-3422, 2012.

Ishikura K, Hirano T, Hirata R et al., Soil carbon dioxide emissions due to oxidative peat decomposition in an oil palm plantation on tropical peat. *Agriculture, Ecosystem and Environment*, **254**, 202-212, 2018.

【Term of Project】

FY2019-2023

【Budget Allocation】

119,200 Thousand Yen

【Homepage Address and Other Contact Information】

hirano@env.agr.hokudai.ac.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project：Aggregate-biosphere: Unveiling hidden regulatory processes in the oceanic carbon cycle

NAGATA Toshi
(The University of Tokyo, Atmosphere and Ocean Research Institute, Professor)

Research Project Number：19H05667　Researcher Number：40183892
Keyword：aggregates, genomic analysis, ocean carbon cycling, microbial community, biological carbon pump

【Purpose and Background of the Research】

The sedimentation of organic aggregates is one of the key mechanisms of "biological carbon pump (BCP)", i.e., the vertical carbon transport from the surface to the deep ocean. The BCP facilitates the storage of carbon in the deeper ocean on centennial to even millennial timescales and helps restrain the increase in the atmospheric concentration of carbon dioxide (Figure 1). Traditionally, organic aggregate dynamics have been studied using a physical model, where the role of microbes in the regulation of the BCP has been only superficially taken into account. This paucity of knowledge on complex interactions between microbes and organic aggregates seriously hampers the improvement of our ability to predict the response of oceanic carbon cycle to climate change.

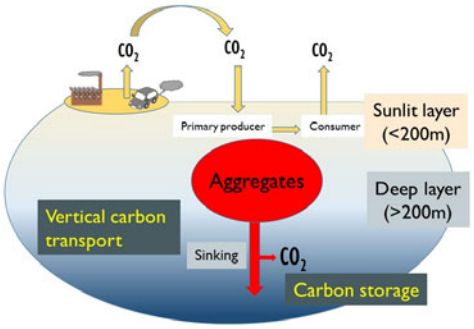


Figure 1. Biological carbon pump

In this research, we propose a new concept "Aggregate-Biosphere" to emphasize the role of diverse microbes, including bacteria, viruses, fungi and protists that flourish on organic aggregates, in exerting influence on their physical structure and dynamics (formation, growth and decay) (Fig. 2). Our goal is to clarify hidden regulatory mechanisms of BCP, involving so-far overlooked actions of the Aggregate-Biosphere. Our research team is composed of the experts from a multitude of scientific fields, including particle dynamics, biogeochemical cycling, microbial ecology, genomic analysis, bioinformatics and mathematical modelling.

【Research Methods】

We conduct field observations, manipulation experiments and mathematical modelling to answer the following three questions concerning the structure, function, and response of the Aggregate-Biosphere. (a) Are there general trends in the compositional pattern of the Aggregate-Biosphere? (b) What are the principal biotic interactions and metabolism that are involved in the regulation of aggregate dynamics? (c) What are the responses of the Aggregate-Biosphere and the BCP to changes in environmental conditions?

【Expected Research Achievements and Scientific Significance】

The expected outcome of this research includes a deeper understanding of the mechanisms by which oceans store carbon and the factors affecting this process. Through this, it contributes to the improvement of our ability to predict future changes in earth's climate and ocean ecosystems. Our research may also reveal a novel feature of the diversity in marine life and its functional consequences. This would contribute to broaden our perspectives concerning the functional role of biodiversity.

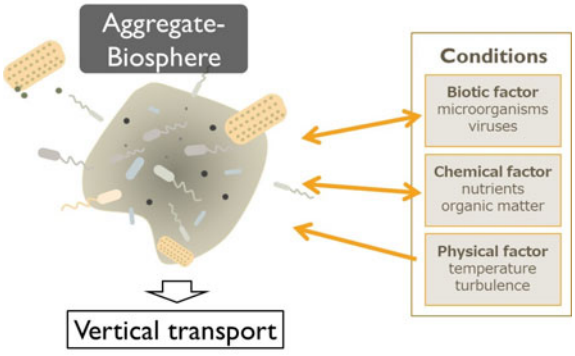


Figure 2. The concept of "Aggregate-Biosphere"

【Publications Relevant to the Project】

・Guidi et al. (2016) Plankton networks driving carbon export in the oligotrophic ocean. Nature, 532, 465-470.
・Yamada et al. (2018) Aggregate formation during the viral lysis of a marine diatom, Frontiers in Marine Science, doi.org/10.3389/fmars.2018.00167

【Term of Project】 FY2019-2023

【Budget Allocation】 154,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://bg.aori.u-tokyo.ac.jp/en/facultyandstaff/nagata/
nagata@aori.u-tokyo.ac.jp

Title of Project：Pan-Arctic Water-Carbon Cycles

HIYAMA Tetsuya
(Nagoya University, Institute for Space-Earth Environmental Research, Professor)

Research Project Number：19H05668　Researcher Number：30283451
Keyword：global warming, Arctic sea ice retreat, atmospheric-terrestrial water cycle, permafrost degradation, greenhouse gases

【Purpose and Background of the Research】

Recent global warming accelerates Arctic sea ice retreat, which derives significant changes in atmospheric-terrestrial water cycle in the Arctic and pan-Arctic regions. Because spatiotemporal variations in emission (or absorption) of greenhouse gases are largely dependent on surface water and vegetation conditions over the terrestrial land surfaces, for better understanding and for better future projection of water-carbon cycles in the pan-Arctic region, it is necessary to conduct an integrated study on atmospheric-terrestrial water-carbon cycles in the region.

The purpose of this research is to integrate atmospheric-terrestrial water and carbon cycles in the pan-Arctic region. We firstly integrate atmospheric- and terrestrial-water cycle models which can calculate spatiotemporal variations in the atmospheric moisture transport, moisture flux convergence, precipitation, vegetation condition, permafrost degradation, and river discharge over the Arctic and pan-Arctic regions, with important boundary conditions of the Arctic sea ice extent. We finally produce spatiotemporal maps of water-covered area, vegetation condition, and fluxes of greenhouse gases. We mainly focus on Northern Eurasia because there are very limited data on the fluxes of greenhouse gases in the region.

【Research Methods】

To achieve above-mentioned goals, we firstly develop a water traceable integrated model (WTIM), based on a water vapor tracer model and a coupled hydrological and biogeochemical model. Then we produce spatiotemporal maps of water-covered area and vegetation condition in Northern Eurasia, using satellite remote sensing data and WTIM products with the help of spatiotemporal data fusion technics. Finally, we estimate spatiotemporal maps on the fluxes of greenhouse gases over Northern Eurasia using a biogeochemical model (Figure 1). To validate the maps, we will continuously measure fluxes of greenhouse gases at eastern Siberia and northern Mongolia.

This study consists of four groups: terrestrial observation group, terrestrial modeling group, atmospheric research group, and integration group. The four groups strongly collaborate each other. We will also organize international scientific symposiums (or workshops) in the research period, and will co-produce our scientific outcomes with Siberian and Mongolian researchers.

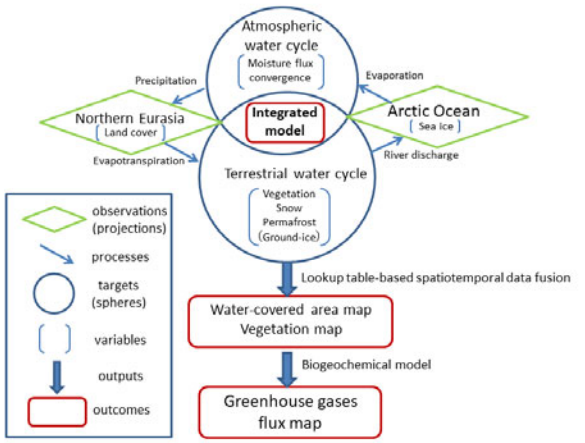


Figure 1 Flowchart of this research

【Expected Research Achievements and Scientific Significance】

This study can reduce uncertainty of the biogeochemical model, and contribute to better understand water-carbon cycles in the pan-Arctic regions. We also contribute to better understand polar amplification in the Arctic and pan-Arctic regions.

【Publications Relevant to the Project】

Hiyama, T. and Takakura, H. (eds.): Global Warming and Human-Nature Dimension in Northern Eurasia. Global Environmental Studies Series, Springer, 224pp, 2018, https://doi.org/10.1007/978-981-10-4648-3

Ohta, T., Hiyama, T. et al. (eds.): Water-Carbon Dynamics in Eastern Siberia. Ecological Studies, 236, Springer, 309pp, 2019, https://doi.org/10.1007/978-981-13-6317-7

【Term of Project】

FY2019-2023

【Budget Allocation】

154,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.isee.nagoya-u.ac.jp/en/index.html
hiyama@nagoya-u.jp

【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project：Assessment on climate impacts of short-lived climate forcers by composition and region with hierarchical numerical models

TAKEMURA Toshihiko
(Kyushu University, Research Institute for Applied Mechanics, Professor)

Research Project Number：19H05669　Researcher Number：90343326
Keyword：short-lived climate forcer, climate model, climate change, air pollution, aerosol

【Purpose and Background of the Research】

Particulates (aerosols) such as PM2.5 and trace gases such as ozone in the atmosphere are both air pollutants and Short-Lived Climate Forcers (SLCFs). Although the United Nations Intergovernmental Panel on Climate Change (IPCC) has made quantitative assessments of imbalance of energy budget, i.e. radiative forcing, for each of the SLCFs, it has not assessed specific climatic changes such as temperature and precipitation.

In this project we quantitatively evaluate the climate change due to SLCFs by composition and region using the climate models developed by the research team. We also aim for a quantitative understanding of the impact of SLCFs on disasters such as extreme temperature and precipitation that have become apparent in recent years.

【Research Methods】

The following are climate and meteorological models of various spatiotemporal scales used in the project that can calculate transport processes and climate effects of SLCFs (Figure 1).

> MIROC-SPRINTARS/CHASER: A climate model which simulates the basic global climatic conditions with a horizontal resolution of several tens of km combining SPRINTARS, which calculates processes related to aerosol, and CHASER, which calculates detailed chemical reaction processes. MIROC-SPRINTARS is also used in the PM2.5 forecast, which is widely available to the general public daily.

> NICAM-Chem: A climate/meteorological model which calculates global atmospheric conditions expressing cloud processes explicitly with a horizontal resolution of 3.5/7/14km combining SPRINTARS/CHASER for calculating the climate effects of SLCFs.

> SCALE-LES: A meteorological model with a horizontal resolution of tens to hundreds of meters that can directly handle cloud processes, which is used for obtaining he knowledge to improve the expression of clouds in climate models.

In the calculations using these climate models, the emission amount related to each SLCF is perturbed, and the changes in the meteorological field such as temperature and precipitation are analyzed. At that time, the calculations are carried out while refining the cloud and precipitation process through improvement of the expression of aerosol-cloud interaction and introduction of a method to prognose raindrops and snowfall.

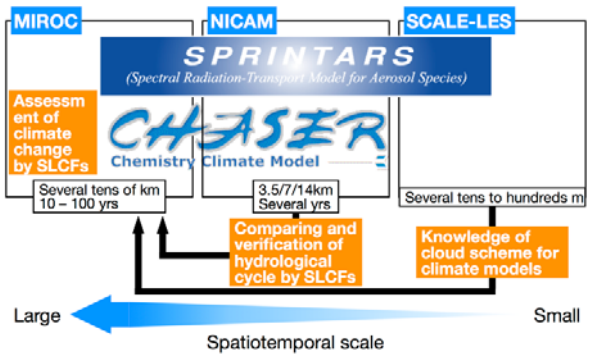


Figure 1　Hierarchical numerical models in this project.

【Expected Research Achievements and Scientific Significance】

It will create the new research area on an unresolved problem of quantitative impact assessment of climate change by SLCFs through this project in which the atmospheric physics on clouds and precipitation is combined with the atmospheric chemistry. It is an advantage that research can be promoted with understanding the mechanism of the climate impact of SLCFs obtained at the development stage of the numerical models developed by members of this research team themselves. It is expected to make concrete recommendations on mitigation of both climate change and air pollution, which are major international environmental issues.

【Publications Relevant to the Project】

Takemura, T. and K. Suzuki: Weak global warming mitigation by reducing black carbon emissions. Sci. Rep., 9, 4419, doi:10.1038/s41598-019-41181-6 (2019).

Suzuki, K. and T. Takemura: Perturbations to global energy budget due to absorbing and scattering aerosols. J. Geophys. Res., 124, 2194-2209, doi:10.1029/2018JD 029808 (2019).

【Term of Project】

FY2019-2023

【Budget Allocation】

153,900 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.riam.kyushu-u.ac.jp/climate/indexe.html

List of the Continuing Projects for Grant-in-Aid for Scientific Research (S) of KAKENHI

○ Broad Section A（ 6 Projects ）　　（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05216	TAMURA Yoshiyuki 20197586	The University of Tokyo, Graduate Schools for Law and Politics, Professor	Cross-Sectional Review of Intellectual Property Laws from the Viewpoint of Fostering and Securing Public Domain	FY2018-2022	110,700
18H05217	WATANABE Tsutomu 90313444	The University of Tokyo, Graduate School of Economics, Professor	Central Bank Communication Design	FY2018-2022	144,500
18H05218	KATO Yasushi 90183780	Hitotsubashi University, Graduate School of Social Sciences, Professor	Towards a global standard of dignity as a philosophical concept: theoretical approaches, conceptual histories, and cross-cultural comparisons	FY2018-2022	130,500
18H05219	IKEDA Takumi 90259250	Kyoto University, Institute for Research in Humanities, Professor	A Study on the historical Development of the Sino-Tibetan Languages and their Typological Geography	FY2018-2022	130,400
18H05220	IKEDA Yoshifumi 40150627	University of the Ryukyus, Faculty of Global and Regional Studies, Professor	The Interdisciplinary Study regarding Conserving and Utilize Methods of the Mongol Shipwrecks	FY2018-2020	82,600
18H05221	BABA Hajime 70332195	National Institutes for Cultural Heritage, Nara National Research Institute for Cultural Properties, Department of Imperial Palace Sites Investigations, History Section, Chief	Development of Integrated Knowledge through Establishment of an Interactive Research Scheme based on the Open-Data of Research Resources for Wooden Tablets and Related Topics	FY2018-2022	96,100

○ Broad Section B（ 15 Projects ）　　（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05222	YAMAMOTO Satoshi 80182624	The University of Tokyo, Graduate School of Science, Professor	Chemical Composition of Disk Forming Regions of Solar-type Protostars and its Evolution to Planetary Systems	FY2018-2022	144,500
18H05223	DOI Mamoru 00242090	The University of Tokyo, Graduate School of Science, Professor	Identifying the origin of the type-Ia supernova by observations just after the explosion	FY2018-2022	147,400
18H05224	KAGI Hiroyuki 70233666	The University of Tokyo, Graduate School of Science, Professor	Material Science of Hydrogen in the deep earth and planets	FY2018-2022	148,500
18H05225	KANODA Kazushi 20194946	The University of Tokyo, Graduate School of Engineering, Professor	Creation of a new discipline, quantum glass, for electronic systems and its development to material science	FY2018-2022	151,400
18H05226	IIJIMA Toru 80270396	Nagoya University, Center for Experimental Studies, Professor	Search for new symmetry violation in leptons	FY2018-2022	147,400
18H05227	MATSUDA Yuji 50199816	Kyoto University, Graduate School of Science, Professor	Rotational Symmetry Breaking in Strongly Correlated Quantum Matters	FY2018-2022	152,500
18H05228	TAKAHASHI Yoshiro 40226907	Kyoto University, Graduate School of Science, Professor	Exploration of new quantum condensed phase by exploiting orbital and spin degrees of freedom of ultracold atomic gases in an optical lattice	FY2018-2022	144,600

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05229	SUGIYAMA Masaaki 10253395	Kyoto University, Institute for Integrated Radiation and Nuclear Science, Professor	Neutron Structural Biology for New Generation	FY2018-2022	151,600
18H05230	HATANAKA Kichiji 50144530	Osaka University, Research Center for Nuclear Physics, Specially Appointed Professor	Search for the neutron electric dipole moment and the time reversal violation	FY2018-2022	152,200
18H05231	KUNO Yoshitaka 30170020	Osaka University, Graduate School of Science, Professor	New Initiative on Search for Charged Lepton Flavor Violation with Highly Intense Muon Source	FY2018-2022	148,500
18H05232	KUBO Tomoaki 40312540	Kyushu University, Faculty of Science, Professor	Experimental study on syn-deformational reaction processes at high pressures: Implications for slab weakening and deep earthquakes	FY2018-2022	108,400
18H05233	BANNAI Kenichi 90343201	Keio University, Faculty of Science and Technology, Professor	Strategic research to construct motivic units using new symmetry	FY2018-2022	91,900
18H05234	KATSUKAWA Yukio 00399289	National Institutes of Natural Sciences, National Astronomical Observatory of Japan, Solar Science Observatory, Associate Professor	High Precision Polarimetric Observation by a Balloon-Borne Solar Telescope: Revealing Conversion Processes of Magnetic Energy in the Stellar Atmosphere	FY2018-2022	109,100
18H05235	YOKKAICHI Satoshi 20360670	RIKEN, Nishina Center, Senior Research Scientist	Origin of hadron mass studied by the systematic measurement of spectral change of mesons in nuclei	FY2018-2022	150,800
18H05236	HATSUDA Tetsuo 20192700	RIKEN, Interdisciplinary Theoretical and Mathematical Sciences, Program Director	From Quarks to Neutron Stars: Challenges in QCD	FY2018-2022	91,600

○ Broad Section C （ 9 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05237	TOMITA Akihisa 60501434	Hokkaido University, Graduate School of Information Science and Technology, Professor	Information communication technology ensuring the long term security over a century	FY2018-2022	148,200
18H05238	YAMASHITA Shinji 40239968	The University of Tokyo, Research Center for Advanced Science and Technology, Professor	Study on digital frontier photonic sensing based on omnipotent fiber lasers	FY2018-2022	144,800
18H05239	ICHIMURA Tsuyoshi 20333833	The University of Tokyo, Earthquake Research Institute, Professor	Development of crust imaging enhanced by hetero-computing for reducing earthquake disaster	FY2018-2022	144,700
18H05240	KAWAHITO Shoji 40204763	Shizuoka University, Research Institute of Electronics, Professor	Ultimately-Time-Resolved Imaging Devices Using Ultrafast Hybrid Cascade Photo-Charge Modulators and Their Applications	FY2018-2022	147,600
18H05241	KITAMURA Takayuki 20169882	Kyoto University, Graduate School of Engineering, Professor	Design on Mechanical and Multi-Physics Properties of Nano-Structured Meta-Interface	FY2018-2022	150,700
18H05242	KAWANO Satoyuki 00250837	Osaka University, Graduate School of Engineering Science, Professor	Dynamical flow control of nanoparticles by machine learning and its application to single molecule identification technologies	FY2018-2022	119,000
18H05243	YANAGIDA Takeshi 50420419	Kyushu University, Institute of Material Chemistry and Engineering, Professor	Fundamental Study of Robust Molecule Recognition Electronics	FY2018-2022	150,200

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05244	ISHIYAMA Atsushi 00130865	Waseda University, Graduate School of Science and Engineering, Professor	Establishment of design principle and basic technology for next generation medical high temperature superconducting skeleton-cyclotron	FY2018-2022	148,800
18H05245	TERAI Hirotaka 10359094	National Institute of Information and Communications Technology, Advanced ICT Research Institute, Executive Researcher	Development of new imaging technology based on superconducting single-photon camera	FY2018-2022	149,400

○ Broad Section D （ 12 Projects ）　　（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05246	TAKANASHI Koki 00187981	Tohoku University, Institute for Materials Research, Professor	Renaissance of Metallic Superlattices	FY2018-2022	150,900
18H05247	TOMISHIGE Keiichi 50262051	Tohoku University, Graduate School of Engineering, Professor	Design and development of novel active sites on heterogeneous catalysts using direct interaction of molecules with solid surfaces	FY2018-2022	146,900
18H05248	AWAJI Satoshi 10222770	Tohoku University, Institute for Materials Research, Professor	Magnet technology development for 50T cryogen-free high temperature superconducting magnet	FY2018-2021	146,100
18H05249	ICHITSUBO Tetsu 40324826	Tohoku University, Institute for Materials Research, Professor	Construction of new mechanism for dual-ion storage batteries concerted by lithium and multivalent ions	FY2018-2022	152,800
18H05250	ITATANI Jiro 50321724	The University of Tokyo, the Institute for Solid State Physics, Associate Professor	Evolution of Attosecond Science by Next-generation Ultrashort-pulse Lasers	FY2018-2022	150,300
18H05251	HARA Michikazu 70272713	Tokyo Institute of Technology, Institute of Innovative Research, Professor	Low temperature ammonia synthesis by heterogeneous catalysts enhancing electron-donating power	FY2018-2022	146,600
18H05253	TAKAHASHI Yukio 00415217	Tohoku University, Institute of Multidisciplinary Research for Advanced Materials, Professor	Creation of platform for the next generation synchrotron radiation microspectroscopy by multi-dimensional X-ray ptychography	FY2018-2022	136,400
18H05254	NAKANO Takayoshi 30243182	Osaka University, Graduate School of Engineering, Professor	“Materials Science of Anisotropy” for induction of bone tissue anisotropy	FY2018-2022	148,800
18H05255	TATSUMISAGO Masahiro 50137238	Osaka Prefecture University, President	Dynamics of Composite Electrodes in All-Solid-State Ionics Devices	FY2018-2022	143,400
18H05256	AMEYAMA Kei 10184243	Ritsumeikan University, College of Science and Engineering, Professor	Clarification of innovative deformation mechanism in harmonic structure materials and creation of design principle for structure materials for next generation	FY2018-2022	155,000
18H05257	KIM Yousoo 50373296	RIKEN, Cluster for Pioneering Research, Chief Scientist	Scanning tunneling microscopy for the development of ultimate nano-optics	FY2018-2022	150,600
18H05258	FUJIWARA Akira 70393759	NTT Basic Research Laboratories, Physical Science Laboratory, Senior Distinguished Scientist	Quantum Standards and Ultimate Precision Measurements Based on Single Electrons	FY2018-2022	151,400

○ Broad Section E （ 7 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05259	NOZAKI Kyoko 60222197	The University of Tokyo, Graduate School of Engineering, Professor	Catalytic Bond-Cleavage Reactions toward Utilization of Renewable Resources	FY2018-2022	147,900
18H05260	AIDA Takuzo 00167769	The University of Tokyo, Graduate School of Engineering, Professor	Multiscale Interfacial Molecular Science for Innovative Functional Materials	FY2018-2022	148,800
18H05261	YAMAGUCHI Shigehiro 60260618	Nagoya University, Institute of Transformative Bio-Molecules, Professor	Chemistry of Boron-Containing π-Electron Materials	FY2018-2022	149,000
18H05262	Kitagawa Susumu 20140303	Kyoto University, Institute for Advanced Study, Institute for Integrated Cell-Material Sciences, Distinguished Professor	Chemistry of Adaptable Space	FY2018-2022	149,500
18H05263	ABE Jiro 70211703	Aoyama Gakuin University, College of Science and Engineering, Professor	Creative Research and Development of Incoherent Nonlinear Photoswitchable Molecules	FY2018-2022	149,700
18H05264	NAKAI Hiromi 00243056	Waseda University, Faculty of Science and Engineering, Professor	Clarification of Ubiquitous Proton Function in Photoreceptive Proteins by Quantum Molecular Dynamics Simulations	FY2018-2022	151,100
18H05265	TAHARA Tahei 60217164	RIKEN, Cluster for Pioneering Research, Chief Scientist	Exploring Interface Science by Concerted Use of Advanced Spectroscopy and Theory	FY2018-2022	148,400

○ Broad Section F （ 4 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05266	ASAMI Tadao 90231901	The University of Tokyo, Graduate School of Agricultural and Life Sciences, Professor	Development of basic technology of chemistry and biology for reducing damage by root parasitic weeds	FY2018-2022	151,600
18H05267	TOUHARA Kazushige 00280925	The University of Tokyo, Graduate School of Agricultural and Life Sciences, Professor	Identification of primer pheromones in mammals and elucidation of a neural basis for the pheromone action	FY2018-2022	147,600
18H05268	MATSUURA Kenji 40379821	Kyoto University, Graduate School of Agriculture, Professor	Antiaging system of long-lived termite kings	FY2018-2022	149,600
18H05269	UEDA Kazumitsu 10151789	Kyoto University, Institute for Advanced Study, Program-Specific Professor	Uncovering the secrets of lipid-transporting ABC proteins	FY2018-2022	148,900

○ Broad Section G （ 7 Projects ）

(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05270	UEDA Hiroki 20373277	The University of Tokyo, Graduate School of Medicine, Professor	Designing the mammalian biological oscillators	FY2018-2022	154,100
18H05271	TOMARI Yukihide 90447368	The University of Tokyo, Institute for Quantitative Biosciences, Professor	Biochemical approaches to understanding the reaction platforms of the piRNA pathway	FY2018-2022	148,900
18H05272	SUZUKI Tsutomu 20292782	The University of Tokyo, Graduate School of Engineering, Professor	Dynamic regulation of RNA modification and biological process	FY2018-2022	149,800

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05273	ARIKAWA Kentaro 20167232	SOKENDAI – The Graduate University for Advanced Studies, School of Advanced Sciences, Professor	Spectral opponency in photoreceptors: neuroethological analysis	FY2018-2022	154,000
18H05274	MATSUBAYASHI Yoshikatsu 00313974	Nagoya University, Graduate School of Science, Professor	Molecular dissection of peptide signaling in plants	FY2018-2022	148,100
18H05275	NAKANO Akihiko 90142140	RIKEN, Center for Advanced Photonics, Deputy Director	Full elucidation of sorting mechanisms in and around the Golgi apparatus by super-resolution live imaging	FY2018-2022	148,300
18H05276	HIRANO Tatsuya 50212171	RIKEN, Cluster for Pioneering Research, Chief Scientist	Molecular mechanisms of condensins I and II	FY2018-2022	148,800

○ Broad Section H（ 3 Projects ）　　（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05277	AKAIKE Takaaki 20231798	Tohoku University, Graduate School of Medicine, Professor	Sulfur-mediated energy metabolism, sulfur respiration: Its discovery and physiological functions	FY2018-2022	148,700
18H05278	TAKEUCHI Osamu 10379092	Kyoto University, Institute for Frontier Life and Medical Sciences, Professor	Analysis of immune regulatory mechanisms mediated by mRNA metabolism	FY2018-2022	148,900
18H05279	ARASE Hisashi 10261900	Osaka University, Research Institute for Microbial Diseases, Professor	Studies on the regulation of infection and immunity via paired receptors	FY2018-2022	148,800

○ Broad Section I（ 8 Projects ）　　（Thousands of Yen）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05280	KIYONO Hiroshi 10271032	The University of Tokyo, The Institute of Medical Science, Distinguished Professor	Multi Regulatory System for Gut Homeostasis and Inflammation	FY2018-2022	147,200
18H05281	SHINOHARA Takashi 30322770	Kyoto University, Graduate School of Medicine, Professor	Molecular Analysis of Spermatogonial Stem Cell Aging	FY2018-2022	148,800
18H05282	KUMANOGOH Atsushi 10294125	Osaka University, Graduate School of Medicine, Professor	Investigation on pathological implications of guidance molecules in neuro-immune-metabolism	FY2018-2022	147,800
18H05283	KOMORI Toshihisa 00252677	Nagasaki University, Graduate School of Biomedical Sciences, Professor	Elucidation of the mechanism in the regulation of chondrocyte-specific Runx2 enhancer and development of the drug for osteoarthritis	FY2018-2022	148,800
18H05284	SUDA Toshio 60118453	Kumamoto University, International Research Center for Medical Sciences, Distinguished Professor	Self-Renewal Capacity of Hematopoietic Stem Cells through the Regulation of Mitochondrial Metabolism	FY2018-2022	140,000
18H05285	YAMAMOTO Kazuhiko 80191394	RIKEN, Center for Integrative Medical Sciences, Deputy Director	Establishment of a novel strategy for pathological analysis of multifactorial diseases using genetic risk variants	FY2018-2022	148,800
18H05286	MORO Kazuyo 90468489	Osaka University, Graduate School of Medicine, Department of Microbiology and Immunology, Laboratory for Innate Immune Systems, Professor	Role of ILC2 in idiopathic interstitial pneumonia	FY2018-2022	148,200

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05287	NISHIMURA Yukio 20390693	Tokyo Metropolitan Institute of Medical Science, Department of Dementia and Higher Brain Function, Neural Prosthesis Project, Project Leader	Neural Mechanisms of Functional Recovery via Artificial Neural Connection	FY2018-2022	113,200

○ Broad Section J （ 4 Projects ）　(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05288	MOTOMURA Masato 90574286	Tokyo Institute of Technology, Institute of Innovative Research, Professor	Innovative Self-Learnable Architecture Platform for Accelerating Intelligent Computing	FY2018-2022	148,300
18H05289	SAKIYAMA Kazuo 80508838	The University of Electro-Communications, Graduate School of Informatics and Engineering, Professor	Resilience Enhancement of IoT Ecosystem by Cryptographic Technologies	FY2018-2022	149,500
18H05290	TANIGUCHI Masanobu 00116625	Waseda University, Graduate School of Science and Engineering, Professor	Introduction of general causality to various observations and the innovation for its optimal statistical inference	FY2018-2022	140,600
18H05291	KAWARABAYASHI Ken-ichi 40361159	Research Organization of Information and Systems, National Institute of Informatics, Principles of Informatics Research Division, Professor	Large Graphs: Theory and Algorithms	FY2018-2022	148,500

○ Broad Section K （ 4 Projects ）　(Thousands of Yen)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
18H05292	IIZUKA Yoshinori 40370043	Hokkaido University, Institute of Low Temperature Science, Associate Professor	Construction of world's most reliable deposited-aerosol database on the Anthropocene (from 1850 to 2020)	FY2018-2022	147,000
18H05293	KUMAGAI Yoshito 00250100	University of Tsukuba, Faculty of Medicine, Professor	Environmental electrophiles exposome and reactive sulfur species as its regulator molecule	FY2018-2022	150,200
18H05294	FUJITA Shuji 30250476	Research Organization of Information and Systems, National Institute of Polar Research, Professor	Study on physics and layers of ice cores containing information of climate change over the past 720 k-years, and study on the "oldest ice"	FY2018-2022	88,600
18H05295	KAMAGATA Yoichi 70356814	National Institute of Advanced Industrial Science and Technology (AIST), Department of Life Science and Biotechnology, Visiting Scientist	Methanogenesis from root organic matters in deep subsurface	FY2018-2022	148,800

(1) Integrated Disciplines （ 51 Projects ）

○ Informatics （ 17 Projects ）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05706	KOBAYASHI Naoki 00262155	The University of Tokyo, Graduate School of Information Science and Technology, Professor	Refinement and Extension of Higher-Order Model Checking	FY2015-2019	149,200
15H05707	AIHARA Kazuyuki 40167218	The University of Tokyo, Institute of Industrial Science, Professor	Establishing Theoretical Foundations for Mathematical Modeling of Pathological Biosystems and its Applications to Personalized Medicine	FY2015-2019	148,000

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05708	FUKUDA Akira 80165282	Kyushu University, Graduate School of Information Science and Electrical Engineering, Professor	Research on Information Infrastructure Platform for Sustainable Smart Mobility	FY2015-2019	153,600
15H05709	TOMONAGA Masami 70237139	Kyoto University, Primate Research Institute, Associate Professor	Wild Cognitive Science: Comparative–Cognitive Approach toward Understanding Evolution and Diversity of Mind	FY2015-2019	152,700
15H05710	KAMITANI Yukiyasu 50418513	Kyoto University, Graduate School of Informatics, Professor	Neural Basis of Mental Images	FY2015-2019	153,700
15H05711	MINATO Shinichi 10374612	Kyoto University, Graduate School of Informatics, Professor	Research on Core Algorithms for Discrete Structure Manipulation Systems	FY2015-2019	103,400
16H06299	MATSUI Shigeyuki 80305854	Nagoya University, Graduate School of Medicine, Professor	Comprehensive research on statistical methodologies and their applications for development of personalized medicine	FY2016-2020	87,500
16H06300	HANYU Takahiro 40192702	Tohoku University, Research Institute of Electrical Communication, Professor	Basic Research of a Dark-Silicon-Based Logic-LSI Technology for Brainware Computing	FY2016-2020	127,100
16H06301	FUJITA Kazuo 80183101	Kyoto University, Graduate School of Letters, Professor Emeritus	Acquisition of the independence of mind: Evolution and development of the mind liberated from the current external environments	FY2016-2020	142,900
16H06302	BABAGUCHI Noboru 30156541	Osaka University, Graduate School of Engineering, Professor	Communication System for Defending against Attacks of Media Clones	FY2016-2020	120,700
16H06303	SHINODA Hiroyuki 40226147	The University of Tokyo, Graduate School of Frontier Sciences, Professor	Systematic Study on Human Response to Noncontact Distributed Haptic Stimulation and Its Applications	FY2016-2020	130,700
16H06304	OGATA Hiroaki 30274260	Kyoto University, Academic Center for Computing and Media Studies, Professor	Educational Cloud Platform for Improving Education and Learning by Using Educational Big Data	FY2016-2020	140,900
17H06099	HU Zhanjiang 50292769	Research Organization of Information and Systems, Information Systems Architecture Science Research Division, Professor by Special Appointment	Software Foundation for Interoperability of Autonomic Distributed Data based on Bidirectional Transformations	FY2017-2021	133,500
17H06100	UCHIDA Seiichi 70315125	Kyushu University, Faculty of Information Science and Electrical Engineering, Professor	From Text Engineering to Text Science	FY2017-2021	116,000
17H06101	NAKAMURA Satoshi 30263429	Nara Institute of Science and Technology, Data Science Center, Professor	Next Generation Speech Translation Research	FY2017-2021	157,100
17H06102	NAGAHARA Hajime 80362648	Osaka University, Institute for Datability Science, Professor	Computational Optical Imaging for Endoscopic Surgery	FY2017-2021	115,800
17H06103	SATOH Ken 00271635	Research Organization of Information and Systems, National Institute of Informatics, Principles of Informatics Research Division, Professor	Advanced Reasoning Support for Judicial Judgment by Artificial Intelligence	FY2017-2021	113,600

○ Environmental Science（10 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05712	HARADA Naomi 70344281	Japan Agency for Marine-Earth Science and Technology, Research Institute for Global Change, Earth Surface System Research Center, Director	Plankton in Polar Regions—toward an Understanding of their Characteristics	FY2015-2019	151,900
15H05713	TODO Takeshi 90163948	Osaka University, Institute for Radiation Sciences, Guest Professor	Mechanism of Genome Integrity Maintenance in Tissue Stem Cell	FY2015-2019	153,800
15H05714	NAGANUMA Akira 80155952	Tohoku University, Graduate School of Pharmaceutical Sciences, Emeritus Professor	Molecular Mechanism for Toxic Effect of Methylmercury	FY2015-2019	151,400
15H05715	SEKINO Tohru 20226658	Osaka University, The Institute of Scientific and Industrial Research, Professor	Physical Photochemical Functionalization of Oxide Nanotubes through Hierarchical Structure Tuning	FY2015-2019	153,700
16H06305	KAJII Yoshizumi 40211156	Kyoto University, Graduate School of Global Environmental Studies, Professor	Precise analysis of HOx cycle in the air by novel techniques and new development of oxidants and aerosols chemical dynamics	FY2016-2020	139,600
16H06306	TAKEDA Shunichi 60188191	Kyoto University, Graduate School of Medicine, Professor	Establishment of Novel Bioassays for in vivo Genotoxicity Prediction and Mechanism Characterization	FY2016-2020	140,900
16H06307	SUGASAWA Kaoru 70202124	Kobe University, Biosignal Research Center, Professor	Molecular mechanisms underlying higher-order regulation of DNA damage recognition for nucleotide excision repair	FY2016-2020	133,500
16H06308	TAKANO Hirohisa 60281698	Kyoto University, Graduate School of Global Environmental Studies, Professor	Comprehensive and systematic study for control/eradication of allergic diseases via environmental and medical approaches	FY2016-2020	139,000
17H06104	ABE Ayako 30272537	The University of Tokyo, Atmosphere and Ocean Research Institute, Professor	Understanding the interaction between ice sheets, ocean and atmosphere under large scale climate changes of the past	FY2017-2021	157,600
17H06105	YOSHIDA Naohiro 60174942	Tokyo Institute of Technology, School of Materials and Chemical Technology, Professor	Environmental diagnosis with isotopologue tracers	FY2017-2021	162,400

○ Complex Systems（24 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05716	INAGAKI Toshiyuki 60134219	University of Tsukuba, Vice President and Executive Director	Design for Driving Automation and Legal Systems Conforming to Characteristic Features and Limitations of Cognition and/or Decision Making of Human Drivers	FY2015-2019	153,400
15H05717	KIMURA Gaku 80153188	Tokyo University of Marine Science and Technology, Project Professor	Urgency Evaluation of the Nankai Great Earthquake and Tsunami by Scientific Ocean Drilling	FY2015-2019	153,500
15H05718	Shuichi Kodaira 80250421	Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics, Director-General	Toward Mitigating Tsunami Hazards from Outer-rise Earthquakes: Mapping Potential Earthquake Faults and Constructing a Tsunami Database	FY2015-2019	154,300
15H05719	SUZUKI Michiyasu 80196873	Yamaguchi University, Graduate School of Medicine, Professor	Evaluation and Control of Epilepsy Dynamics Based on Multimodal Brain Signals and Thermal Neuromodulation Using Focal Brain Cooling	FY2015-2019	152,600
15H05720	KATAOKA Jun 90334507	Waseda University, Faculty of Science and Engineering, Professor	Toward New Frontiers in High-Resolution 3D Color Radiology Imaging	FY2015-2019	112,200
15H05721	HAGIWARA Masatoshi 10208423	Kyoto University, Graduate School of Medicine, Professor	Therapeutic Drug Discovery and Elucidation of RNA Disease Pathogenesis by Use of CRISPR-Based Disease iPS Cells and Animal Models	FY2015-2019	153,800

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05722	SAITO Hirohide 20423014	Kyoto University, Center for iPS Cell Research and Application, Professor	Cellular Programming Using Synthetic RNP Nanosystems	FY2015-2019	124,800
15H05723	NAKAI Junichi 80237198	Tohoku University, Graduate School of Dentistry, Professor	Development of Fluorescent Probes with Molecular Evolution Engineering	FY2015-2019	154,500
15H05724	OGAWA Sonoko 50396610	University of Tsukuba, Faculty of Human Sciences, Professor	Neuroendocrinology of Social Behavior	FY2015-2019	151,300
16H06309	KAN Hironobu 20294390	Kyushu University, Graduate School of Integrated Sciences for Global Society, Professor	Advanced Interdisciplinary Research on Coastal Areas based on Shallow Seafloor Geomorphology: Development of a Paradigm through 3D Seafloor Mapping	FY2016-2020	126,600
16H06310	KATO Teruyuki 80134633	Hot Springs Research Institute of Kanagawa Prefecture, Others, Director	A challenge to develop GNSS buoy system for high-functional tsunami monitoring and continuous observation of ocean-bottom crustal movements	FY2016-2020	141,900
16H06311	TSUBOKI Kazuhisa 90222140	Nagoya University, Institute for Space-Earth Environmental Research, Professor	Dynamical, thermodynamical and cloud-microphysical studies of violent wind and heavy rain-producing tropical cyclones: Quantitative improvement of intensity estimations/forecasts	FY2016-2020	136,600
16H06312	TEI Yuichi 30345053	The University of Tokyo, Graduate School of Engineering, Professor	Development of “4-dimensional scaffold system” that integrates signaling factors and 3-dimensional structural biomaterials	FY2016-2020	126,600
16H06313	AKIYOSHI Kazunari 90201285	Kyoto University, Graduate School of Engineering, Professor	Development of nanogel hybrid materials for medical application	FY2016-2020	133,100
16H06314	KURODA Shunichi 60263406	Osaka University, The Institute of Scientific and Industrial Research, Professor	Development of Neo-Bionanocapsules: Drug and Gene Delivery System to Wide Range Tissues with Virus-derived Functional Domains	FY2016-2020	139,100
16H06315	MURATA Michio 40183652	Osaka University, Graduate School of Science, Professor	Dynamic structure and domain formation of membrane lipids in model bilayer systems	FY2016-2020	140,600
16H06316	TAKUMI Toru 00222092	RIKEN, Center for Brain Science, Team Leader	Integrative Biology of Autism Spectrum Disorder	FY2016-2020	139,200
16H06317	OKAMOTO Hitoshi 40183769	RIKEN, Center for Brain Science, Laboratory for Neural Circuit Dynamics of Decision Making, Team Leader	Neural circuit mechanisms controlling social conflicts	FY2016-2020	142,900
17H06107	SHIROUZU Hajime 60333168	The University of Tokyo, Center for Research and Development on Transition from Secondary to Higher Education, Professor	Renovating Assessment for the Future: Design-Based Implementation Research for a Learning-in-Class Monitoring System Based on the Learning Sciences	FY2017-2021	154,500
17H06108	KOSHIMURA Shunichi 50360847	Tohoku University, International Research Institute of Disaster Science, Professor	Fusion of sensing and simulation of tsunami damage assessment towards innovation of disaster medical system	FY2017-2021	156,900
17H06109	YOKOTA Takanori 90231688	Tokyo Medical and Dental University, Graduate School of Medical and Dental Sciences, Professor	Development of heteroduplex oligonucleotide crossing the blood-brain barrier	FY2017-2021	133,100
17H06110	INOUE Masayuki 70322998	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Expanding the medicinally relevant chemical space with architecturally complex natural products and their synthetic analogues	FY2017-2021	157,800
17H06112	HANDA Hiroshi 80107432	Tokyo Medical University, Department of Nanoparticle Translational Research, Professor	Search for novel modulators of cereblon, the target of thalidomide that regulates neural stem cell proliferation and differentiation	FY2017-2019	139,300
17H06113	IINO Yuichi 40192471	The University of Tokyo, Graduate School of Science, Professor	Dissection of molecules and neural circuits underlying a behavioral switch	FY2017-2021	156,800

(2) Humanities and Social Sciences（17 Projects）

○ Humanities（7 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
16H06319	MAZUKA Reiko 00392126	RIKEN, Center for Brain Science, Team Leader	Seeking the onset of infant speech development: An explanation of developmental mechanisms from the perspective of Asian languages	FY2016-2020	87,200
16H06320	TAKEZAWA Yasuko 70227015	Kyoto University, Institute for Research in Humanities, Professor	Integrated Research into the Processes and Mechanisms of Racialization	FY2016-2020	116,100
17H06114	NAGASHIMA Yuji 50138137	Kogakuin University, Faculty of Informatics, Professor	Research into Constructing a Japanese Sign Language Multi-Dimensional Database	FY2017-2020	109,200
17H06115	KARIMATA Shigehisa 50224712	University of the Ryukyus, Research Institute for Islands and Sustainability, Professor	Comparative historical research on Ryukyuan by using linguistic family trees	FY2017-2021	135,600
17H06116	SHIROYAMA Tomoko 60281763	The University of Tokyo, Graduate School of Economics, Professor	The Hydrosphere and Socioeconomics in Modern Asia - Exploring a New Regional History Using a Database and Spatial Analysis	FY2017-2021	140,800
17H06117	TAJIMA Isao 80292796	The University of Tokyo, Historiographical Institute, Professor	Advancing Japanese Bibliographics and Improving the Accessibility of Documents Held by Royal and Aristocratic Archives - Clarifying the Structure and Transmission of Knowledge Systems	FY2017-2021	157,000
17H06118	NAKATSUKA Takeshi 60242880	Nagoya University, Graduate School of Environmental Studies, Professor	Reorganization of prehistorical structure of calendar age and evaluation of climate change effect in Japanese archipelago using tree ring oxygen isotope ratios	FY2017-2021	160,000

○ Social Sciences（10 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05726	WADA Hajime 30158703	Nagoya University, Graduate School of Law, Professor	Employment Sustainability and the Shifting Paradigm of Labor Law	FY2015-2019	76,000
15H05727	MASUYAMA Mikitaka 50317616	National Graduate Institute for Policy Studies, School of Policy Studies, Professor	An Analytical and Practical Approach to Universal and International Access to Policy Information	FY2015-2019	139,900
15H05728	ONO Yoshiyasu 70130763	Osaka University, Institute of Social and Economic Research, Specially Appointed Professor	Behavioral-Economic Analysis of Long-Run Stagnation	FY2015-2019	153,600
15H05729	KAMIHIGASHI Takashi 30324908	Kobe University, Center for Computational Social Science, Professor	Risk Management of Comprehensive Monetary/Fiscal Policy: Theory, Empirics, and Simulations	FY2015-2019	141,400
16H06318	MATSUDA Motoji 50173852	Kyoto University, Graduate School of Letters, Professor	“African Potential” and overcoming the difficulties of modern world: comprehensive area studies that will provide a new perspective for the future of humanity	FY2016-2020	140,000
16H06321	SATO Iwao 80154037	The University of Tokyo, Institute of Social Science, Professor	Research on Disputing Behavior and Judicial Policy in the Super-Aging Society	FY2016-2020	127,700
16H06322	FUKAO Kyoji 30173305	Hitotsubashi University, Institute of Economic Research, Professor	Service Sector Productivity in Japan: Determinants and Policies	FY2016-2020	98,900
16H06323	AKABAYASHI Hideo 90296731	Keio University, Faculty of Economics, Professor	Investigation of the long-term causal effect of economic inequality on educational inequality based on longitudinal survey and experiments of parent-child pairs and international comparison	FY2016-2020	140,400

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
16H06324	KAMEDA Tatsuya 20214554	The University of Tokyo, Graduate School of Humanities and Sociology, Professor	Understanding of cognitive, neural and ecological bases of human collective behavior	FY2016-2020	140,500
16H06325	SEKIYAMA Kaoru 70216539	Kyoto University, Graduate School of Advanced Integrated Studies in Human Survivability, Professor	Lifestyle and Brain Function: Inquiry in Psychological Science into Successful Aging	FY2016-2020	101,800

(3) Science and Engineering (120 Projects)

○ Interdisciplinary Science and Engineering (23 Projects)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05731	KIMURA Yuki 50449542	Hokkaido University, Institute of Low Temperature Science, Associate Professor	Nucleation	FY2015-2019	134,100
15H05732	KAWAKAMI Yoichi 30214604	Kyoto University, Graduate School of Engineering, Professor	Achievement of Tailor-made Lighting Sources by the Control of Nanoscopic Carrier Localization in Nitride Semiconductors	FY2015-2019	146,300
15H05733	HIRAYAMA Hideki 70270593	RIKEN, Cluster for Pioneering Research, Quantum Optodevice Laboratory, Chief Scientist	Research on Unexplored Frequency Quantum-Cascade Lasers Using Nitride Semiconductors	FY2015-2019	154,500
15H05735	NOTOMI Masaya 50393799	Tokyo Institute of Technology, School of Science, Department of Physics, Professor	Novel Photonic Integration Platform with Hybrid Nanophotonics-Nanomaterials Systems	FY2015-2019	142,600
15H05736	HAMAGUCHI Satoshi 60301826	Osaka University, Graduate School of Engineering, Professor	Quantum Theoretical Analyses of Plasma Processing for Novel and Diverse Materials Using Multi-Scale Numerical Simulations	FY2015-2019	116,900
15H05737	NISHINO Yoshinori 40392063	Hokkaido University, Research Institute for Electronic Science, Professor	Cell Dynamics Studied by X-Ray Laser Diffraction	FY2015-2019	153,900
16H06326	KOSAKA Hideo 20361199	Yokohama National University, Faculty of Engineering, Professor	Research for quantum media conversion in diamond nano quantum system	FY2016-2020	138,900
16H06327	SUGAWARA Yasuhiro 40206404	Osaka University, Graduate School of Engineering, Professor	Assembly of nanostructure on insulating surfaces and investigation of gas reaction mechanism using atomic force microscopy	FY2016-2020	139,100
16H06328	FUJII Teruo 30251474	The University of Tokyo, Institute of Industrial Science, Professor	Microfluidic approach to single cell transcriptome analysis and its applications	FY2016-2020	136,600
16H06329	TAKEUCHI Shoji 90343110	The University of Tokyo, Department of Mechano-Informatics, Graduate School of Information Science and Technology, Professor	Establishment of Cell Fiber Engineering For Next Generation of 3D Tissue Culture	FY2016-2020	144,900
16H06330	SHIRAISHI Masashi 30397682	Kyoto University, Graduate School of Engineering, Professor	Semiconductor Spin-currentronics	FY2016-2020	134,400
16H06331	MATSUDA Kazunari 40311435	Kyoto University, Institute of Advanced Energy, Professor	Development and application of valley-spin photonics in atomically thin layered materials	FY2016-2020	142,800
16H06332	MITANI Seiji 20250813	National Institute for Materials Science, Research Center for Magnetic and Spintronic Materials, Deputy Director	Microscopic understanding of interface spin-orbit coupling and development of perpendicular magnetic anisotropy devices	FY2016-2020	145,000

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
16H06333	SUENAGA Kazutomo 00357253	National Institute of Advanced Industrial Science and Technology, Nano-Materials Research Institute, Prime Senior Researcher	Advanced Single-Atom Spectroscopy	FY2016-2020	130,900
16H06334	BABA Toshihiko 50202271	Yokohama National University, Graduate School of Engineering, Professor	High-performance nanolaser biosensor with an ion-sensitivity	FY2016-2020	130,400
17H06119	MURATA Yasujiro 40314273	Kyoto University, Institute for Chemical Research, Professor	Creation and Development of Nanoscale Laboratory	FY2017-2021	160,100
17H06120	OIKAWA Akira 10321902	Osaka University, The Institute of Scientific and Industrial Research, Professor	Interconversion of Quantum States Between Photon and Electron Spin Using Electrically Controlled Quantum Dots	FY2017-2021	166,100
17H06121	ANDO Toshio 50184320	Kanazawa University, Nano Life Science Institute (WPI-NanoLSI), Professor	Realization of nano-dynamics imaging of protein molecules in extremely soft membrane environments	FY2017-2021	126,400
17H06122	YAMADA Hirofumi 40283626	Kyoto University, Graduate School of Engineering, Professor	Direct visualization of molecular recognition forces by high-resolution atomic force microscopy and spectroscopy	FY2017-2021	141,900
17H06123	TAKEYA Junichi 20371289	The University of Tokyo, Graduate School of Frontier Sciences, Professor	Giant strain effect of charge transport in organic single-crystal semiconductors and flexible mechano-electronics	FY2017-2021	163,300
17H06124	TANAKA Koichiro 90212034	Kyoto University, Graduate School of Science, Professor	New development of nonlinear photoelectronics based on terahertz strong field physics	FY2017-2021	162,300
17H06125	NODA Susumu 10208358	Kyoto University, Graduate School of Engineering, Professor	Spectral control of near-field thermal radiation for highly efficient thermo-photovoltaic power generation	FY2017-2021	154,900
17H06126	MIYAKE Yasuhiro 80209882	High Energy Accelerator Research Organization, Institute of Materials Structure Science, Professor	Transmission Muon Microscope by muon microbeam, realizing 3-D Imaging	FY2017-2021	159,300

○ Mathematical and Physical Sciences（ 42 Projects ）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05738	KONDO Shigeyuki 50186847	Nagoya University, Graduate School of Mathematics, Professor	Lattices, Automorphic Forms and Moduli Spaces	FY2015-2019	68,400
15H05739	FUJIWARA Koji 60229078	Kyoto University, Graduate School of Science, Professor	Geometric Group Theory	FY2015-2019	60,800
15H05740	YAMAMOTO Masahiro 50182647	The University of Tokyo, Graduate School of Mathematical Sciences, Professor	Renovating Solutions and Applications of Coefficient Inverse Problems for Partial Differential Equations	FY2015-2019	140,000
15H05742	SAITO Naohito 20321763	High Energy Accelerator Research Organization, J-PARC Center, Director	Sensitive Search for New Physics Law with Precision Measurement of Muon Anomalous Magnetic Moment	FY2015-2019	155,700
15H05743	OTANI Chiko 50281663	RIKEN, Center for Advanced Photonics, Team Leader	Investigation of Inflation Cosmology with Ground-based Experiment of Large-angle Distribution of CMB B-mode Polarization	FY2015-2019	153,200
15H05744	MATSUURA Shuji 10321572	Kwansei Gakuin University, School of Science and Technology, Professor	Probing into the Intra-Halo Light and the Epoch of Cosmic Re-Ionization by Rocket Experiments to Measure the Cosmic Infrared Background	FY2015-2019	100,000

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05745	ISHIDA Kenji 90243196	Kyoto University, Graduate School of Science, Professor	Understanding of the Superconducting Mechanism and Search for a Novel Superconducting State in Uranium Heavy-Fermion Compounds	FY2015-2019	153,800
15H05746	KANEKO Kunihiko 30177513	The University of Tokyo, Graduate School of Arts and Sciences, Professor	Macroscopic Theory for Robustness and Plasticity in Cells	FY2015-2019	140,400
15H05747	FUJII Ryoichi 00132712	Nagoya University, Institute for Space-Earth Environmental Research, Emeritus Professor	The Quest for the Ultimate Production Mechanism of Pulsating Auroras with Extremely High Time Resolution and Coordinated Observations from Space and Ground	FY2015-2019	152,600
15H05748	OHTANI Eiji 60136306	Tohoku University, Graduate School of Science, Fellow	Creation of the Best Model of the Earth's Core	FY2015-2019	149,700
15H05749	NARAOKA Hiroshi 20198386	Kyushu University, Faculty of Science, Professor	Advanced Trace Organic Compound Study in Planetary Materials: Development of High Sensitivity and High Resolution	FY2015-2019	154,800
15H05750	ONO Yasushi 30214191	The University of Tokyo, Graduate School of Frontier Sciences, Professor	2D Imaging Study of High Power Heating / Acceleration of High Magnetic Field Reconnection for its Physics and Application	FY2015-2019	153,900
15H05751	Tanaka Kazuo 70171741	Osaka University, Open and Transdisciplinary Research Initiatives, Professor	Proof of Fast Ignition Scheme Using Super-penetration of Laser Light	FY2015-2019	145,000
16H06335	MORIWAKI Atsushi 70191062	Kyoto University, Graduate School of Science, Professor	New development of algebraic geometry viewed from theoretical physics	FY2016-2020	61,700
16H06336	KANEKO Masanobu 70202017	Kyushu University, Faculty of Mathematics, Professor	Multiple Zeta Values and Functions	FY2016-2020	75,400
16H06337	TAKAHASHI Atsushi 50314290	Osaka University, Graduate School of Science, Professor	Fusion of Birational Geometry and Theory of Periods; A New Era for Studies of Mirror Symmetry	FY2016-2020	79,900
16H06338	OSADA Hirofumi 20177207	Kyushu University, Graduate School of Mathematics, Professor	Stochastic Analysis on Infinite Particle Systems	FY2016-2020	90,100
16H06339	KOZONO Hideo 00195728	Waseda University, Faculty of Science and Engineering, Professor	New development of mathematical theory of turbulence by collaboration of the nonlinear analysis and computational fluid dynamics	FY2016-2020	123,600
16H06340	SUDA Toshimi 30202138	Tohoku University, Research Center for Electron-Photon Science, Professor	Precise determination of the proton charge radius by electron scattering off proton at ultra-low momentum transfer region	FY2016-2020	128,500
16H06341	SHIGEYAMA Toshikazu 70211951	The University of Tokyo, Graduate School of Science, Associate Professor	Study of binary neutron star merger by high cadence optical observations	FY2016-2020	98,300
16H06342	YONETOKU Daisuke 40345608	Kanazawa University, College of Science and Engineering, Professor	Identification of Gravitational Wave Sources with X-ray Transient Monitor and Study of Black Hole Formation Mechanism	FY2016-2020	140,800
16H06343	YAMANAKA Taku 20243157	Osaka University, Graduate School of Science, Professor	Search for new physics in rare kaon decays	FY2016-2020	133,800
16H06344	MARUYAMA Takasumi 80375401	High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Associate Professor	Searching for a sterile neutrino at J-PARC MLF	FY2016-2020	140,100
16H06345	IMADA Masatoshi 70143542	Waseda University, Waseda Research Institute for Science and Technology, Senior Researcher	Materials Design and Exploration of Functions for Strongly Correlated Materials – Challenges to Non-Equilibrium and Non-Periodic Systems	FY2016-2020	85,400

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
16H06346	KATO Reizo 80169531	RIKEN, Cluster for Pioneering Research, (Condensed Molecular Materials Laboratory), Chief Scientist	Molecular quantum liquids in strongly correlated electron systems	FY2016-2020	142,600
16H06347	MICHIBAYASHI Katsuyoshi 20270978	Nagoya University, Graduate School of Environmental Studies, Professor	Physical properties of uppermost mantle structure and the Mohorovicic seismic discontinuity	FY2016-2020	141,700
16H06348	NAKAMURA Michihiko 70260528	Tohoku University, Graduate School of Science, Professor	Development of near-real-time volcanology based on in-situ observation experiments of shallow magmatic processe	FY2016-2020	136,100
16H06349	YURIMOTO Hisayoshi 80191485	Hokkaido University, Faculty of Science, Professor	Physicochemical analysis of early solar system based on formation kinetics of refractory inclusions of meteorites	FY2016-2020	140,700
17H06127	SAITO Masahiko 80183044	Kobe University, Center for Mathematical and Data Sciences, Professor	Algebraic Geometry and Integrable Systems - Deepning of Theory and New Developments in Mathematics and Mathematical Physics -	FY2017-2021	92,000
17H06128	SAEKI Osamu 30201510	Kyushu University, Institute of Mathematics for Industry, Professor	Innovative Research of Geometric Topology and Singularities of Differentiable Mappings	FY2017-2021	62,800
17H06129	Masayuki Akiyama 50425401	Tohoku University, Astronomical Institute, Professor	Establishing processes of galaxy structure revealed by a Subaru tomographic adaptive optics	FY2017-2021	161,300
17H06130	KOHNO Kotaro 80321587	The University of Tokyo, Graduate School of Science, Professor	Study of cosmic star-formation history based on an unbiased survey of millimeter- and submillimeter-wave emission-line galaxies	FY2017-2021	163,700
17H06131	TESHIMA Masahiro 40197778	The University of Tokyo, Institute for Cosmic Ray Research, Professor	Study of the Extreme Universe with the CTA Large Size Telescopes	FY2017-2021	157,100
17H06132	AOKI Shigeki 80211689	Kobe University, Graduate School of Human Development and Environment, Professor	Cosmic gamma-ray observation by balloon borne emulsion telescope to study unsolved issues	FY2017-2021	153,900
17H06133	KANDA Nobuyuki 50251484	Osaka City University, Graduate School of Science, Professor	Calibration Standard and High-Precision Data Analysis toward the Observational Era of Gravitational Waves	FY2017-2021	139,600
17H06134	TAJIMA Osamu 80391704	Kyoto University, Graduate School of Science, Associate Professor	Quest for the origin of the Big-Bang and measurements of sum of the neutrino masses by using the world's largest CMB telescope array	FY2017-2021	161,100
17H06135	MIHARA Satoshi 80292837	High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Professor	Study on the charged lepton flavor mixing using the high-intensity pulsed muon beam	FY2017-2021	152,000
17H06136	MAENO Yoshiteru 80181600	Kyoto University, Graduate School of Science, Professor	DC Electric Field and Current: Novel Control Parameters for Strongly Correlated Electron Systems	FY2017-2021	159,000
17H06137	KAWAMURA Hikaru 30153018	Osaka University, Graduate School of Science, Professor	Frustration-induced spin textures	FY2017-2021	165,300
17H06138	HATSUGAI Yasuhiro 80218495	University of Tsukuba, Division of Physics, Professor	Variety and universality of bulk-edge correspondence in topological phases: From solid state physics to transdisciplinary concepts	FY2017-2021	157,800
17H06139	OKAMOTO Hajime 10333783	Kyushu University, Research Institute for Applied Mechanics, Professor	Analysis of cloud microphysics and vertical velocity by synergy use of next generation space-borne active sensors	FY2017-2021	147,900
17H06140	OMURA Yoshiharu 50177002	Kyoto University, Research Institute for Sustainable Humanosphere, Professor	Analyses and Verification of Particle Acceleration and Scattering by Electromagnetic Cyclotron Waves in Space Plasmas	FY2017-2021	133,700

○ Chemistry（17 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05752	TAKATSUKA Kazuo 70154797	Kyoto University, Fukui Institute for Fundamental Chemistry, Research Leader	Nonadiabatic Electron Dynamics in Chemistry of Charge Separation, Proton Transfer, Electron Transmission, and Huge Electronic-State Fluctuation	FY2015-2019	126,800
15H05753	SUZUKI Toshinori 10192618	Kyoto University, Graduate School of Science, Professor	Ultrafast Photoelectron Spectroscopy of Solution Chemistry	FY2015-2019	146,500
15H05755	ISHIHARA Kazuaki 40221759	Nagoya University, Graduate School of Engineering, Professor	Development of High Performance Acid–Base Combined Nanocatalysts	FY2015-2019	153,800
15H05756	MURAKAMI Masahiro 20174279	Kyoto University, Graduate School of Engineering, Professor	Development of Molecular Transformations by Means of Light and Metals Directing towards Straightforward Synthesis	FY2015-2019	154,600
15H05757	YAMAMOTO Kimihisa 80220458	Tokyo Institute of Technology, Institute of Innovative Research, Professor	Creation of Superatoms Based on the Precision Inorganic Synthesis and Elucidation of its Function	FY2015-2019	154,500
15H05758	WATANABE Masayoshi 60158657	Yokohama National University, Graduate School of Engineering, Professor	Role of Liquid for Controlling Autonomy of Soft Materials Containing Ionic Liquids	FY2015-2019	155,300
16H06351	SUZUKI Keisuke 90162940	Tokyo Institute of Technology, School of Science, Department of Chemistry, Professor	Studies on Chemical Synthesis of Polyketide-Derived, Biologically Active Complex Natural Products	FY2016-2020	141,800
16H06352	YAMAGO Shigeru 30222368	Kyoto University, Institute for Chemical Research, Professor	New Organic Chemistry and Material Science of Curved π-Conjugated Molecules	FY2016-2020	145,600
16H06353	AWAGA Kunio 10202772	Nagoya University, Graduate School of Science, Professor	Novel Energy and Information Conversions, Created by Solid-State Electrochemical Processes	FY2016-2020	143,000
16H06354	TERADA Masahiro 50217428	Tohoku University, Graduate School of Science, Professor	Development of Functional Organosuperbase Catalysts Enabling Molecular Recognition	FY2016-2020	143,500
16H06355	SEKI Takahiro 40163084	Nagoya University, Graduate School of Engineering, Professor	New polymer film processing based on the amplified conversion triggered from the free surface	FY2016-2020	138,200
16H06356	SUGIYAMA Hiroshi 50183843	Kyoto University, Graduate School of Science, Professor	Regulation and mechanistic investigation of gene expression by artificial genetic switches	FY2016-2020	133,700
17H06141	ADACHI Shin-ichi 60260220	High Energy Accelerator Research Organization, Institute of Materials Structure Science, Professor	Visualizing ultrafast dynamics of molecular structure with femtosecond X-ray solution scattering	FY2017-2021	154,400
17H06142	YAMAMOTO Hisashi 20026298	Chubu University, Molecular Catalyst Research Center, Professor	New Frontier of Substrate-Controlled Chemical Reaction	FY2017-2021	159,200
17H06143	IWASAWA Nobuharu 40168563	Tokyo Institute of Technology, School of Science, Professor	Development of Carbon Dioxide Fixation Reactions	FY2017-2021	161,300
17H06144	Jian Ping Gong 20250417	Hokkaido University, Faculty of Advanced Life Science, Professor	Utilizing the Sacrificial Bonding Principle to Create Soft-Hard Composites with Toughness that Surpasses Metals and Novel Functions	FY2017-2021	157,000
17H06145	KANNO Ryoji 90135426	Tokyo Institute of Technology, Institute of Innovative Research, Professor	Creation of superionic conductors	FY2017-2020	129,500

○ Engineering（38 Projects）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05759	GAO Wei 70270816	Tohoku University, Graduate School of Engineering, Professor	Frontier of Precision Optical Metrology Created by the Ultra-Precision Optical Nano-Grid Reference Artifact and the Absolute Optical Scale Comb	FY2015-2019	77,700
15H05760	MARUYAMA Shigeo 90209700	The University of Tokyo, Graduate School of Engineering, Professor	Construction of Functionalized Carbon Nano-Materials and Development of Innovative Energy Devices	FY2015-2019	154,100
15H05764	ENPUKU Keiji 20150493	Kyushu University, Research Institute of Superconductor Science and Systems, Research Fellow	Development of Advanced Biosensing Systems Utilizing Magnetic Markers and Magnetic Sensors	FY2015-2019	131,200
15H05765	NAKAKITA Eiichi 70183506	Kyoto University, Disaster Prevention Research Institute, Professor	Integrated Research on State-of-the-art Multi-sensors In-situ Observation of Storm Genesis and Reduction of Serious Disaster due to Heavy Rainfall	FY2015-2019	159,500
15H05766	KAINUMA Ryosuke 20202004	Tohoku University, Graduate School of Engineering, Professor	Ferrous Structural Superelastic Alloys - New Stage of Shape Memory Materials -	FY2015-2019	154,100
15H05767	TSUJI Nobuhiro 30263213	Kyoto University, Graduate School of Engineering, Professor	Novel Material Design Based on Unified Understanding on Unique Mechanical Behaviors in Bulk Nanostructured Metals	FY2015-2019	154,700
15H05768	TAKAKI Setsuo 90150490	Kyushu University, Research Center for Steel, Specially-appointed Professor	Systematization of Academic Foundation on Grain Refinement Strengthening in Steel	FY2015-2019	121,600
15H05769	TAMIYA Eiichi 60179893	Osaka University, Graduate School of Engineering, Professor	Development of Digital Bio-Molecular Device and Biomedical Applications	FY2015-2019	129,700
15H05770	KOMURASAKI Kimiya 90242825	The University of Tokyo, Graduate School of Engineering, Professor	Discharge Induced in a High-Energy Electromagnetic Beam and its Engineering Applications	FY2015-2019	154,500
15H05771	KATO Yasuhiro 40221882	The University of Tokyo, Graduate School of Engineering, Professor	New Developments in Science and Engineering of Mineral Resources from Present and Past Oceans	FY2015-2019	154,500
16H06357	MIURA Hideo 90361112	Tohoku University, Graduate School of Engineering, Professor	Establishment of Scientific Basis of the Strength and Reliability of Materials Based on the Order of Atom Arrangement and Its Application to the Explication of the Degradation Process of Various Materials	FY2016-2020	80,800
16H06358	YAMAUCHI Kazuto 10174575	Osaka University, Graduate School of Engineering, Professor	Development of zoom condenser system for X-ray free electron laser by high precision deformable reflective optics	FY2016-2020	141,800
16H06359	MURAYAMA Akihiro 00333906	Hokkaido University, Graduate School of Information Science and Technology, Professor	Photoelectric conversion system of spin-information utilizing semiconductor quantum dots	FY2016-2020	142,500
16H06360	CHO Yasuo 40179966	Tohoku University, Research Institute of Electrical Communication, Professor	Origin elucidation of problems in interface electric charge transportation phenomenon by using scanning nonlinear dielectric microscopies	FY2016-2020	149,700
16H06361	OTSUJI Taiichi 40315172	Tohoku University, Research Institute of Electrical Communication, Professor	Creation of 2D-Atomically-Thin-Layered Hetero- junctions and their Applications to Novel Terahertz Photonic Devices	FY2016-2020	144,600
16H06362	MATSUI Yoshihiko 00173790	Hokkaido University, Faculty of Engineering, Professor	Innovative Water Treatment System Combining Pretreatments and Membrane Separation for Sustainable Supply of Safe High-quality Water	FY2016-2020	100,800
16H06363	AOKI Takayoshi 10202467	Nagoya City University, Graduate School of Design and Architecture, Professor	Development of Preservation/Renovation Techniques for Seismic Performance Improvement and Authenticity of Historical Buildings	FY2016-2020	136,300

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
16H06364	NAGAO Tadaaki 40267456	National Institute for Materials Science, International Center for Materials Nanoarchitectonics, Group Leader / MANA Principal Investigator	Infrared Energy Harvester by Artificially Structured Heterojunction	FY2016-2020	141,400
16H06365	TSUZAKI Kaneaki 40179990	Kyushu University, Graduate School of Engineering, Professor	Research on supreme fatigue property in steel: importance of microstructurally-small fatigue crack	FY2016-2020	151,000
16H06366	TSUREKAWA Sadahiro 40227484	Kumamoto University, Faculty of Advanced Science and Technology, Professor	Breakthrough toward “second-generation” grain boundary engineering	FY2016-2020	137,900
16H06367	ADSCHIRI Tadasumi 60182995	Tohoku University, WPI - Advanced Institute for Materials Research (WPI-AIMR), Professor	Fabrication of fluidic ceramics with supercritical fluid technology toward dynamic thermal management	FY2016-2020	140,700
16H06368	NODA Suguru 50312997	Waseda University, School of Advanced Science and Engineering, Professor	Creating Soft-Batteries by Simple and Rapid Processes and Innovating Capacity by Reversible Structure Change	FY2016-2020	142,900
16H06369	GOTO Masahiro 10211921	Kyushu University, Graduate School of Engineering, Professor	Creation of Transdermal Drug Delivery Systems Using Solid-in-oil Nano-dispersion Technique	FY2016-2020	128,500
16H06370	KOIZUMI Hiroyuki 40361505	The University of Tokyo, Graduate School of Frontier Sciences, Associate Professor	All-round Micro-propulsion System for Multipurpose Utilization of Microsatellite	FY2016-2020	128,800
17H06146	JU Yang 60312609	Nagoya University, Graduate School of Engineering, Professor	Creation and development of high-order nano-space structures through innovative control of stress field	FY2017-2021	161,000
17H06147	KAWAMURA Atsuo 80186139	Yokohama National University, Faculty of Engineering, Professor Emeritus	Realization of Sustainable Green Society Through 99.9% Class Efficiency Electric Power Conversion	FY2017-2021	138,000
17H06148	TAKAGI Shinichi 30372402	The University of Tokyo, School of Engineering, Professor	Precise structure control of 3-dimensional integration CMOS using high mobility materials through layer transfer	FY2017-2021	158,900
17H06149	SOMEYA Takao 90292755	The University of Tokyo, School of Engineering, Professor	Evaluation of Drug Response by Elastic Multipoint Electrode Array Using Cardiomyocyte Sheet	FY2017-2021	157,100
17H06150	OSUKA Koichi 50191937	Osaka University, Graduate School of Engineering, Professor	Source of various behaviors of living things that understands from zombification of insects	FY2017-2021	136,800
17H06151	IKAGA Toshiharu 30302631	Keio University, Faculty of Science and Technology, Professor	Field survey on Impact of living environments on brain, cardiovascular, respiratory and locomotive system, and co-benefit evaluation of disease and long-term care prevention	FY2017-2021	159,700
17H06152	HONO Kazuhiro 60229151	National Institute for Materials Science, Vice President and Director of Research Center for Magnetic and Spintronic Materials	Spin-dependent conduction mechanism of half-metallic Heusler alloys and applications to practical devices	FY2017-2021	162,400
17H06153	HOSONO Hideo 30157028	Tokyo Institute of Technology,Research Center for Element Strategy,Institute Professor and Director of Materials	New evolution of materials concept and application of electrides	FY2017-2021	134,600
17H06154	MAKINO Akihiro 30315642	Tohoku University, New Industry Creation Hatchery Center, Professor	Research and development on artificial production of next generation of Rare-Earth Free Magnets with $L1_0$ phase similar to Cosmic magnet.	FY2017-2021	156,600
17H06155	YASUDA Hideyuki 60239762	Kyoto University, Graduate School of Science and Engineering, Professor	Modeling of solidification dynamics supported by 3D time-resolved in-situ observations	FY2017-2021	130,200

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
17H06156	WADA Yuji 40182985	Tokyo Institute of Technology, School of Materials and Chemical Technology, Professor	The Theory of Microwave-induced Nonequilibrium State and its Application to the Manipulation of Solid/Interfacial Chemical Reactions	FY2017-2021	160,200
17H06157	OMASA Takeshi 00252586	Osaka University, Graduate School of Engineering, Professor	Integrated platform for mammalian cell-based cell and bioprocess engineering	FY2017-2021	118,400
17H06158	TAKEYAMA Haruko 60262234	Waseda University, Faculty of Science and Engineering, Professor	Development of platform for ultra high-throughput screening of novel bioactive compound producers	FY2017-2021	157,700
17H06159	TAKAHASHI Hiroyuki 70216753	The University of Tokyo, Institute of Engineering Innovation, Professor	Study on Multi-photon gamma-ray coincidence tomography	FY2017-2021	158,300

(4) Biological Sciences (59 Projects)

○ Biological Sciences (9 Projects)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05772	YUZAKI Michisuke 40365226	Keio University, School of Medicine, Professor	How are Synapses Formed, Fine-tuned and Eliminated in vivo?—Novel Mechanisms by the Complement Family Proteins	FY2015-2019	135,800
15H05773	GOTOH Yukiko 70252525	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Elucidation of Mechanisms Regulating Neural Stem/Progenitor Cell Fate	FY2015-2019	143,000
15H05774	MIYAZONO Kohei 90209908	The University of Tokyo, Graduate School of Medicine, Professor	Transcriptional Regulation by TGF-β Signaling and its Relation to Progression of Cancer	FY2015-2019	153,800
16H06371	YAMAMOTO Daisuke 50318812	National Institute of Information and Communications Technology, Advanced ICT Research Institute, Executive Researcher	How sexual experience modulates innate behavior: a neurogenetic study in Drosophila	FY2016-2020	140,900
16H06373	HATAKEYAMA Masanori 40189551	The University of Tokyo, Graduate School of Medicine, Professor	Mechanism and regulation of “Hit-and-Run” carcinogenesis by Helicobacter pylori CagA	FY2016-2020	141,600
16H06374	KIKUCHI Akira 10204827	Osaka University, Graduate School of Medicine, Professor	Investigation of the novel mechanisms underlying tumorigenesis due to aberrant Wnt signal networks	FY2016-2020	136,300
17H06160	SAKANO Hitoshi 90262154	University of Fukui, Faculty of Medical Sciences, Adjunct Professor	Decision Making in the Mouse Olfactory System	FY2017-2021	158,800
17H06161	MIYASHITA Yasushi 40114673	RIKEN, Center for Brain Science, Laboratory for Cognition Circuit Dynamics, Team Leader	Elucidation of cortical neural circuits for meta-memory: Optogenetic manipulation of retrospection	FY2017-2021	161,000
17H06162	NISHIKAWA Hiroyoshi 10444431	Nagoya University, Graduate School of Medicine, Professor	Association of immune responses with racial differences of cancer development	FY2017-2021	161,700

○ Biology (13 Projects)

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05775	FUJIYOSHI Yoshinori 80142298	Tokyo Medical and Dental University, TMDU Advanced Research Institute, Distinguished Professor	Studies in Structural Physiology of Channels	FY2015-2019	138,500

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05776	NISHIMURA Ikuko 00241232	Konan University, distinguished professor	Endomembrane-Mediated Organ Straightening and Defense in Plants	FY2015-2019	153,800
15H05777	TERAKITA Akihisa 30212062	Osaka City University, Graduate School of Science, Professor	Contribution of Opsin Properties to Non-Visual Functions	FY2015-2019	134,400
15H05778	FUJIWARA Haruhiko 40183933	The University of Tokyo, Graduate School of Frontier Sciences, Professor	Molecular Mechanisms of Color Pattern Formation in Mimicry Controlled by Supergene.	FY2015-2019	153,800
16H06375	OHSUMI Yoshinori 30114416	Tokyo Institute of Technology, Institute of Innovative Research, Honorary Professor	Molecular mechanism and physiological understanding of Autophagy	FY2016-2020	143,700
16H06376	AGATA Kiyokazu 70167831	Gakushuin University, Faculty of Science, Department of Life Science, Researcher	Evoking limb regeneration from non-regenerative animals	FY2016-2020	136,800
16H06377	FUKUDA Hiroo 10165293	The University of Tokyo, Graduate School of Science, Professor	Molecular basis of pluripotency of vascular stem cells	FY2016-2020	141,800
16H06378	HASEBE Mitsuyasu 40237996	National Institute of Natural Sciences, National Institute for Basic Biology, Division of Evolutionary Biology, Professor	Spatiotemporal regulation of cell division axis as a grand plan of plant developmental evolution	FY2016-2020	150,100
17H06164	ARAI Hiroyuki 40167987	The University of Tokyo, Graduate School of Medicine, Center for Disease Biology and Integrative Medicine, Visiting Researcher	The roles of membrane lipids for intracellular signaling platform	FY2017-2021	156,700
17H06165	AKIYAMA Shuji 50391842	National Institute of Natural Sciences, Institute for Molecular Science, Research Center of Integrative Molecular Systems, Professor	An Integrated Multi-scale Approach for Studying Cyanobacterial Circadian Clock System	FY2017-2021	157,400
17H06166	SAGA Yumiko 50221271	Research Organization of Information and Systems, National Institute of Genetics, Genetic Strains Research Center, Professor	Mechanism of sex differentiation of germ cells	FY2017-2021	156,200
17H06167	FUKAGAWA Tatsuo 60321600	Osaka University, Graduate School of Frontier Biosciences, Professor	Molecular mechanisms for centromere formation	FY2017-2021	157,100
17H07424	KOHCHI Takayuki 40202056	Kyoto University, Graduate School of Biostudies, Professor	Sex differentiation in land plant: mechanism of genetic robustness and plasticity	FY2017-2021	141,500

○ Agricultural Sciences（ 13 Projects ）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05779	TERAUCHI Ryohei 50236981	Kyoto University, Graduate School of Agriculture, Professor	Towards Understanding Molecular Interactions of Rice and the Blast Fungus Magnaporthe Oryzae	FY2015-2019	151,500
15H05780	KUBO Yasuyuki 80183797	Kyoto Prefectural University, Graduate School of Life and Environmental Sciences, Professor	Molecular Basis of Infection Strategy in Plant Pathogenic Fungi: Host Recognition and Infection Structure Development	FY2015-2019	98,500
15H05781	SATO Ryuichiro 50187259	The University of Tokyo, Graduate School of Agriculture and Life Sciences, Professor	Analysis on Molecular Nutritional Functions of Bile Acids as a Feeding Signal, and Regulation of Metabolic Response to Feeding by Food Factors	FY2015-2019	147,700
16H06379	MAKINO Amane 70181617	Tohoku University, Graduate School of Agricultural Sciences, Professor	Production of Super High-yielding Rice Plants for Environmental Conservation as the Green Evolution II	FY2016-2020	108,300

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
16H06380	TAKAYAMA Seiji 70273836	The University of Tokyo, Graduate School of Agriculture and Life Sciences, Professor	Molecular Mechanism and Evolution of Self-Incompatibility in Plants	FY2016-2020	140,800
16H06381	SAKO Yoshihiko 60153970	Kyoto University, Graduate School of Agriculture, Professor Emeritus	Comprehensive, Spatiotemporal Study and Applied Research of Carboxydotrophs	FY2016-2020	133,100
16H06382	ADACHI Yasuhisa 70192466	University of Tsukuba, Faculty of Life and Environmental Science, Professor	Environmental Interface Engineering Based on Dynamic Analysis of Colloidal Focculation	FY2016-2020	102,000
16H06383	MATSUDA Hiroshi 80145820	Tokyo University of Agriculture and Technology, Institute of Agriculture, Professor	Redefinition of intractable inflammatory diseases based on mast cell activation syndrome	FY2016-2020	144,900
17H06168	NISHIYAMA Makoto 00208240	The University of Tokyo, Biotechnology Research Center, Professor	Studies on mechanisms of biosynthesis of biomolecules via amino-group carrier protein and expansion of structural diversity of secondary metabolites	FY2017-2021	160,700
17H06169	ASANO Yasuhisa 00222589	Toyama Prefectural University, Faculty of Engineering, Professor	Development of soluble expression technology and utilization of enzymes from plants and animals	FY2017-2021	157,700
17H06170	UCHIDA Koji 40203533	The University of Tokyo, Graduate School of Agriculture and Life Sciences, Professor	Life science basis of short-lived reactive species originated from foods	FY2017-2021	157,100
17H06171	FUNAKAWA Shinya 20244577	Kyoto University, Graduate School of Global Environmental Studies, Professor	Establishment of “Minimum-loss” agriculture	FY2017-2021	148,500
17H06172	SHIRASU Ken 20425630	RIKEN, Center for Sustainable Resource Science, Group Director	Molecular elucidation of plant-pathogen interactions	FY2017-2021	156,100

○ Medicine, Dentistry, and Pharmacy（ 24 Projects ）

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05783	SEKIMIZU Kazuhisa 90126095	Teikyo University, Institute of Medical Mycology, Professor	Development of Novel Anti-Infectious Drugs Exhibiting Therapeutic Effects	FY2015-2019	154,500
15H05785	NAGATA Shigekazu 70114428	Osaka University, Immunology Frontier Research Center, Endowed Research Department Professor	Engulfment of Apoptotic Cells and Asymmetry of Plasma Membranes	FY2015-2019	118,100
15H05787	TANIGUCHI Tadatsugu 50133616	The University of Tokyo, Research Center for Advanced Science and Technology, Research Fellow	Elucidation of the Host’s Homeostatic Responses by the Regulation of Immune System and its Application to the Prevention and Treatment of Immunological Disorders	FY2015-2019	132,300
15H05788	FUJITA Toshiro 10114125	The University of Tokyo, Research Center for Advanced Science and Technology, Emeritus Professor	Development of a Novel Strategy for Life Style Disease through Exploration of the Roles of Mineral- and Gluco-Corticoids in Hypertension and Organ Dysfunction	FY2015-2019	153,800
15H05789	UEKI Kohjiro 00396714	The University of Tokyo, Graduate School of Medicine, Professor	Development of a Novel Anti-Aging Strategy by Elucidating the Mechanisms Regulating Aging through a Muscle Centric Organ Network	FY2015-2019	153,800
15H05790	KABASHIMA Kenji 00362484	Kyoto University, Graduate School of Medicine, Professor	Understanding the Mechanism How the Skin Responses to External Stimuli	FY2015-2019	147,000
15H05791	MORI Masaki 70190999	Kyushu University, Graduate School of Medical Science, Professor	Achievement of Highly Accurate Diagnosis of Early Pancreatic Cancer in Japanese Patients through a Comprehensive/ Integrated Approach	FY2015-2019	153,800

Research Project Number	Principal Investigator (Name, Researcher Number, Research Institution)		Title	Term of Project	Total (Thousand yen)
15H05792	MAEHARA Yoshihiko 80165662	Fukuoka Dental College, Faculty of Oral Dentistry, Guest professor	Development of Innovative Treatment Targeting the Sphere Formation Mechanism Involving Cancer Stem Cells	FY2015-2019	144,000
16H06384	TAKEMOTO Yoshiji 20227060	Kyoto University, Graduate School of Pharmaceutical Sciences, Professor	Innovative catalysts for the synthesis of large- and medium-sized molecules bearing glycopeptides	FY2016-2020	123,300
16H06385	MIURA Masayuki 50202338	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	Mechanisms and physiological functions of intercellular communication by cell death	FY2016-2020	140,900
16H06386	KUSUMI Akihiro 50169992	Okinawa Institute of Science and Technology Graduate University, Membrane Cooperativity Unit, Professor	Signal transduction by transient molecular complexes and its regulation by actin membrane skeleton: single-molecule tracking study	FY2016-2020	145,500
16H06387	SHIBUYA Akira 80216027	University of Tsukuba, Life Science Center for Survival Dynamics, Tsukuba Advanced Research Alliance, Professor	Regulation of innate immune responses by inhibitory immunoreceptors	FY2016-2020	142,600
16H06388	MIYAKE Kensuke 60229812	The University of Tokyo, Institute of Medical Science, Professor	The study on the molecular and cellular bases underlying the crosstalks between innate immunity and cell metabolism in lysosomes	FY2016-2020	140,900
16H06389	MIYAZAKI Toru 30396270	The University of Tokyo, Faculty of Medicine, Professor	Elucidation of the mechanism required for AIM activation, and its therapeutic application to NASH-induced hepatocellular carcinoma	FY2016-2020	133,800
16H06390	SAKAI Juro 80323020	Tohoku University, Graduate School of Medicine, Professor	Elucidation of lifestyle-related diseases development due to environmental factors and epigenetic memory	FY2016-2020	140,700
16H06391	AKASHI Koichi 80380385	Kyushu University, Graduate School of Medicine, Professor	Regulation of self-renewal vs. quiescence status in human myeloid leukemia stem cells	FY2016-2020	118,500
16H06393	NISHIMURA Riko 60294112	Osaka University, Graduate School of Dentistry, Professor	Development of innovative medical technology based on integrated understanding of both protection and destruction of articular cartilage homeostasis	FY2016-2020	139,900
17H06173	UCHIYAMA Masanobu 00271916	The University of Tokyo, Graduate School of Pharmaceutical Sciences, Professor	New Molecular Technologies to Open Up Multiple Applications of Light in Life Science and Materials Science	FY2017-2021	163,300
17H06174	IWAI Kazuhiro 60252459	Kyoto University, Graduate School of Medicine, Professor	Extensive analyses of the LUBAC ubiquitin ligase	FY2017-2021	157,100
17H06175	YOSHIMURA Akihiko 90182815	Keio University, School of Medicine, Professor	Immune systems involved in the resolution of inflammation and tissue repair	FY2017-2021	158,300
17H06176	SATO Toshiro 70365245	Keio University, School of Medicine, Professor	Gaining Integrative Understanding of Gastrointestinal Disease Phenotypes through Establishment of an Organoid Library	FY2017-2021	159,000
17H06177	NISHINAKAMURA Ryuichi 70291309	Kumamoto University, Institute of Molecular Embryology and Genetics, Professor	Kidney reconstitution and disease modeling based on nephron induction methods in vitro	FY2017-2021	157,100
17H06178	YAMASHITA Toshihide 10301269	Osaka University, Graduate School of Medicine, Professor	Generation of neural network repair medicine	FY2017-2021	158,600
17H06179	IMAI Yumiko 50231163	National Institute of Biomedical Innovation, Health and Nutrition, Laboratory for Regulation of Intractable Infectious Diseases, Project Leader	Identification of higher-order-epigenetic modification machineries and development of potential novel therapeutics in severe virus infection	FY2017-2021	150,900

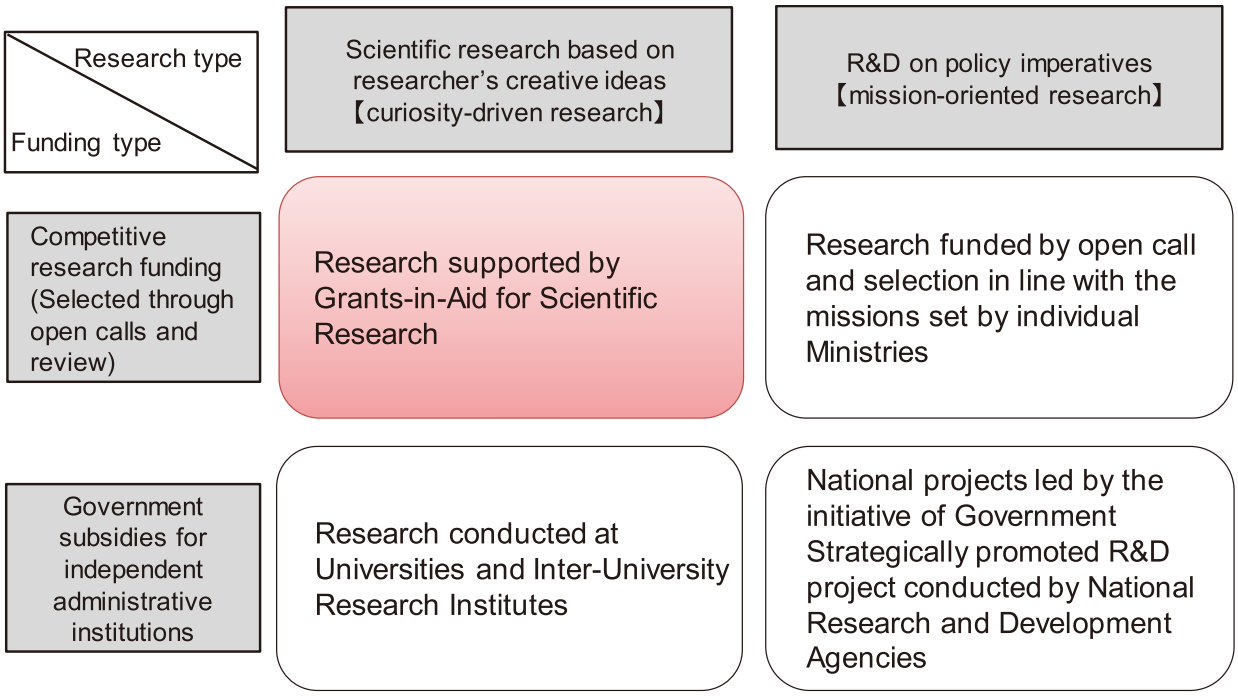
Reference

I. Outline of the Grants-in-Aid for Scientific Research-KAKENHI-

1. Purpose and Character of Grants-in-Aid for Scientific Research-KAKENHI-

Grants-in-Aid for Scientific Research (hereinafter referred to as "KAKENHI") are competitive funds that are intended to promote development of scientific research (based on original ideas of researchers), encompassing basic to applied researches in all fields ranging from humanities and social sciences to natural sciences. The grants provide financial support for creative and pioneering research projects that will become the foundation of social development. The research projects are selected by peer-review process.

The placement of "KAKENHI" in the policy on the promotion of science, technology and scientific research in Japan



2. Research Categories

Different research categories of KAKENHI listed below are provided so as to meet the variety of the research content and budget scale.

❖ As of September 2019

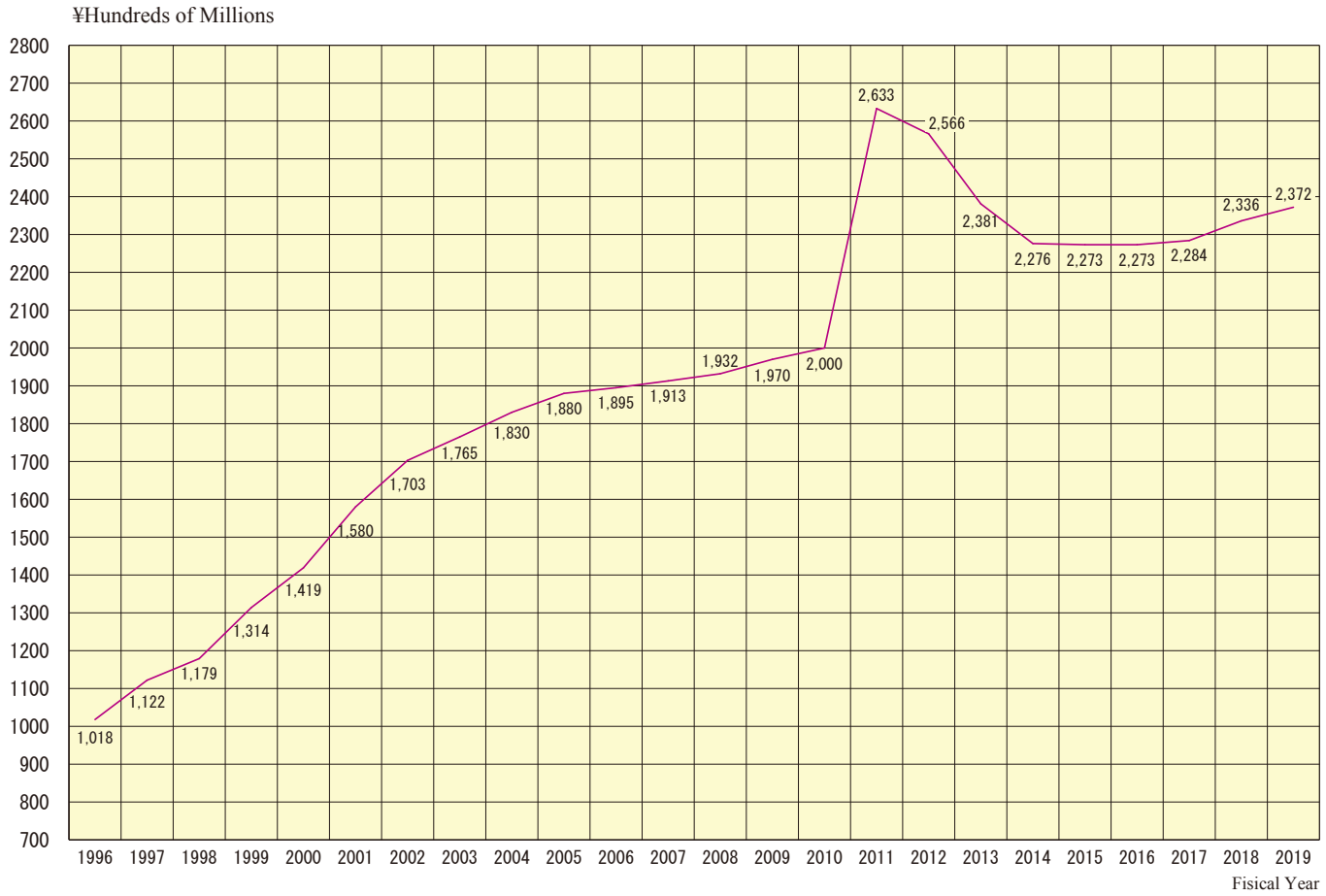
Research categories	Purposes and description of each research category	Type of fund*1	
Grants-in-Aid for Scientific Research			
Grant-in-Aid for Specially Promoted Research	Outstanding and distinctive research conducted by one or a relatively small number of researchers expected to achieve remarkably excellent research results that open up a new scientific field. (The research period is 3 to 5 years. In a truly necessary case, period up to 7 years is acceptable.) The budget ranges from 200 million to 500 million yen (only in a truly necessary case, budget exceeding 500 million yen is asked for.).	SG	
Grant-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area)	This category is intended to foster novel research areas proposed by diverse groups of researchers that are expected to lead to development and heightening of Japan's research level in the respective fields, to be conducted by collective research efforts through collaboration, scholarly training, shared use of equipment, etc. (The period is 5 years. The budget range is generally set between 10 million to 300 million yen per fiscal year per proposed area.)	SG	
Grant-in-Aid for Scientific Research	(S): Creative/pioneering research conducted by one or a relatively small number of researchers. 5 years (in principle) 50 million to 200 million yen (A), (B), (C): Creative/pioneering research conducted by one researcher or jointly by multiple researchers. (A) 3 to 5 years 20 million to 50 million yen (B) 3 to 5 years 5 million to 20 million yen (C) 3 to 5 years 5 million yen or less	(S)	SG
		(A)	SG
		(B)	SG
		(C)	MF
Grant-in-Aid for Challenging Research (Pioneering/Exploratory)	Research conducted by a single or multiple researchers that aims at radically transforming the existing research framework and/or changing the research direction and has a potential of rapid development. The scope of the (Exploratory) category encompasses research proposals that are highly exploratory and/or are in their budding stages. (Pioneering) 3 to 6 years 5 million to 20 million yen (Exploratory) 2 to 3 years 5 million yen or less	Pioneering	SG
		Exploratory	MF
Grant-in-Aid for Young Scientists	[No new proposals have been called since FY2017.] (A), (B): Research conducted individually by a researcher of age 39 or younger. (A) 2 to 4 years 5 million to 30 million yen (B) 2 to 4 years 5 million yen or less	(A)	SG
		(B)	MF
Grant-in-Aid for Early-Career Scientists	[A call for proposals started from FY2018.] Research conducted by an individual researcher (*2) who is less than 8 years after Ph.D. acquisition. As a transitional measures, a non-Ph.D. researcher who is 39 years old or younger can also apply. 2 to 4 years 5 million yen or less	MF	
Grant-in-Aid for Research Activity Start-up	Research conducted by a single researcher who has been freshly appointed to a research position, or who has returned from his/her maternity, childcare or other kinds of leave. Up to2 years Up to 1.5 million per fiscal year	MF	
Grant-in-Aid for Encouragement of Scientists	Research conducted by an individual who is ineligible for application for other KAKENHI categories (e.g. Individuals who belong to educational or research institutions, private companies, etc. and engage in the researches to contribute to the promotion of the science). 1 year 100 thousand to 1 million yen	SG	

*1 SG: Series of Single-year Grants, MF: Multi-year Fund

*2 Individuals who are in the prospect of acquiring Ph.D. are also eligible. When counting the years after Ph.D. acquisition, the period of maternity leave and childcare leave can be excluded.

Grant-in-Aid for Special Purposes	Research projects of pressing urgency and importance.	MF
Grant-in-Aid for Publication of Scientific Research Results		SG
Publication of Research Results	Subsidy for publication and/or international dissemination of research achievements of high academic values executed by academic associations and other organizations.	
Enhancement of International Dissemination of Information	Subsidy for efforts by academic societies and other scholarly organizations to strengthen international dissemination of academic information for the purpose of international academic exchange.	
Scientific Literature	Subsidy for academic publication of research results (books) authored by an individual or a group of researchers.	
Databases	Subsidy for creation and operation of a database open to public use by an individual or a group of researchers.	
Grant-in-Aid for JSPS Fellows	Funding period is up to 3 years for research conducted by JSPS Fellows (including Foreign JSPS Fellows). As for Cross-border Postdoctoral Fellowship (CDP) the period is up to 5 years	SG
Fund for the Promotion of Joint International Research		MF
Fostering Joint International Research	(A) Support of joint international research project conducted by a KAKENHI grantee in collaboration with researcher(s) at foreign university or research institution. Over a period of 6 to 12 months. The grant seeks to markedly advance research plans for the root research project and to foster independent researchers who can be internationally competitive. (The budget is up to 12 million yen.) (The category name is changed from FY2018 call for proposals.) (B) Support of joint international research project conducted by multiple domestic researchers and a researcher who belongs to overseas research institution. In addition to the development of scientific research, the grant seeks to build out infrastructure of joint international research or further strengthen joint international research and to foster researchers who can be internationally competitive. (The period is 3 to 6 years. The budget is up to 20 million yen.)	
International Activities Supporting Group	Support of international activities within Scientific Research on Innovative Areas. (Set period of the Area, up to 15 million yen per fiscal year) *After FY2018 call for proposal, “International Activities Supporting Group” have been incorporated into “Grant-in-Aid for Scientific Research on Innovative Areas “Administrative Group”.	
Home-Returning Researcher Development Research	Support of research to be conducted by a Japanese researcher with current affiliation abroad who is to be newly appointed at university or research institution in Japan. (The period is up to 3 years. The budget is up to 50 million yen.)	
Generative Research Field	[No new proposals have been called since FY2020.] This category set for “Scientific Research (B/C)” is open to research proposals for which review within the conventional framework of research fields may be difficult and/or to applicants who prefer their proposals to be screened from a broader perspective relevant to the Generative Research Field. (The research period that can be applied for differs depending on the year of application.)	MF

3. Changes in Budgets



Fisical Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Budget (¥hundreds of millions)	1,018	1,122	1,179	1,314	1,419	1,580	1,703	1,765	1,830	1,880	1,895	1,913	1,932	1,970	2,000	2,633	2,566	2,381	2,276	2,273	2,273	2,284	2,336	2,372
Year-on-year increase (%)	10.2	10.2	5.1	11.5	8.0	11.3	7.8	3.6	3.7	2.7	0.8	0.9	1.0	2.0	1.5	31.7	−2.5	−7.2	−4.4	−0.1	−0.1	0.5	2.3	1.5

4. Actual Subsidization of Grants-in-Aid for Scientific Research for FY2019

(1) New Projects

As of October 2019

Research category	Number of proposed projects: Applications	Number of proposed projects: Applications approved	Approval rate	Amount allocated	Amount allocated per project: Average	Amount allocated per project: Maximum
				Thousands of Yen	Thousands of Yen	Thousands of Yen
Grants-in-Aid for Scientific Research	〔 101,337 〕 **100,258**	〔 25,562 〕 **28,612**	〔 25.2 〕 **28.5**	〔 61,417,400 〕 **65,391,370** **【 19,617,411 】**	〔 2,403 〕 **2,285**	〔 145,100 〕 **150,900**
Specially Promoted Research	〔 105 〕 **106**	〔 12 〕 **12**	〔 11.4 〕 **11.3**	〔 1,123,500 〕 **1,123,000** **【 336,900 】**	〔 93,625 〕 **93,583**	〔 145,100 〕 **150,900**
Scientific Research on Innovative Areas (Research in a proposed research area)	〔 6,158 〕 **5,079**	〔 1,011 〕 **966**	〔 16.4 〕 **19.0**	〔 6,383,500 〕 **6,184,070** **【 1,855,221 】**	〔 6,314 〕 **6,402**	〔 139,400 〕 **103,700**
Scientific Research	〔 58,322 〕 **60,225**	〔 15,825 〕 **16,931**	〔 27.1 〕 **28.1**	〔 40,764,600 〕 **42,726,700** **【 12,818,010 】**	〔 2,576 〕 **2,524**	〔 105,100 〕 **91,600**
Scientific Research (S)	〔 704 〕 **659**	〔 80 〕 **81**	〔 11.4 〕 **12.3**	〔 3,279,800 〕 **3,114,800** **【 934,440 】**	〔 40,998 〕 **38,454**	〔 105,100 〕 **91,600**
Scientific Research (A)	〔 2,454 〕 **2,412**	〔 605 〕 **605**	〔 24.7 〕 **25.1**	〔 7,310,100 〕 **7,116,900** **【 2,135,070 】**	〔 12,083 〕 **11,763**	〔 32,900 〕 **35,000**
Scientific Research (B)	〔 11,577 〕 **11,396**	〔 2,965 〕 **3,327**	〔 25.6 〕 **29.2**	〔 15,170,200 〕 **16,862,200** **【 5,058,660 】**	〔 5,116 〕 **5,068**	〔 12,800 〕 **13,400**
Scientific Research (C) (*)	〔 43,587 〕 **45,758**	〔 12,175 〕 **12,918**	〔 27.9 〕 **28.2**	〔 15,004,500 〕 **15,632,800** **【 4,689,840 】**	〔 1,232 〕 **1,210**	〔 3,200 〕 **3,100**
Challenging Research	〔 12,634 〕 **11,514**	〔 1,508 〕 **1,469**	〔 11.9 〕 **12.8**	〔 3,832,100 〕 **3,808,000** **【 1,142,400 】**	〔 2,541 〕 **2,592**	〔 17,500 〕 **17,500**
Challenging Research (Pioneering)	〔 823 〕 **699**	〔 82 〕 **81**	〔 10.0 〕 **11.6**	〔 595,500 〕 **564,400** **【 169,320 】**	〔 7,262 〕 **6,968**	〔 17,500 〕 **17,500**
Challenging Research (Exploratory) (*)	〔 11,811 〕 **10,815**	〔 1,426 〕 **1,388**	〔 12.1 〕 **12.8**	〔 3,236,600 〕 **3,243,600** **【 973,080 】**	〔 2,270 〕 **2,337**	〔 4,500 〕 **4,800**
Young Scientists (*)	〔 20,369 〕 **19,590**	〔 6,256 〕 **7,831**	〔 31 〕 **40.0**	〔 8,273,100 〕 **10,130,700** **【 3,039,210 】**	〔 1,322 〕 **1,294**	〔 3,100 〕 **3,200**
Research Activity Start-up (*)	〔 3,749 〕 **3,744**	〔 950 〕 **1,403**	〔 25.3 〕 **37.5**	〔 1,040,600 〕 **1,418,900** **【 425,670 】**	〔 1,095 〕 **1,011**	〔 1,200 〕 **1,100**
Fund for the Promotion of Joint International Research	〔 2,335 〕 **1,599**	〔 234 〕 **280**	〔 10 〕 **17.5**	〔 673,300 〕 **749,900** **【 224,970 】**	〔 2,877 〕 **2,678**	〔 8,900 〕 **7,100**
Fostering Joint Interntional Research (B)(*)	〔 2,335 〕 **1,599**	〔 234 〕 **280**	〔 10 〕 **17.5**	〔 673,300 〕 **749,900** **【 224,970 】**	〔 2,877 〕 **2,678**	〔 8,900 〕 **7,100**
Total	〔 103,672 〕 **101,857**	〔 25,796 〕 **28,892**	〔 24.9 〕 **28.4**	〔 62,090,700 〕 **66,141,270** **【 19,842,381 】**	〔 2,407 〕 **2,289**	〔 145,100 〕 **150,900**

Notes:
1. "Specially Promoted Research", "Scientific Research on Innovative Areas (Research in a proposed research area)", "Scientific Research" (excluded Generative Research Fields), "Challenging Research" (excluded Generative Research Fields Review Divisions), "Young Scientists", "Research Activity Start-up", and "Fund for the Promotion of Joint International Research (Fostering Joint Interntional Research (B))" are listed.
2. The figures in 〔 〕 indicate the previous fiscal year.
3. The figures in 【 】 indicate indirect expense (excluded from the total).
4. (*)As these rants are covered under the Multi-year Fund, the columns "Amount allocated" and "Amount allocated per project" are calculated based on the projects' initial lans for FY 2019.
5. Due to roundin off, the total and breakdown figures may not agree.

(2) New and Ongoing Projects

As of October 2019

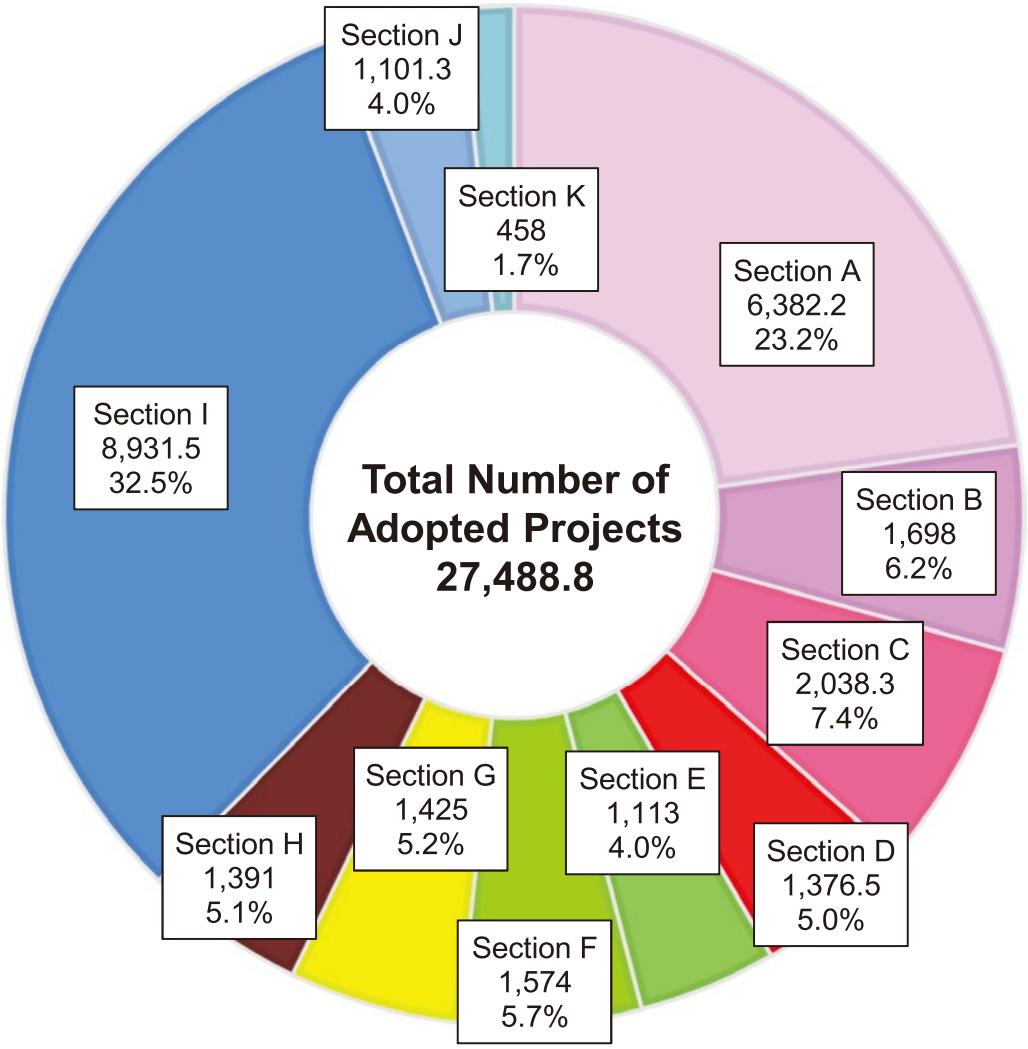
Research category	Number of proposed projects		Applications allocated	Amount allocated per project	
	Applications	Applications approved		Average	Maximum
			Thousands of Yen	Thousands of Yen	Thousands of Yen
Grants-in-Aid for Scientific Research	〔 150,916 〕 **149,988**	〔 74,861 〕 **78,113**	〔 162,277,303 〕 **163,914,123** **【 49,174,237 】**	〔 2,168 〕 **2,098**	〔 162,400 〕 **178,200**
Specially Promoted Research	〔 160 〕 **158**	〔 67 〕 **64**	〔 5,447,500 〕 **5,168,000** **【 1,550,400 】**	〔 81,306 〕 **80,750**	〔 162,400 〕 **178,200**
Scientific Research on Innovative Areas (Research in a proposed research area)	〔 7,741 〕 **6,674**	〔 2,594 〕 **2,561**	〔 21,749,272 〕 **21,185,325** **【 6,355,598 】**	〔 8,384 〕 **8,272**	〔 139,400 〕 **103,700**
Scientific Research	〔 91,892 〕 **94,617**	〔 49,292 〕 **51,253**	〔 104,598,250 〕 **106,484,798** **【 31,945,439 】**	〔 2,122 〕 **2,078**	〔 105,100 〕 **91,600**
Scientific Research (S)	〔 1,045 〕 **988**	〔 421 〕 **410**	〔 12,075,400 〕 **11,475,800** **【 3,442,740 】**	〔 28,683 〕 **27,990**	〔 105,100 〕 **91,600**
Scientific Research (A)	〔 4,063 〕 **4,046**	〔 2,202 〕 **2,229**	〔 18,879,700 〕 **18,913,260** **【 5,673,978 】**	〔 8,574 〕 **8,485**	〔 32,900 〕 **35,000**
Scientific Research (B) (*1)	〔 18,059 〕 **18,113**	〔 9,402 〕 **9,984**	〔 35,319,050 〕 **37,580,338** **【 11,274,101 】**	〔 3,757 〕 **3,764**	〔 12,800 〕 **13,400**
Scientific Research (C) (*2)	〔 68,725 〕 **71,470**	〔 37,267 〕 **38,630**	〔 38,324,100 〕 **38,515,400** **【 11,554,620 】**	〔 1,028 〕 **997**	〔 3,200 〕 **3,100**
Challenging Research	〔 14,305 〕 **13,781**	3,179 〕 **3,736**	〔 7,259,900 〕 **8,158,500** **【 2,447,550 】**	〔 2,284 〕 **2,184**	〔 17,500 〕 **17,500**
Challenging Research (Pioneering)	〔 917 〕 **874**	176 〕 **256**	〔 1,102,400 〕 **1,416,300** **【 424,890 】**	〔 6,264 〕 **5,532**	〔 17,500 〕 **17,500**
Challenging Research (Exploratory) (*2)	〔 13,388 〕 **12,907**	3,003 〕 **3,480**	〔 6,157,500 〕 **6,742,200** **【 2,022,660 】**	〔 2,050 〕 **1,937**	〔 4,500 〕 **4,800**
Young Scientists (*2)	〔 20,369 〕 **25,653**	〔 6,256 〕 **13,894**	〔 8,273,100 〕 **16,212,700** **【 4,863,810 】**	〔 1,322 〕 **1,167**	〔 3,100 〕 **3,200**
Young Scientists (A) (*1,3)	〔 980 〕 **604**	〔 956 〕 **575**	〔 3,675,917 〕 **1,839,171** **【 551,751 】**	〔 3,845 〕 **3,199**	〔 13,200 〕 **8,800**
Young Scientists (A) (*2,3)	〔 9,302 〕 **3,808**	〔 9,270 〕 **3,808**	〔 8,424,400 〕 **2,657,800** **【 797,340 】**	〔 909 〕 **698**	〔 2,600 〕 **2,200**
Research Activity Start-up	〔 4,695 〕 **4,686**	〔 1,775 〕 **2,215**	〔 1,799,463 〕 **2,207,829** **【 662,349 】**	〔 1,014 〕 **997**	〔 1,500 〕 **1,800**
Fund for the Promotion of Joint International Research	〔 2,335 〕 **1,856**	〔 234 〕 **537**	〔 673,300 〕 **1,786,600** **【 535,980 】**	〔 2,877 〕 **3,327**	〔 8,900 〕 **11,100**
Fostering Joint Interntional Research (B) (*2)	〔 2,335 〕 **1,856**	〔 234 〕 **537**	〔 673,300 〕 **1,786,600** **【 535,980 】**	〔 2,877 〕 **3,327**	〔 8,900 〕 **11,100**
Total	〔 153,251 〕 **151,844**	〔 75,095 〕 **78,650**	〔 162,950,603 〕 **165,700,723** **【 49,710,217 】**	〔 2,170 〕 **2,107**	〔 162,400 〕 **178,200**

Notes:

1. This chart combines the figures for newly selected and continuing projects.
2. "Specially Promoted Research", "Scientific Research on Innovative Areas (Research in a proposed research area)" , "Scientific Research" (excluded Generative Research Fields), "Challenging Exploratory Research", "Challenging Research" (excluded Generative Research Fields Review Divisions), "Young Scientists", "Research Activity Start-up", and "Fund for the Promotion of Joint International Research (Fostering Joint International Research (B))" are listed. As for “Challenging Exploratory Research”, since only seven extended projects remains, its details included in the "Grants-in-Aid for Scientific Research" total.
3. The figures in 〔 〕indicate the previous fiscal year.
4. The figures in 【 】indicate indirect expense (excluded from the total).
5. (*1)Amomg these projects, there are projects selected in from FY2013 to FY2014 that are partially covered under the Multi-year Fund; their columns “Amount allocated per project” are calculated based on the projects' initial plans for FY 2019.
6. (*2)As these grants are covered under the Multi-year Fund, the columns “Amount allocated" and “Amount allocated per project" are calculated based on the projects' initial plans for FY 2019.
7. (*3)Only continuing projects are included.
8. Due to rounding off, the total and breakdown figures may not agree.

5. Chart for the Budget by Research Section (FY2019)

New Projects



Notes:
1. For Medium-sized and Basic Sections where there are multiple corresponding Broad Section, the number of adopted cases and the allocated amount are apportioned proportionally.
2. "Specially Promoted Research", "Scientific Research on Innovative Areas (Research in a proposed research area)" (planned research or invited research), "Scientific Research" (excluded Generative Research Fields), "Challenging Research" (excluded Generative Research Fields Review Divisions), "Young Scientists", and "Fund for the Promotion of Joint International Research (Fostering Joint International Research (B))" are included. ("Research Activity Start-up" is not included because the review is performed by individual review section.)
3. Due to rounding off, the total and breakdown figures may not agree.

Inquiries:

Scientific Research Aid Division, Research Promotion Bureau,
Ministry of Education, Culture, Sports, Science & Technology
3-2-2 Kasumigaseki, Chiyoda-ku, Tokyo 100-8959
Tel: +81-3-6734-4094
(in charge of Scientific Research on Innovative Areas(Research in a proposed research area))
URL: https://www.mext.go.jp/a_menu/shinkou/hojyo/main5_a5.htm

Research Aid Division II, Research Program Department,
Japan Society for the Promotion of Science
5-3-1 Kojimachi, Chiyoda-ku, Tokyo 102-0083
Tel: +81-3-3263-4254 (in charge of Specially Promoted Research)
Tel: +81-3-3263-4388 (in charge of Scientific Research (S))
URL: https://www.jsps.go.jp/english/e-grants/grants.html