Attached Table 2 Research Outline of Research Areas Showed on Attached Table 1

When applying for Publicly Offered Research, the applicant should note the following points.

- Research period is 2 years (Application of research period other than this period is not subject to screening).

- The Principal Investigator cannot set up a team of project members together with a Co-Investigator. (However, Research Collaborator is allowed to participate in research project when necessary.)

- Please be aware that the maximum application amount listed is not the total amount for the research period (two years) but the amount equal to a single fiscal year.

- It is possible to receive grants for up to 2 projects in Publicly Offered Research.
  In case that there are no projects of Publicly Offered Research for which grants has currently been received, it is possible to apply and receive grants for new 2 projects. However, it is not possible to apply and receive grants for 2 projects in the same research area.
  In case that grants have been received for 2 projects continuation of which will be in FY2024 in Publicly Offered Research, it is not possible to apply for another project.

- Please refer to the website of each research area for the details of application contents.

Research Outline of Research Areas

Human behavioral science for subjectification (“tojisha-ka”) by interaction-based & rule-/story-based understanding of the brain & the world
https://tojishaka.net/english/

Number of Research Area	:	21A101	Term of Project :	FY2021-2025
Head Investigator	:	KASAI Kiyoto		
Research Institution	:	The University of Tokyo Hospital		

1. Details of Research Area

People with minority characteristics that do not match the world designed to be predictable for the majority have developed the knowledge that noticing the discrepancy between their own rules/stories and those of the world is the beginning of recovery. Learning from this, we consider rules and stories as follows. When humans interact with the world, if the same event is repeated many times, the brain internalizes it as a rule and uses it to predict the next situation, which is defined as rule-based process. On the other hand, story-based process is defined as the internalization of a single event in the world as an episode, a position, and its transition with a spatio-temporal beginning and end point. If we define rule-/story-based process in this way, it is possible that this two-dimensionality is the basic mode of recognizing and internalizing the environment and events by the brain in animals in general including humans. Furthermore, the cognitive process by which human beings find and internalize rules and stories in the world when they earnestly interact with the real world, which is difficult to predict and difficult to follow, is defined as "tojisha-ka”. We will elucidate the adolescent developmental process and mechanism of “tojisha-ka” through academic innovation that integrates the academician's own “tojisha-ka”, co-production with user researchers with minority characteristics, and the integrative sciences.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

Research group A01 calls for theoretical research that constructs a brain model of the individual-world interaction loop that can be applied to population science based on reinforcement learning theory, game theory, etc. However, cognitive enhancement research using AI, etc., should be submitted after careful consideration of the possibility that the research results will be enjoyed exclusively by the majority, leading to increased social disparity. For A02, we are looking for empirical research on the individual-world interaction loop and the process of “tojisha-ka” through population science using domestic and international adolescent cohorts. For A03, we expect research proposals on the interaction of era, generation, geography, and gender in the individual-world interaction loop that integrate a wide range of academic methods, including evolutionary science, brain science, social psychology, cultural psychology, medical anthropology, and sociology. The subject can be a large group or a small number of individuals, and the analysis method can be either quantitative or qualitative. However, if the results of the analysis of animal collective behavior are to be used to interpret the nature of human groups, please apply after careful scientific and ethical consideration so as not to merely endorse the mechanisms that have caused social disparities in human history. For B01, we are looking for psychological and behavioral analysis research on the mechanism of “tojisha-ka” and the process of adolescent development, especially based on the understanding of the rule-/story-based process in the individual-world interaction. Theoretical studies and intervention studies using methods such as user-led research, complex systems science, and knowledge science are also eligible. B02 calls for research on experimental animals or human subjects that will lead to the elucidation of the brain basis of “tojisha-ka”. We expect new research proposals that address the brain basis for modeling the individuals' interactions with the world. Research that deals only with the elemental functions of the brain by simply reading prediction/prediction error, episodic memory, and the formation/elimination of fear conditioning as rule-based or story-based function is not eligible. Despite conventional dichotomy of rule-based process as targets in natural science and story-based process as those in humanities and social science, this research area is expected to produce results that will lead to an integration of these two fields, as well as the integration of Planned Research A: Research on Interaction Loop and Planned Research B: Research on Rule/Story (see the area website). We welcome applications from young researchers, female researchers, and user researchers with diverse backgrounds. With the support of the Coordinating Team, we hope that researchers will actively participate in the academic transformation of “tojisha-ka” themselves and co-production of research with user researchers.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Population neuroscience of brain-behavior model of “tojisha-ka” based on individual brain-world interaction loop	Large-scale research : 5.2 Small-scale research : 3	Large-scale research : 5 Small-scale research : 10
A02	Population science of real-world process of `tojisha-ka” based on individual-world interaction loop		
A03	Elucidation of era, generation, and gender effects of individual brain-world interaction loop		
B01	Behavioral science of rule-/story-based process during “tojisha-ka” and co-production		
B02	Neuroscience of rule-/story-based process during “tojisha-ka”		

Research Outline of Research Areas

Integrated Sciences for Sustainable Human-Aqua Environment
https://mizu kyosei.net

Number of Research Area	:	21A102	Term of Project :	FY2021-2025
Head Investigator	:	ARAYA Kunio		
Research Institution	:	Kyushu University, Faculty of Social and Cultural Studies		

1. Details of Research Area

The hydrosphere environment, which is essential for life, is constantly subject to "fluctuations" caused by a variety of internal and external factors, such as climate change, ecosystem transition, and changes in social conditions related to water. As the range of these "fluctuations" increases, human society and ecosystems will be greatly affected by frequent weather disasters, water resource conflicts, and loss of biodiversity. Reducing these water crises and risks, and realizing a society where water, humans, and creatures can coexist in a sustainable manner, is an internationally important issue. In this Research Area, we consider the hydrosphere environment as a "water cycle system" established by the interaction of the geosphere, biosphere, and anthroposphere. We aim to create a new academic area, "Aqua Science," with the main objective of elucidating the historical transition and current dynamics of the balance among these three spheres, exploring ways to solve social issues related to the water environment in line with local conditions, and proposing a vision for the future.

There are four research plans under three Research Groups targeting the geosphere (A), anthroposphere (B), and biosphere (C) in this Research Area. Planned Research A01 is to create information to understand the interaction between the geosphere, biosphere, and anthroposphere dynamically from the viewpoint of the water cycle based on the measurement and analysis of information on water and the surrounding environment, and to develop an information translation approach necessary for utilizing the information in other Planned Research. Planned Research B02 is to dynamically clarify the fluctuation of the water cycle system from the past to the present from the viewpoint of social culture and history, and to extract the socio-cultural factors that should be protected or modified in order to create a desirable water symbiotic society. Planned Research B03 will empirically analyze, from the standpoint of economics, what kind of water use methods are suitable for realizing healthy and prosperous lives in regions where water resources are scarce and water infrastructure is poor, and what kind of management measures and systems are necessary to conserve and improve the water environment to explore the ideal form of sustainable water resource governance. Planned Research C01 will assess the health of the basin ecosystem system by investigating the characteristics of the ecosystem and biodiversity that form the basis of the "basin sphere" where the natural environment surrounding water and human society and culture coexist to explore ways to conserve, restore, and sustainably use the water cycle system in ecosystems.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In the Publicly Offered Research, proposals are invited to elucidate the dynamics of the water cycle system, explore ways to solve social issues related to the water environment in line with local conditions, and propose a vision for the future to create Aqua Science. There are four Research Groups (A01, B02, B03, and C01) related to Planned Research and two Research Groups (D01 and E01) related to the entire Research Area, which aim to adopt about 7 research plans with an upper limit of 1.1 million yen per year and about 8 research plans with an upper limit of 3.6 million yen per year. Examples for each Research Group are shown below. For details, please refer to our website.

Research Group A01 calls for research that addresses social issues related to the water environment with other Planned Research Groups through the development and utilization of information on water and its surrounding environment. Research Group B02 calls for research on society, culture, and behavior related to the dynamics of the water circulation system. Specifically, research that addresses the socio-cultural factors involved in the creation of Aqua Science and research that contributes to the development of future visions and scenarios is expected. Research Group B03 invites applications that create Aqua science through research on waterborne diseases and poverty in developing countries, research on agricultural water use and water pollution, research on water quality management and agricultural management, historical research on water resource allocation issues among industrial sectors, historical empirical analysis of water resource use and water-related disasters, and research on the history of water and sewage system development. In Research Group C01, research on empirical clarification of the basin ecosystem is expected for the creation of Aqua Science, including economic approaches to realize a regional circulation symbiosis zone in the basin ecosystem, construction of a biological monitoring system using environmental DNA, and research proposals on bio-environment interactions in the basin ecosystem using stable isotopes. Research Group D01, which is related to the entire Research Area, calls for research on the relationship between the water cycle system and human activities. Research Group E01, which is also related to the entire Research Area, calls for research on the interaction between the geosphere, biosphere, and anthroposphere regarding water. The accepted researchers are expected to actively participate in the research activities of each Planned Research and the entire Research Area, especially in the joint field research. Young and female researchers are expected to actively apply for any of the Research Groups. An environment that facilitates the participation of diverse researchers will be created, such as enabling remote participation in web conferences and setting hours that take into consideration researchers of child-rearing age.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Research on the development and utilization of information on water and its surrounding environment	1.1 3.6	7 8
B02	Research on fluctuations in the water cycle system and society, culture, and behavior		
B03	Research on various problems related to water use and water environment, and countermeasures against them		
C01	Research on empirical clarification of basin ecosystems		
D01	Research on the relationship between the water cycle system and human activities		
E01	Research on the interaction among the geosphere, biosphere, and anthroposphere regarding water		

Research Outline of Research Areas

Qualia Structure: Bridging a gap between subjective conscious experience and scientific objectivity by establishing a super interdisciplinary research program

https://sites.google.com/monash.edu/a2023-2027/home_english

Number of Research Area : 23A101 Term of Project : FY2023-2027
Head Investigator : Naotsugu Tsuchiya
Research Institution : Advanced Advanced Telecommunications Research Institutes International

1. Details of Research Area

Do subjective consciousness and the brain as objective matter belong to completely different domains? How are qualia, the contents of consciousness, related to the brain? The question of consciousness and the brain is not only of scientific interest. It is also directly related to everyday situations associated with difficulties in understanding feelings in others. Quality of experience, or qualia, is difficult to verbalize. To avoid this difficulty, conventional studies of consciousness have focused on the experimental paradigms, where experience can be reducible to a binary judgment (e.g., seeing vs. not seeing) by fixing perceptual stimuli, then they tried to isolate the neural correlates of consciousness. Recently, we have established a new paradigm to characterize Qualia Structures: by measuring a massive number of similarity judgements between a range of visual qualia. From there, we are to reveal their neural correlates and their information structures. This Research Area will expand the Qualia Structure paradigm by adding phenomenological studies, cognitive development, and constructivist approaches. By targeting perceptual and emotional qualia, this Research Area aims to establish the Qualia Structure paradigm. The outcome of this Research Area includes a better understanding of the consciousness of others, including animals and artifacts, aiming to address the issues that matter in real society.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The overall aim of this Research Area is to understand the relationship between the structure of qualia and the structure of information obtained from brain information. Towards this aim, this Research Area takes the following basic strategy: 1) to focus on perception and emotional qualia, 2) to employ various theoretical and empirical methods, which generates synergy between them. However, with this limited strategy, it is difficult to arrive at our ultimate goal of a better understanding of the consciousness of others in a way that tackles the issues in real society. Thus, we invite Publicly Offered Research to collaborate with our Planned Research. In particular, those research that 1) deals with **research topics or employing methods, which are not employed by Planned Research**, 2) deals with **qualia with a structural approach,** 3) without focusing on a particular type of qualia, deals with **the relationship between the unconscious and consciousness**, **self-consciousness, changes of qualia structures associated with changes in levels of consciousness** (e.g., dreams, sleep, anesthesia, etc.). Those Publicly Offered Research will be overseen by relevant Planned Research to enable effective collaboration. We hope to attract those represented less in the field (e.g., young, female, or non-Japanese researchers) to participate, either individually or in teams with collaborators. To promote diverse participants, meetings in Research Areas will be recorded via web conferencing as much as possible, and consideration will be given to researchers of child-rearing age. The selected researchers will be expected to actively participate in the research activities of this Research Area, such as public relations through YouTube and SNS, the Qualia Summer School (from 2024~) to promote this Research Area to be recognized at the international level. The following summarizes some example projects. See our website for details.

A01: Using large-scale online experiments, try to deal with qualia for value, beauty, and free will. Approaches from ethics, aesthetics, and religious studies are welcomed. Similarities and other methods can be used to visualize their qualia structures. Mathematical approach such as quantum cognition, topological data analysis.
A02: Philosophy, religious studies, aesthetics. Dealing with the relationship between embodiment, culture, and qualia.
A03: Human infants and mammals: comparative cognitive-behavioral research in atypical development (other than autism). Qualia structure approach from cultural psychology, evolutionary studies, etc.
B01: Qualia structure research by brain measurement and manipulation.
C01: Qualia structure research using information structure and model research and real neuronal data.
C02: Constructivism research using AI and robots (natural language processing, cognitive robotics, etc.). Also, research related to symbol emergence and consciousness in linguistics, sociology, cultural anthropology, etc.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Budget (M JPY/year)	# of projects to be selected
A01	Experimental psychology and mathematics of qualia structures	5 3	10 10
A02	Phenomenological studies of qualia structures		
A03	Typical/atypical development of qualia structures		
B01	Measuring/manipulating brain activity related to qualia structures		
C01	Correspondence between informational structures and qualia structures		
C02	Symbol emergence from qualia structures		
D01	Unconsciousness, self, levels of consciousness and qualia structures		

Research Outline of Research Areas

Integrative bioarchaeological studies on human prehistory in the Japanese archipelago
http://i-bioarchaeology.org

Number of Research Area	:	23A102	Term of Project :	FY2023-2027
Head Investigator	:	YAMADA Yasuhiro		
Research Institution	:	Tokyo Metropolitan University, graduate school of Humanities		

1. Details of Research Area

Prehistoric archaeology is currently at a major turning point. It is clear that the results of many conventional, pure archaeological research methods, are forced to be revised due to recent results of natural scientific analyses.
Today, it is no longer possible to understand the real picture of the past using purely traditional archaeological methods. In order to escape from this crisis, archeology itself needs to shift from the traditional humanities academic field and be reborn as a new academic field.
Therefore, we advocate for the construction of a new form of integrative bioarchaeology, a comprehensive academic field that takes bioarchaeology and other current archaeological methods mainly focusing on excavated materials such as human bones, animal and plant remains, etc. in Japan and interweaves them with natural scientific methods such as radiocarbon dating, isotope analysis, and genomic analysis.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The research area of this project consists of the following 11 Planned Research.
A01: Research on the social structure of prehistoric humans using archaeological methods,
A02: Research on the relationships among prehistoric peoples using genomic data and osteological features,
A03: Research on age, dietary restoration, and migration through the isotopic analysis of prehistoric bone,
B01: Elucidation of the formation process of prehistoric humans in the Japanese archipelago,
B02: Establishment of prehistoric humans and culture in Hokkaido,
B03: Establishment of prehistoric humans and culture in the Ryukyu Islands,
B04: Establishment of prehistoric humans and culture in the Honshu, Shikoku, and Kyushu regions,
B05: Research on the population dynamics of prehistoric humans,
C01: Research on paleoenvironmental changes in the Japanese archipelago,
C02: Research on artificial environment formation (fauna) by prehistoric humans,
C03: Research on artificial environment formation (flora) by prehistoric humans.
The aim of this project is to improve the quality of research and help advance the field in this Research Area, to further the broaden the scope of research in this entire field, and to recruit for focus areas not currently covered. If possible, we expect research application to cover multiple Research Groups. Please refer to the homepage of the relevant research area for details of the contents of recruitment for each Research Group. In addition, we welcome active applications from female and early career researchers to help further the goal of fostering and supporting female and young researchers and their research pursuits.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Research on Yayoi period tomb systems and social structure in Eastern Japan	2 5	10 6
A02	Research on the environmental conditions and kinship structures at archaeological sites using osteological features and genomic data		
A03	Research on stable isotopic ratio mapping and the creation of an isotopic ratio database		
B01	Research on a high-resolution reconstruction of coastline changes in the Japanese archipelago in the late Pleistocene		
B02	Group Formation Theory, Ethnicity/Racial Theory, Multispecies Research, Environmental Change Research		
B03	Research on the movement and exchange of people, material goods, and culture in the Nansei Islands and Kyushu		
B04	Research on human migration and inter-regional networks in the Jomon, Yayoi, and Kofun periods		
B05	Research on population dynamics in the Yayoi and Zoku-Jomon periods		
C01	Environmental archaeological research on prehistoric human migration and population change based on high-precision climate change data		
C02	Research on the relationship between humans and animals in the Japanese archipelago using archaeological and genomic analyses		
C03	Research on the relationship between humans and plants in the Japanese archipelago using archaeological and genomic analyses		

Research Outline of Research Areas

Establishing the Field of "Dignity Studies": Toward an Interdisciplinary Paradigm of Social Integration Based on the Concept of Dignity

https://songengaku.jp/

Number of Research Area : 23A103 Term of Project : FY2023-2027
Head Investigator : KATO Yasushi
Research Institution : Sugiyama Jogakuen University, School of Cross-Cultural Studies

1. Details of Research Area

The concept of dignity originated with Cicero's translation of Plato's "*axia*" (the inner value of human beings) as "*dignitas*".
In England, "dignity" became associated with social position or status and was characterized as a value that could increase or decrease. In contrast, Kant characterized it as an "internal absolute value" that cannot fluctuate, and regarded it as normative. After the two World Wars, this concept emerged as an ideal that supported the new international and social order, and it became an object of legal interest. E.g., in international contexts, conventions against gender discrimination and ableism tend to highlight the importance of "human dignity". In the field of bioethics, "dignity" has also been used to promote an appropriate social acceptance of medical technologies in questions of brain death, organ transplantation, genome editing, and death with dignity. In that sense, AI technologies (especially chatbots like ChatGPT), robots, big data, etc., also need to be examined from the ethical perspective of dignity. Also, in the "Basic Guidelines" of the Ministry of Health, Labor and Welfare in Japan, the dignity of animals is explicitly mentioned.
In this way, the concept of "dignity" has been incorporated into the foundations of social and international order as an ideal for integration. However, when "human dignity" was introduced into the EU constitution, differences in content between Germany's objectivist "*Menschenwürde*" and the UK's subjectivist "human dignity" were pointed out. While the concept of "dignity" has been used as an ideal to solve social issues, it faces the problem of lacking a comprehensive interpretation and definition. Hence, we aim to integrate diverse academic fields, including natural sciences, and comprehensively discuss the concept of dignity while also seeking to establish the clinical and praxis-oriented field of "Dignity Studies".

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The framework of this research area consists of "theoretical and conceptual historical research" (A01-04), "clinical applied research" (B01-05), as well as "social implementation" (C01). In order to establish the field of "Dignity Studies," it is necessary to base it on fundamental research. Therefore, we will examine the value-based justification of "dignity" and, based on this, construct a conceptual history that includes the non-Western world. Based on the research results, we will analyze the clinical application of advanced science and medical technology. Moreover, we will examine the concrete implementation of the concept of dignity in society by applying it to various educational settings and develop through it the concept of dignity. The open call for publicly offered research proposals will complement the above plan. We welcome proposals that will offer perspectives and arguments that are not envisioned in this research area, even critical ones.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Philosophical Possibilities of Absolute Value	1	16
A02	History of the concept of dignity (Ancient and Medieval Western Philosophy)		
	History of the concept of dignity (Contemporary Western Modernity)		
A03	A study on view of human in traditional cultures in non-Western countries		
	A study on present conditions of human rights in developing countries		
A04	The concept of 'dignity' in the non-Western world		
	Gender and the concept of 'dignity' in world philosophy		
B01	Dignity provisions in the constitutions of Asian countries and their interpretation		
	The concept of dignity in social security and employment insurance		
B02	Dignity in the international relations		
B03	Research on Human/Personal Dignity in Clinical Psychiatry		
B04	Robots and Gender		
	Artificial Intelligence and War		
B05	Reproductive Technology and Ethics		
	Advanced Biotechnology and Human Dignity		
C01	Research on "Dignity Education" in Japan and the World		

Research Outline of Research Areas

The Natural Laws of Extreme Universe--A New Paradigm for Spacetime and Matter from Quantum Information
https://www2.yukawa.kyoto-u.ac.jp/~extremeuniverse/en

Number of Research Area	:	21A201	Term of Project :	FY2021-2025
Head Investigator	:	TAKAYANAGI Tadashi		
Research Institution	:	Kyoto University, Yukawa Institute for Theoretical Physics		

1. Details of Research Area

Conventionally, physics has explained the laws of nature using time, space, and matter as its basic building blocks. However, in the extreme situations in nature (which we call the "extreme universe" in our area), due to the strong quantum nature of the target physical systems, the degrees of freedom of space, time, and matter themselves fluctuate enormously, and existing theoretical approaches in physics face difficulties in the following three limits: the "limit of space" (quantum theory of black holes), the "limit of time" (quantum theory of cosmology), and the "limit of matter" (dynamics of quantum matter). However, as soon as the field of quantum information emerged in the 21st century, this new way of looking at things began to bring dynamic changes to physics. For example, the extreme universe based on quantum gravity can be regarded as an accumulation of quantum information, while such accumulation of quantum information also provides a highly accurate numerical analysis method for quantum materials called tensor network. In addition to the limits of space, time, and matter, this Research Area aims to bring together researchers involved in the study of the "limit of information" (quantum information), and to promote interdisciplinary research beyond the boundaries of existing fields toward the ultimate laws of physics associated with the various problems in the extreme universe.

The goals of Planned Research are as follows. In the limit of space, the quantum theory of black holes is to be clarified and verified by integrating the viewpoint of quantum information into the gauge-gravity correspondence (B01), ultra-cold atom experiments (B02), and the general relativity (B03). In the limit of time, we explore quantum theory of cosmology by introducing quantum information theoretic ideas into quantum gravity (C01), quantum Hall experiment (C02) and cosmology (C03). In the limit of matter, we aim to reveal the dynamics of quantum matter by incorporating the concept of quantum information into quantum field theory (D01) and quantum many-body problems (D02). In addition, A01 will promote theoretical research on quantum information, and bridge the latest progress in quantum information research to physics of the extreme universe. Another important objective of this area is to promote international research on the extreme universe in the light of quantum information, and to actively encourage young researchers. Through these efforts, we aim to realize the above research goals and to transform physics into a discipline suitable for the era of quantum information.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

This Research Area brings together various researchers in quantum information and physics to study quantum information and the extreme universe (quantum theory of black holes, quantum theory of cosmology, and dynamics of quantum matter). We also aim to create new developments beyond conventional research fields. In addition to research directly related to Research Groups A01-D02, we expect theoretical and experimental proposals complementary to Research Groups or those covering multiple research topics above. For example, various research on quantum information theory such as quantum computational complexity, quantum algorithms, quantum cryptography, quantum communication, and quantum error correction; research related to the implementation of quantum computers; applications of tensor networks, quantum circuit models, and quantum computers for simulating physical systems; studies on strongly correlated matter, quantum many-body systems and their non-equilibrium dynamics; gauge/gravity correspondence and quantum field theory; cosmology and numerical relativity; experiments related to the above. In addition, experimental research of highly controllable systems like qubit systems, and new approaches based on experiments and observations in the fields of elementary particles, atomic nuclei, and cosmology are also envisaged. We also appreciate innovative ideas connecting quantum information and physics, as well as bridging theory and experiment. In addition, we welcome proposals promoting international collaborations and fostering next-generation researchers such as graduate students. For details of Research Groups, please refer to the homepage of this Research Area.

The upper limit of the annual budget is set at 2 million yen and 3.5 million yen per year, depending on the scale of the research; 2 million yen is mainly for theoretical research, while 3.5 million yen is mainly for experimental research.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
E01	Theoretical or Experimental Research on Quantum Information	3.5	6
E02	Theoretical Research on Extreme Universe	2	16
E03	Experimental Research on Extreme Universe		

Research Outline of Research Areas

Creation of Materials by Super Thermal Field: Neo-3D printing by Manipulating Atomic Arrangement through Giant Potential Gradient

http://www.mat.eng.osaka-u.ac.jp/super3dp

Number of Research Area	:	21A202	Term of Project : FY2021-2025
Head Investigator	:	KOIZUMI Yuichiro	
Research Institution	:	Osaka University, Graduate School of Engineering	

1. Details of Research Area

The target of this area is the mechanisms of unique crystal growth under superthermal fields generated by local heating by electron beams or lasers, which have been found to occur in metal 3D printing (3DP). Studies to be conducted include advanced in-situ observations, such as high-speed temperature field analysis, synchrotron X-ray transmission imaging, and laser irradiation in a transmission electron microscope, focusing on the occurrence of absolute stability, as well as numerical simulations using computational thermal fluid dynamics, phase-field method, molecular dynamics, precisely matched to the experiments to elucidate the mechanisms. Furthermore, artificial intelligence to analyze the process of microstructure to structure performance correlation and establish the Science for Creation of Materials by Superthermal Field, which contributes to the creation of new materials, such as 3DP of high-quality single-crystals. The outcomes will contribute to a great novelty in materials science.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The followings describe the scope of planned research for the groups A01, A02, A03, the publicly offered research for each. Researches that can be linked to the scope, or that will open new developments to the cited research fields, are welcomed. For more information, see the website of this area.

Research Group A01 "Construction of Digital Research Infrastructure for Superthermal Field Material Fabrication Science"

【Digital twin science for creation of materials by super-thermal field (A01-a)】 In-process monitoring of a 3DP and computer simulation to evaluate the dynamic changes of the superthermal field. **《Expected proposal》** Advanced analytical methods such as *in-situ* measurement of crystal orientation in 3DP processes, large-scale, high-accuracy, computer simulations of melting, fluid flow, crystal growth, microstructure formation, and diffusion. **【Materials informatics for creation of materials by super thermal field (A01-b)】** Discovery of the laws in the relationships among the process, thermal field, microstructure, and material properties. Derivation of the parameters for the simulation byA01-a. **《Expected proposal》** Monitoring big data analysis, the creation of microstructure-property correlation data, computer simulation, image sharpening processing (in collaboration with A02).

Research Group A02 "In-situ and Precise Analysis of Crystal Growth under Superthermal Field"

【Micro-dynamics of crystal growth by superthermal field (A02-a)】 *In-situ* observation by synchrotron X-ray imaging of rapid melting, rapid solidification, and crystal growth in superthermal field. **《Expected proposal》** Improvement of resolution of imaging, the advanced analysis of imag data, *in-situ* observation of crystal growth by various of microscopy (in collaboration with A01 and A03). **【Lattice defects analysis of materials created by superthermal field (A02-b)】** Analysis of microstructure, composition, stress, strain, and lattice defects using advanced analytical methods such as electron microscopy, neutron diffraction, and positron annihilation. **《Expected proposal》** Atom probe tomography, theoretical and simulation research on defect formation, the evaluation of lattice defects by various methods, and 3D observation by serial sectioning tomography.

Research Group A03 "Fabrication of Transcendental Materials Utilizing Superthermal Fields"

【Science for creation of super-titanium by superthermal field (A03-a)】 Development of lightweight and heat-resistant super-titanium materials by controlling crystal orientation and microstructure using superthermal fields **《Expected proposal》** Analysis of thermal stress with crystal anisotropy (in collaboration with A01 and A02), measurement of fundamental properties of the new titanium alloys, strengthening and fracture mechanisms of 3DP titanium alloys and related materials, and advanced research using advanced methods. **【Science for creation of biomaterials by super thermal field (A03-b)】** Improvement of metallic implant devices by controlling mechanical biocompatibility through crystal orientation control of biomedical metallic materials by using superthermal fields, and by surface fabrication using superthermal fields. **《Expected proposal》** Computer simulation of surface fabrication in 3DP process by superthermal field (in collaboration with A01 and A02), and molecular orientation control and surface fabrication of polymer materials by superthermal field. **【Science for creation of ceramic materials by super thermal field (A03-c)】** Establishment of the academic basis for the fabrication of new ceramics materials by applying superthermal fields to melt growth, gas phase growth, and solid particle deposition, direct observation of crystal growth front. **《Expected proposal》** Research on interactions between lasers and inorganic crystalline materials, correlations with atomic bonding, and heterogeneous absorption due to microstructure.

Research Group B01"Groundbreaking Research" Researche that brings new aspects to the materials creation in superthermal fields in new matters such as molecular crystals, low-dimensional materials, organic materials, MOF, soft matter, polymer materials, and semiconductors, formation of new ultra-temperature fields, thermodynamic theory research in ultra-temperature fields, and operando measurement methods.

3. Research Group, Upper Limit of Annual Budget and Number of research projects to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Digital twin science for creation of materials by super-thermal field (A01-a)	3.5	16
	Materials informatics for creation of materials by super thermal field (A01-b)		
A02	Micro-dynamics of crystal growth by super thermal field (A02-a)		
	Lattice defects analysis of materials created by super thermal field (A02-b)		
A03	Science for creation of super-titanium by super thermal field (A03-a)		
	Science for creation of biomaterials by super thermal field (A03-b)		
	Science for creation of ceramic materials by super thermal field (A03-c)		
B01	Groundbreaking research		

Research Outline of Research Areas

Science of Slow to Fast Earthquakes
https://slow-to-fast-eq.org

Number of Research Area	:	21A203	Term of Project :	FY2021-2025
Head Investigator	:	IDE Satoshi		
Research Institution	:	The University of Tokyo, Graduate School of Science		

1. Details of Research Area

Slow earthquakes, first discovered in the 21st century, result from shear deformation like previously recognized fast earthquakes, but they do not radiate strong seismic waves. As our understanding of slow earthquakes deepens, the relationship between slow and fast earthquakes, including large earthquakes, has become a high research priority. To update earthquake science based on a comprehensive understanding of slow and fast earthquakes and to make a quantitative forecast of future earthquakes, we have launched a research initiative: Science of Slow-to-Fast Earthquakes in 2021.

The critical question for a comprehensive and holistic understanding is "How and when does a slow earthquake become a fast earthquake?" and this question involves many related questions. Answering these questions requires the cooperation of researchers from many different fields. In addition to geophysics (seismology and geodesy), understanding crustal materials cannot be achieved without inputs from geology and geochemistry. Studies of earthquake rupture and frictional sliding are underpinned by fundamental physics. Developments in instrument technology open new avenues for geophysical observation, and application of information science and statistical methods can extract information from the large and expanding earthquake datasets.

This research initiative inherits the DNA of the research project "Science of Slow Earthquakes." Following the strategy of the previous research project, we promote collaborative research in various fields and incorporate technological innovations progressing in related fields. The initiative is organized around a core of six Research Groups (A01 Experimental Physics, A02 Structural Anatomy, A03 International Comparison, B01 New Technology Observation, B02 Information Science, and B03 Model Prediction), supported by Publicly Offered Research projects to be solicited this time.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

We plan to fund 22 projects with maximum annual budgets of either 2 or 4 million yen (see below). The research plan for each proposed project should match with one or more of research activities of the six Research Groups. The projects include research on slow earthquakes, but also research on ordinary earthquakes and research that is aware of the connection between earthquakes and society. Proposal from women, young researchers, non-Japanese researchers, etc. that contribute to increasing diversity in the field are also very welcome.

Research Group A01: Research on physical and chemical processes of slow-to-fast phenomena. Rock/analog experiments considering in-situ environments, scale, and geometry effects; theoretical physical modeling of non-equilibrium states.

Research Group A02: Research on the structure and state of the slow-to-fast earthquake zone. Geophysical survey for structure and materials; field observation, experiments, and modeling to clarify deformation, reaction, fluid movement, etc.

Research Group A03: International comparative study on regional characteristics of seismological structure, resistivity, and friction parameters; research for various slow-to-fast phenomena, such as landslides, volcanism, and mud volcanism.

Research Group B01: Development of instruments and methods with higher spatial and temporal resolution and lower noise; Comparison of the accuracy of developed instruments with existing instruments; multi-scale and multi-method observations

Research Group B02: Various data-driven research. Discovery of new phenomena; investigation of interactive phenomena; development of methods to characterize seismic wavefields; construction of seismic catalogs to understand scaling laws

Research Group B03: Modeling of static and dynamic deformation to understand of slow-to-fast earthquakes; modeling and forecast of seismicity and shaking using numerical simulations; research for social advice on slow-to-fast phenomena.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Physicochemical processes in slow-to-fast phenomena	4	6
A02	Anatomy of Slow-to-Fast seismogenic zones		
A03	SF Eqs through comparison across global subduction zones		
B01	Development of multiscale observation techniques	2	16
B02	Data-driven discovery & monitoring of Slow-to-Fast earthquakes		
B03	Multiscale modeling and forecast of Slow-to-Fast earthquakes		

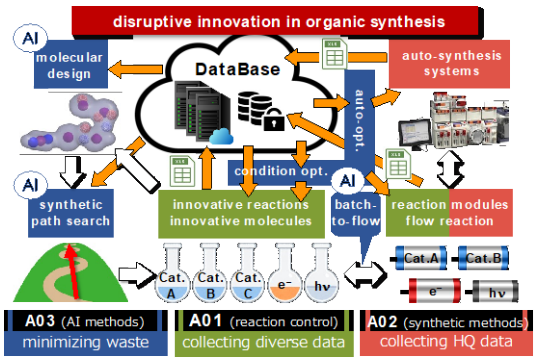
Research Outline of Research Areas

Digitalization-driven Transformative Organic Synthesis (Digi-TOS)
https://en.digi-tos.jp/

Number of Research Area : 21A204 Term of Project : FY2021-2025
Head Investigator : OHSHIMA Takashi
Research Institution : Kyushu University, Graduate School of Pharmaceutical Sciences

1. Details of Research Area

Synthetic organic chemistry plays a vital role in manufacturing by transforming readily available organic materials into complex and valuable molecules. With the advent of digitalization, the field is undergoing significant changes. There is an urgent need to establish a foundation for digital organic synthesis—a fusion of experimental (synthetic organic chemistry) and information sciences—that leads to disruptive innovations. This research area focuses on developing automated methods that leverage artificial intelligence (AI) techniques, such as molecular design, synthetic pathway search, optimization of reaction conditions, batch-to-flow conversion, and autonomous synthesis systems. The aim is to eliminate waste, accelerate innovation, and create novel reactions and molecules. Additionally, we will construct our own specialized database optimized for machine learning (ML) in organic chemistry to serve as the basis for automated methods development.



2. Call for Proposals and Expectations for Publicly Offered Research, etc.

This research area consists of three Research Groups: A01 (deepening reaction control with AI), A02 (deepening synthetic methods with AI), and A03 (deepening AI methods to support organic synthesis). The key to success lies in integrating synthetic organic chemistry and information science effectively. Rapid accumulation of reliable reaction data for ML and its utilization for verifying predictions or devised molecules, reaction conditions, and pathways in actual experiments are crucial. The Publicly Offered Research proposals for Groups A01 and A02 should contribute to providing data to the database and utilize AI and ML techniques, while those for Group A03 must collaborate with experimental groups.

Research Group A01 aims to develop innovative reactions with advanced control (reversal) of selectivity and elucidate their mechanisms. In the Publicly Offered Research, we welcome researchers interested in exploring diverse "novel reactions" that go beyond the scope of the Planned Research. Proposals should actively leverage ML techniques for optimizing reaction conditions and catalyst design. Thorough analysis of reaction mechanisms is essential, and we encourage proposals that utilize ML methods for in-depth analysis.

Research Group A02 focuses on promoting automation of organic synthesis and applying new scientific principles. Proposals are sought for the development of solid-phase support methods for catalysts, converting batch reactions to flow reactions, highly reliable systems for rapid data collection, and autonomous synthesis systems with automatic optimization of reaction conditions and in-line analysis.

Research Group A03 aims to deepen AI methods for organic synthesis, support Groups A01 and A02, and create a new theory of informatics through interdisciplinary collaboration. Proposals are invited to contribute to the discovery of innovative chemical reactions, enhance development efficiency through parameter optimization, identify key factors controlling reactions, and develop AI methods for understanding and predicting reaction mechanisms. Novel molecular (reaction) generation techniques suitable for organic chemistry diversity and research on synthetic route design, including retrosynthetic analysis, are encouraged. Proposals integrating computational science and ML are expected, particularly those exploring innovative and creative ML methods beyond simple predictive model construction.

Since this research area integrates data science and organic synthesis, joint research must reaffirm data recognition. To construct our next-generation, ML-optimized database, we plan to collect side reaction and negative data not typically available publicly, along with comprehensive chemoselectivity data using a functional group evaluation kit. We encourage researchers who comprehend the research area's objectives, can contribute to data provision (closed, shared, and open stages), and structure the data to apply. Active participation in various project research and contribution to overall research progress in this area are welcomed. We particularly encourage young and female researchers to apply.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Deepening reaction control with AI support	3.5	16
A02	Deepening synthetic method with AI support	3.5	8
A03	Deepening AI methods to support organic synthesis	3.0	7

Research Outline of Research Areas

Bottom-up creation of cell-free molecular systems: surpassing nature
https://bottomup-biotech.elsi.jp /en/

Number of Research Area	:	21A205	Term of Project :	FY2021-2025
Head Investigator	:	MATSUURA Tomoaki		
Research Institution	:	Tokyo Institute of Technology, Earth-Life Science Institute		

1. Details of Research Area

In this Research Area, we aim to construct molecular systems which have capabilities that exceed those of natural cells, or that natural cells do not possess, from the bottom up. Outcomes of this research will have applied and social impacts, e.g., material production, drug discovery, sensing, environmental and energy technology, etc.

Research on the bottom-up biology has progressed substantially around the world, resulting in reconstituted molecular systems that mimic various cellular functions and properties. However, the bottom-up construction of molecular systems aimed at applied and socially relevant goals has seldomly been pursued. Moreover, there are a limited number of examples of constructing molecular systems from the bottom-up which utilize the concept of Darwinian evolution to screen for an optimal combination of multiple components among various combinations, suggesting that research which incorporates continuous trials followed by selection may dramatically improve bottom-up research outcomes. In this Research Area, we define cell-free molecular systems as those constructed from defined molecules and materials from the bottom up, without using cells or organelles themselves as components. To construct cell-free molecular systems that can contribute to practical and applied goals, we will combine biomolecules, organic compounds, polymers, and micro- and nano-devices, while utilizing theoretical studies. In addition, we will search for optimum combinations of components, as nature has done in the course of Darwinian evolution, and elucidate the interactions among the components. In this way, we will construct a molecular system in which the components are highly functional by virtue of evolved interactions, and simultaneously systematize the methodology to create such systems.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

We invite a wide range of researchers working on Research Group F01 and F02.

Research Group F01: Experimental work on bottom-up construction of cell-free molecular systems. Research proposals aiming to construct cell-free molecular systems that contribute to practical applications (material production, drug discovery, sensing, environmental/energy technology, etc.) by combining biomolecules, organic compounds, polymers, nano/microdevices, etc. are solicited. The components of molecular systems are not limited to those mentioned earlier. Researchers from a wide range of fields such as biophysics, bioengineering, applied physics, applied chemistry and nano-, micro-technology, are expected. Research on the construction of molecular systems which use as components living cells or organelles, and research on the construction of systems consisting of a single molecular species are out of scope. In addition, research aimed merely at the construction of molecular systems that mimic natural cellular functions are also out of scope.

Research Group F02: Theoretical studies that contribute to the construction of cell-free molecular systems. Research proposals are solicited that aim to design cell-free molecular systems composed of multiple components, or theories for optimizing cell-free molecular systems and the design of their constituent using statistical science, AI, MD, etc. Research proposals that aim to construct theories and implement them in experimental themes in collaboration with Planned Research Groups are desired but not mandatory. A wide range of fields such as mathematical science, information science, systems engineering, biophysics, and bioinformatics is expected. For details of each Planned Research Group, please refer to the area website.

The Principal Investigators of the Publicly Offered Research have access to the “Center for Systems Materials” and the “Center for Measurements and Analysis” organized and run by the Planed Research Groups (see the website for details). Proposals that assume the use of materials and methods provided by the Centers are encouraged.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
F01	Experimental work on bottom-up construction of cell-free molecular systems	4	21
F02	Theoretical studies that contribute to the construction of cell-free molecular systems	4	4

Research Outline of Research Areas

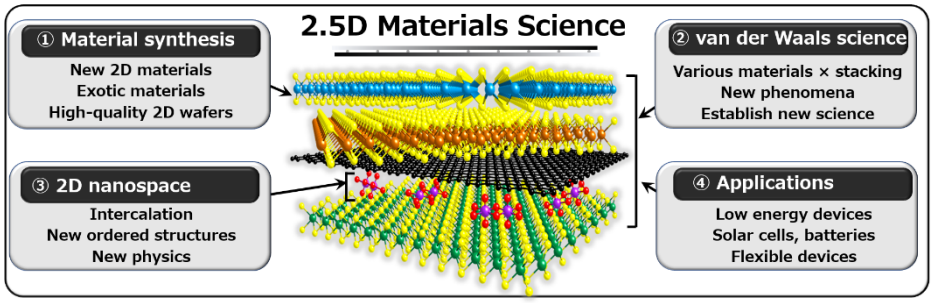
Science of 2.5 Dimensional Materials: Paradigm Shift of Materials Science Toward Future Social Innovation
http://25d-materials.jp/en/

Number of Research Area	:	21A206	Term of Project :	FY2021-2025
Head Investigator	:	AGO Hiroki		
Research Institution	:	Kyushu University, Global Innovation Center (GIC)		

1. Details of Research Area

Materials science has established the basis of our modern society through the development of emergent internet of things (IoT) technologies. Traditional materials science is mainly based on the precise control of bulk materials with rigid chemical bonds. On the other hand, two-dimensional (2D) materials, such as graphene, offer innovative approaches to create new materials by integrating different layers via van der Waals interaction. This is accomplished by stacking 2D materials with controlled compositions and stacking angles, an approach that is expected to significantly expand the frontiers of materials science. Furthermore, the well-defined 2D nanospace between the layers of stacked 2D materials provides opportunities to explore novel physical and chemical phenomena and to synthesize new materials.

In this Research Area we propose to explore the "Science of 2.5 dimensional materials" by introducing the concepts of "freedom of integration" and "2D nanospace", in combination with the synthesis of a wide variety of 2D materials. We aim to develop academic research based on this unique "2.5D" concept to achieve world-leading results, giving rise to upcoming future social innovation. This Research Area consists of five Research Groups (A01~A05), and all the members in this area collaborate closely to establish the new scientific field. In addition, the collaborations are supported by the joint research centers organized in this Area, allowing access to a wide range of facilities, such as automatic stacking equipment, to all the members.



2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In this Research Area, we are developing unique and novel 2.5D material research by integrating the strength of each member through extensive collaboration. Therefore, researchers applying to this Publicly Offered Research are strongly encouraged to provide a detailed plan of collaboration with some of our group members in addition to an original research plan. Applicants also should show how their proposed research can contribute to this Research Area.

Here, "0.5D" symbolizes the new degrees of freedom offered by 2D materials including material stacking, 2D nanospace science, and the integration of 2D materials with 0D, 1D, and 3D materials into mixed-dimensional heterostructures. Emergence of new materials, physical properties, and applications are expected through the introduction of this "0.5D" concepts in 2D materials research. The followings are the details of the intended candidates:

(1) Researchers studying 2D material and planning to develop 2.5D research through extensive collaborations
(2) Researchers who have not worked with 2D materials, but want to start 2.5D research based on their original concepts and techniques
(3) Researchers with specialized analysis techniques which are applicable to 2.5D materials
(4) Researchers studying theoretical physics and materials informatics that can form the basis of 2.5D research
(5) Researchers studying semiconductor devices, energy creation/storage, or areas that contribute to social innovation
(6) Young researchers and female researchers

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Materials synthesis for 2.5D structures	Experimental: 5 Experimental or theoretical: 3	4 15
A02	Assembly for 2.5D integrated structures		
A03	Development of analysis methods for 2.5D structures		
A04	Development of novel physical properties with 2.5D structures		
A05	Development of electronic, photonic, and energy applications with 2.5D structures		

Research Outline of Research Areas

1000-Tesla Chemical Catastrophe : Science of Chemical Bonding under Non-perturbative Magnetic Fields
https://ymatsuda.issp.u-tokyo.ac.jp/

Number of Research Area : 23A201 Term of Project : FY2023-2027
Head Investigator : MATSUDA Yasuhiro
Research Institution : University of Tokyo, Institute for Solid State Physics

1. Details of Research Area

Magnetic fields are essential to the formation of nature, but on the Earth, their effects are generally weak and perturbative. On the other hand, the strong magnetic field in space, which is 16 orders of magnitude larger than the Earth's magnetic field, gives non-perturbative magnetic field effects. In this research area, we use the recently developed 1000 T ultrahigh magnetic field to clarify the non-perturbative magnetic field effects in the nature on the Earth. The 1000-T magnetic field gives electron spins an energy change of 1350 K in terms of thermal energy, which exceeds the Curie temperature of the iron and the melting point of gold. The phenomenon of Chemical catastrophe, which is a destructive effect on chemical bonds, is expected to be realized in solids. From solids to molecules, biomolecules, elementary particles, and plasma, innovative phenomena such as the creation of new crystals by magnetic fields will allow us to explore the essence of the mechanisms that shape the natural world.

There are six Research Groups in the Planned Research: A01 Molecular Orbital Catastrophe, A02 Spin Catastrophe, A03 Band Electron Catastrophe, A04 Chemical Reaction Catastrophe, A05 Elementary Particle Universe Catastrophe, and A06 Magnetic Field Catastrophe Theory, each with one Planned Research project.

A01 to A03 are on solid-state physics. One of the chemical catastrophe phenomena is crystal deformation due to a magnetic field. Through the wave function shape, Zeeman effect, Landau quantization, etc., the crystal structure is optimized in a magnetic field, which makes it possible to create new crystals in a magnetic field that cannot be realized in a low magnetic field. Solid oxygen, which undergoes a phase transition from monoclinic to cubic at 120 T by reconfiguration of molecular steric configuration, is one of the typical examples, but the research objectives of the field are to expand the research to a wider range of target materials and to understand the phase transition mechanism quantum mechanically. In A04, the main research target is non-perturbative magnetic field effects on photochemical reactions in molecules and polymers. Non-perturbative effects of magnetic fields, including photoexcited states, on chemical reaction processes through the Zeeman effect and Lorentz force will be the subject of research. The correlation between chirality and spin currents and magnetic fields will also be utilized to create new molecules in high magnetic fields and to understand their formation mechanisms. A05 studies non-perturbative magnetic field effects on plasma and elementary particle phenomena. The following phenomena are studied: production, scattering, and decay reactions of dark matter and dark energy, birefringence and anomalous synchrotron radiation in a quantized vacuum, and shock waves, jet collimation, and magnetic reconnection in magnetized plasmas, which are expected to occur when catastrophic phenomena in outer space are reproduced. We will conduct ultrahigh magnetic field experiments using a variety of quantum beams. We will elucidate the mechanisms at the microscopic level of elementary particles and plasmas, and clarify the role of magnetic fields in extreme space environments. A06 aims to theoretically elucidate the non-perturbative magnetic field effects of ultrahigh magnetic fields of up to 1000 T in molecules, polymers, plasmas, and elementary particles, with a focus on solids.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

As Research Group B01, we invite applications for experimental and theoretical studies of catastrophic phenomena induced by non-perturbative magnetic field effects in solids. The research topics include crystal deformations induced by magnetic field control of the spatial extent of wavefunctions, violation of the effective mass approximation due to interference with the crystal period, structural phase transitions caused by competitions of the magnetic energy and several excitations, nonperturbative magnetic field effects on phonons, and so on. We expect proposals beyond the framework of conventional magnetic field research. Plans to complement the target material groups in Planned Researches A01-A03 are also welcome. Research Group B02 invites experimental and theoretical studies of nonperturbative magnetic field effects on chemical reactions of molecules and macromolecules, and biological phenomena. Proposals for target molecules, macromolecules, and biological materials that complement Planned Research A04, and studies of magnetic field effects on catalysis and artificial photosynthesis are expected. For Research Group B03, we expect experimental or theoretical studies that pioneer non-perturbative magnetic field phenomena in astrophysics and particle physics. Hadron physics, solar physics, and other research topics that are related to Planned Research A05 are also open to applications. Researchers with no previous experience in high magnetic field experiments are also eligible to apply, as technical guidance will be provided after the proposal is accepted. (It is expected that high magnetic field experiments will be conducted using the shared use system of domestic magnetic field facilities and the portable pulsed magnetic field equipment to be developed in this research area.)

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
B01	Non-perturbative magnetic field catastrophe in solids	Experiment 2.5 Theory 1.5	8 4
B02	Non-perturbative magnetic field catastrophe to chemical reactions	Experiment 2.5 Theory 1.5	3 3
B03	Non-perturbative magnetic field catastrophe to particles and space	Experiment 2.5 Theory 1.5	3 3

Research Outline of Research Areas

Unveiling, Design, and Development of Asymmetric Quantum Matters
https://asymmetry.hiroshima-u.ac.jp

Number of Research Area	:	23A202	Term of Project :	FY2023-2027
Head Investigator	:	ONIMARU Takahiro		
Research Institution	:	Hiroshima University, Graduate School of Advanced Science and Engineering		

1. Details of Research Area

In this research area, we transcend the understanding of electromagnetic effects such as cross-correlation response and non-reciprocal conduction that arose from the asymmetric electronic states in solids by employing the multipole concepts and develop innovative functions. Recent developments of quantum beam and physical properties measurements in high resolution facilitate the visualization of the orders of multipoles and the quantification of the susceptibility to the external fields. We construct a theoretical model describing the cross-correlation mechanism based on the obtained knowledge and it helps us to design new asymmetric quantum matters. We apply this model to molecular clusters, artificial materials, and broader target, to lead the evolution of next-generation material science and to frame the "asymmetronics". In planned research A01, we conduct microscopic analysis using quantum beams, and in A02, we develop new functions by combining microfabrication technology and various macroscopic measurements in high resolution. The theory group B01 constructs basic theoretical models that incorporate many-body effects and designs new materials. In C01, solid crystals are synthesized to develop new asymmetric quantum matters, and in C02, the strategy is to expand the material scales in wider range.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In publicly offered research, promotion of strong research collaboration in the research area is highly expected. Research that advances complementary with the planned research and that expands this research area are expected. The former involves various measurements of polarized quantum beams, precise macroscopic measurements using microfabricated samples, and research using advanced many-body numerical calculation techniques. The latter includes research that expand the concept of asymmetric quantum matters to softer and broader materials such as organic compounds and molecular clusters, as well as artificial substances. We welcome themes that utilize shared equipment, such as a cryogen-free low-temperature automatic measurement system and a focused ion beam processing equipment, or themes related to sophistication of the equipment. We expect applications from young researchers working on ambitious themes.

A01: Researches using advanced quantum beam analysis techniques to investigate the electronic states of asymmetric quantum matters and the order parameters of multipoles. For example, they include resonant inelastic X-ray scattering (RIXS), neutron PDF analysis, and fluorescent X-ray holography to clarify the electronic states.
A02: Experimental researches that will lead to technological innovation, such as providing new functions of matters and realizing a huge response by microfabrication and the practical application of anisotropic superconductivity. The concept is widely applied to organic chemistry and metamaterials to detect electrical, magnetic, thermal, and elastic cross-correlation responses and control them using various external fields.
B01: Theoretical researches that construct basic theories based on multipoles and promote its application. For example, theory to evaluate responses to external fields, elucidation of mechanisms of multipole order, applications to mesoscales, and development of new asymmetric quantum matters using first-principles calculations and materials informatics.
D01: Experimental researches that can collaborate with C01 and C02, with sufficient prospects for development of new materials, novelty of synthetic methods, and development and control of functional properties. A wide range of materials are objects based on a scale-seamless perspective, e.g., not only crystals without inversion symmetry, but also molecular clusters, metal complexes, organic compounds, and artificial materials such as metamaterials.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Probing Microscopic Properties of Asymmetric Quantum Matters through Quantum Beam Analysis	Theoretical: 1 Experimental: 2.5	6 13
A02	Exploring Novel Functionalities in Asymmetric Quantum Matters through Precise Measurements		
B01	Fundamental Theories and Theoretical Design of Asymmetric Quantum Matters		
D01	Development of Asymmetric Quantum Matters		

Research Outline of Research Areas

Materials Science of Meso-Hierarchy
https://mesohierarchy.jp/en/

Number of Research Area	:	23A203	Term of Project :	FY2023-2027
Head Investigator	:	YAGAI Shiki		
Research Institution	:	Chiba University, Graduate School of Engineering		

1. Details of Research Area

In this research area, we define "meso-hierarchical materials" as materials that are hierarchically self-assembled in the mesoscopic scale, and provide a platform for researchers to collaborate on supramolecular chemistry, design theory to induce meso-hierarchical structures, structure visualization technology, methodology for controlling energy levels of nano-structured materials through strong coupling by resonator, and characterization methods on mechanical properties of the meso-hierarchical materials. By promoting this research area through the collaboration of researchers from various research fields, we will accumulate knowledge and promote an integrated understanding of meso-hierarchical materials. This will establish the interdisciplinary field of "meso-hierarchical materials science" that links the nano to the macro, and will bring about an innovation in the creation of materials. Seven planned researches are being pursued: "synthesis" and "visualization" in A01, "photofunctional science" and "optical characterization" in A02, "stimulus-responsive materials" and "nonlinear response" in A03, and "theoretical computation" in B01. In the Publicly Offered Research, we expect research proposals that complement the above researches or are based on new ideas.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

C01 Synthesis and Characteriation of Meso-Hierarchical Structures: We welcome challenging research proposals that control self-assembly of organic and inorganic materials, or their hybrids in a hierarchical manner to realize structural control in the mesoscopic region. Organic molecules are expected to be π-electron molecules, functional dyes (preferably systems in which π-electron systems can interact to realize meso-scale exciton transfer), and functional biomolecules, etc. Inorganic materials are expected to be metal nanoclusters and quantum dots, etc. The meso-hierarchical structures can be of any morphology, but should not diverge to macroscopic scales without forming hierarchical structures. We also welcome research proposals that use original methods to analyze and observe the hierarchical structures that appear in the formation process of these materials. → Corresponding to Planned Research A01

C02 Analysis and Utilization of Photophysical/Mechanical Properties of Meso-Hierarchical Structures: Meso-hierarchical materials are expected to exhibit various physical properties based on the hierarchical structures. We expect proposals that elucidate optical and mechanical properties unique to meso-hierarchical materials, as well as research proposals that prepare materials that intentionally utilize these properties. For example, we welcome challenging and original research proposals on the control of the number of excitons and oxidized/reduced molecules via photoexcited states, long-range exciton transfer and its control by force, and physical property measurements of photofunctional mesohierarchical structures capable of energy amplification. → Corresponding to Planned Research A02　Also, research proposal for novel methods to analyze and visualize the mechanical properties unique to meso-hierarchical structures, or techniques for manipulating energy levels through resonator strong coupling. We also welcome applied research that proposes unique and novel applications, for example, meso-hierarchical mechano-functional materials and exciton circuits using ultra-long range exciton transfer. → Corresponding to Planned Research A03

C03 Theoretical Analysis of Meso-Hierarchy: A key to construct meso-hierarchical materials is to discover the fundamental theoretical principles that generate emergent phenomena as the system size increases from the atomic to the macroscopic level. We expect proposals for the construction of theories to analyze the formation mechanism and stability of meso-hierarchical structures, as well as their optical and dynamical properties and functions, and their application calculations. Theoretical researchers in not only molecular theoretical models such as quantum chemistry (first principles) calculations and (coarse-grained) molecular dynamics, but also in peripheral fields such as condensed matter theory, soft matter physics, and elasticity theory are welcome. → Corresponding to Planned Research B01

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
C01	Synthesis and Characterization of Meso-Hierarchical StructuresMeso-Hierarchy Synthesis and structural analysis of structures	3.5	12
C02	Analysis and Utilization of Photophysical/Mechanical Properties of Meso-Hierarchical Structures	3	6
C03	Theoretical Analysis of Meso- Hierarchy	2	5

Research Outline of Research Areas

Latent Chemical Space Based on Diverse Natural Products for Bio-active Molecular Design

https://latent.chemical.space

Number of Research Area	:	23A204	Term of Project :	FY2023-2027
Head Investigator	:	KIKUCHI Kazuya		
Research Institution	:	Osaka University, Graduate School of Engineering		

1. Details of Research Area

The discovery and identification of biologically active molecules using two typical compound resources, natural products (first) and synthetic compound libraries (second), has been a driving force in promoting chemical biology research, a field that integrates chemistry and biology. In this research area, we propose a third resource to follow these two. This third resource is virtually generated from the Latent Chemical Space, which is constructed by deep learning technology based on bioactivity data of natural products, and is realized in real space using robust organic synthesis. The Latent Chemical Space created by the fusion of natural products and informatics research will bring about a paradigm shift in data-driven chemical biology research and revolutionize the design of biologically active molecules. To realize this, we will launch the "Cyber Bioactive Molecule Design Lab" consisting of three groups: Chemical Biology, Informatics, and Organic Synthesis. The goal is to establish a new science of bioactive molecule design that can develop innovative molecules that lead to the clarification of new biological functions and to the seeds for pharmaceuticals and agrochemicals, starting from the compounds created from this third resource.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

We invite applications for research members to add depth and breadth to our research perspectives and backgrounds, and to strengthen our research system to achieve the goals of this research area, which aims to create new scientific principles for designing biologically active molecules by integrating chemical biology, informatics, and synthetic organic chemistry research. The goal is to create a new science of biologically active molecular design method. In order to achieve research objective, it is necessary to recruit a wide range of research topics that share the same sense of purpose and to accumulate successful research examples. In order to lay the foundation for the future development of the research field, we expect active applications from active female and young researchers who share the same vector of research goals. The following are the main points of the research topics for which applications are solicited.

For research item A01 (Chemical Biology Group), it is necessary to increase the variation of evaluation methods, and we invite applications from researchers who can strongly promote activity evaluation methods from unique viewpoints. In order to construct a high-quality compound potential space, a more comprehensive activity evaluation is desirable. For this purpose, we envision the adoption of group members specializing in bio-related chemistry and structural biology, which provide excellent activity evaluation methods and structural biological basis. Furthermore, we expect to receive applications from researchers specializing in natural product chemistry who are updating the first resource using original evaluation methods.

For research item B01 (Informatics Group), we are seeking researchers who can further expand the chemical latent space, which is constructed based on a deep learning method originally developed by the planned research members of this research area, from the knowledge of computer science. Specifically, we are widely inviting proposals for research on the application of latent spaces to virtual screening and chemoinformatics, the development of novel machine learning methods, and the learning and application of language models (not limited to natural language). Researchers specializing in deep learning, data mining, and graph information processing are also welcome, as this research area will collect various labeled data on compounds and organize them in graph data structures. Even if they have no previous experience in chemistry or biology, we expect applications from researchers who develop and apply excellent algorithms and methods in the fields of computer science and artificial intelligence.

In research item C01 (Organic Synthesis Group), the following two points will be pursued in parallel: (1) synthesis of novel bioactive candidate molecules derived from compound potential space, and (2) construction and expansion of a library of novel synthetic compounds based on bioactive molecules. In order to respond to the structural diversity of new molecules proposed by information analysis, it is important to advance and diversify the synthetic technologies possessed by this research area. Therefore, we expect applications from researchers who possess original technologies and high synthetic capabilities useful for the synthesis of complex molecules, and who can actively contribute to the deepening of the chemical space by working on the above items (1) and (2) through further advancement of these technologies.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Chemical Biology: Collection of bioactivity data from diverse compounds	3	7
B01	Informatics: Construction and application of latent chemical space		7
C01	Organic Synthesis: Construction of synthetic compounds for evaluation of biological activity		7

Research Outline of Research Areas

The creation of multi-messenger astrophysics -- The unified picture of dynamical universe driven by births of black holes
https://multimessenger.jp/en/

Number of Research Area	:	23A205	Term of Project :	FY2023-2027
Head Investigator	:	YOSHIDA Shigeru		
Research Institution	:	International Center for Hadron Astrophysics, Chiba University		

1. Details of Research Area

The gravitational energy produced by the mighty gravity of black holes has been the primary energy source of the universe since the Big Bang and is the source of the diversity of the universe, driving the growth of black holes, the synthesis of elements that are the origin of matter, and the creation of ultra-high energy cosmic ray nuclei with enormous energy that has never been achieved by human-made accelerators. In this Research Area, we will promote multi-messenger observations that combine neutrino and gravitational wave measurements which have made overwhelming progress in recent years, with traditional electromagnetic wave observations, in order to obtain the unified picture of the final fate of gravitational energy, from the growth process of ultra-dense fireball plasma produced by the strong gravitational field to elemental synthesis and high-energy radiation.

This Research Area consists of three groups: Group A, which is a collection of the subgroups to dramatically advance observational research in multi-messenger astrophysics by strengthening the observational experiments and facilities currently in operation; Group B, which conducts future-oriented development research; and Group C, which promotes theoretical research. Each of these research groups is as follows. Cosmic neutrinos (IceCube - A01), gravitational waves (LIGO - A02), visible, near-infrared and radio waves (A03), X-rays (A04), gamma rays (CTA - A05), astroparticle detection technology (B01), multi-messenger observation satellite (B02), theoretical study of high energy neutrino astrophysics (C01), and theory of strong gravitational radiation from astronomical objects (C02).

Multi-messenger astrophysics is a newly born interdisciplinary field that requires the formation of a new community of researchers with expertise in different research backgrounds. The ultimate goal of this Research Area is to create an expert group of multi-messenger astrophysics with a diverse spectrum of astrophysics researchers and make world-leading discoveries to reveal the nature of extreme universe.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

Multi-messenger astrophysics, by its very nature, is related to a wide range of astronomical, space, and particle physics research fields. Although each of the Planned Research Groups has introduced a top-down approach for integrating various specialized research fields, there are many research topics and projects that cannot be covered by this top-down program. We expect bottom-up research proposals that broaden the base of interdisciplinary research in the open call for Publicly Offered Research proposals. We welcome observation research proposals that are not part of the top-down research agenda, such as observational research using balloons and other flying objects, survey observation specializing in a certain wavelength band, and cosmic particle observation using ground-based detectors, as well as proposals for detector development based on novel ideas. We also expect seed research proposals that will promote interdisciplinary research, such as developments on methods for integrating and analyzing data of different quality, and theoretical research proposals on cosmology, particle theory, gravity theory and so on, which will form the basis of the framework of multi-messenger astrophysics.

We would also like to remark that the Research Group Number E01 can accept truly pioneering proposals which requests annual budget up to 5 million yen, in order to promote relatively large-scale observation and development programs.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
E01	Observational study or R&D for multi-messenger astrophysics : Large-scale programs	5	2
E02	Observational study, numerical simulation, or R&D for multi-messenger astrophysics	3	8
E03	Theoretical research on multi-messenger astrophysics	1	8

Research Outline of Research Areas

Green Catalysis Science for Renovating Transformation of Carbon-Based Resources
https://greencatalysis.jp

Number of Research Area	:	23A206	Term of Project :	FY2023-2027
Head Investigator	:	OOI Takashi		
Research Institution	:	Institute of Transformative Bio-Molecules, Nagoya University		

1. Details of Research Area

Considering the sustainable development of society, organic synthesis must evolve into an environmentally benign technology that can efficiently convert any molecule for providing value-added organic molecules. In other words, there is an urgent need for a transformative shift toward greener organic synthesis in view of effective utilization of ubiquitous carbon resources, molecular transformations using renewable energy, and minimization of waste. However, achieving this goal within the framework of conventional organic synthesis is extremely challenging. This is mainly because most of the existing synthetic methods rely on ionic reactions using thermal energy, which require functional groups as a handle for executing precise transformations of starting materials. On the other hand, radical reactions are not dependent on functional groups and hold significant potential for implementing truly sustainable chemical synthesis with a wide range of carbon resources. However, it is very difficult to tame short-lived, highly reactive radicals, and no guiding principle has been established for the development of radical-mediated selective organic transformations. The research area "Green Catalysis Science" aims to realize precise control of radical reactions by the development of catalysts capable of harnessing light and/or electric energy based on the integration of inorganic coordination chemistry, solid surface chemistry, and organic chemistry, leading to transform organic synthesis into a form suitable for a sustainable society. Specifically, we will pursue the design of inorganic complexes and solid-state catalysts with the ability to generate radicals at targeted positions in starting materials through light excitation or electron transfer with electric energy. Meanwhile, organic molecular and metal catalysts will also be rationally designed for rigorous control of the subsequent bond-forming processes of radicals. These catalysts will be exploited in developing molecular transformations to assemble high value-added molecules, which were previously considered nearly impossible to synthesize, from small molecules such as methane and hexane, polymers, and biomass, which have been difficult to use as starting materials, in the shortest possible steps. This will revolutionize methods for the transformation of carbon resources, establishing the next-generation organic synthesis that embodies greenness and is independent on the structure of molecules.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In this research area, research is conducted through the organization of three groups: Research Group A01 (Control of Radical Generation), Research Group A02 (Control of Radical Reactions), and Research Group A03 (Expansion of Synthetic Processes). To achieve the goal of the area, a fusion of a wide range of fields is essential. Particularly, collaborative research based on understanding and controlling radical species through photo- and electrochemical approaches, advanced measurement science, theoretical and computational science, and broad catalysis science creates a basis for exploring methodologies for the transformation of carbon resources. The content expected for publicly offered research in each research group is as follows:

In **Research Group A01**, the focus is on controlling radical generation and developing methodologies to generate radicals from a wide range of carbon resources, such as small molecules like CO_2 and methane, biomass, and polymers, for use as starting materials. Therefore, proposals related to the exploration of catalytic methods for radical generation are expected with an emphasis on the activation of molecules that have been difficult to use as starting materials in conventional organic synthesis.

In **Research Group A02**, the focus is on catalytic control of selectivity associated with radical-mediated bond formations. Proposals for catalyst development based on various approaches, such as enzymatic and supramolecular catalysis, are expected. Proposals related to molecular design and methodology development for the application of inorganic complexes and solid-state catalysts to the control of radical reactions are also welcome.

In **Research Group A03**, the focus is on expanding synthetic processes by radical reactions. This includes not only the development of new reactions with organic small molecules but also novel methods effective for natural product synthesis, polymer synthesis, and even the development of photo- and electrochemical reactions with polymers. Proposals to merge catalytic radical reactions utilizing light and electric energy with process chemistry and flow synthesis are also encouraged.

For each of the research group, proposals that contribute to the "understanding" to control radicals and develop new reactions are welcomed from theoretical science and advanced measurement science. As diversity is the foundation of interdisciplinary collaboration, applications from young and female researchers with diverse backgrounds are especially encouraged.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Control of radical generation	3	20
A02	Control of radical reactions		
A03	Expansion of synthetic processes		

Research Outline of Research Areas

Census-based biomechanism of circuit construction and transition for adaptive brain functions
https://ac-census.org/

Number of Research Area	:	21A301	Term of Project :	FY2021-2025
Head Investigator	:	ISOMURA Yoshikazu		
Research Institution	:	Tokyo Medical and Dental University, Graduate School of Medical and Dental Sciences		

1. Details of Research Area

We will focus on neural circuit formation and transitions responsible for adaptive brain functions. Combining cutting-edge technologies of advanced neuroscience that enable measuring and manipulating neural circuit activity and single-cell gene expression analysis will provide detailed information about cell type-specific adaptive circuits. In this Research Area, Adaptive Circuit Census (ACC), we will experimentally validate the responsible circuits and theoretically establish adaptive circuit operating principles. To further promote the ACC Research Area, we establish a seamless, interdisciplinary cooperative framework to exchange creative and innovative ideas as well as cutting-edge experimental and analytical techniques. The Research Groups are divided into A01, "Census of adaptive circuit construction," and B01, "Census of adaptive circuit transition," based on timescale differences. In addition, Research GroupC01 (Experimental) and C02 (Theoretical), "Technology and theory for adaptive circuit census," interacts with A01 and B01 to facilitate targeting of adaptive circuits.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

Research Group A01 aims to elucidate the mechanism of formation/reorganization of neuronal circuits during dynamic structural changes such as development, homeostasis, formation of instinct behaviors, brain degenerative diseases, and relevant compensatory responses. Research Group B01 aims to elucidate how neuronal circuits change brain state and lead to adaptation during functional transitions such as memory/learning, emotion, decision making, consciousness, mental illness, and drug addiction. We will use a unique experimental animal that suits each question and employ a precise cell type census and neuronal circuit identification method to capture the properties of specific neuronal circuits. We then compare and analyze the results from each Research Group to obtain comprehensive knowledge of the ACC.

We utilize profiling technology that captures cell types and dissects cell-type specific neuronal circuits; however, profiling itself is not the project's primary purpose. Instead, we expect to reveal the responsible adaptive circuits and fundamental operation mechanisms that alter animal behavior using various methodologies (spatial distribution, circuit structure, and neuronal activity information).

The profiling methodology is not necessarily limited to transcriptome analysis (various types of RNA-seq), and experience with transcriptomic analysis is not necessary since the integration of neuroscience and omics-based analyses is a key focus of the project. Moreover, to perform RNA-seq for the first time, it is crucial to make a detailed experimental design and collect preliminary data such as the cell viability and RNA amount before starting transcriptomic analysis to obtain a successful result. Therefore, the ACC offers consultation of experimental plan, technical advice, and financial support related to transcriptomic analysis to the members.

Research Group C01 aims to develop profiling technology to reveal the mechanism of adaptive circuits. Experience in the neuroscience field is not necessary. We also seek theoretical and bioinformatics experts in Research Group C02, who can verify the operating principle of adaptive circuits by theoretical models and simulations or identify circuit structures responsible for adaptation from experimental data. Altogether, we expect to establish a seamless, interdisciplinary cooperative framework to exchange creative and innovative ideas as well as cutting-edge experimental and analytical techniques.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Cell type census for adaptive circuit construction	6	4
B01	Cell type census for adaptive circuit transition	4	10
C01	Technology and theory for adaptive circuit census (Experimental)	5	4
C02	Technology and theory for adaptive circuit census (Theory)	2	3

Research Outline of Research Areas

New cross-scale biology
https://structure.m.u-tokyo.ac.jp/xscalebio

Number of Research Area	:	21A302	Term of Project :	FY2021-2025
Head Investigator	:	KIKKAWA Masahide		
Research Institution	:	The University of Tokyo Graduate School of Medicine		

1. Details of Research Area

In this research area, we aim to elucidate the molecular and cellular mechanisms of life phenomena and diseases by using quantitative cross-scale measurements. In particular, we focus on "meso-entangled bodies (MEBs)." We define MEB as a sub-cellular "body," where molecules are disordered, whose size is 20 to 500 nm, and hypothesize that the transition from MED to an ordered state is the determinant of the fate of cells and organisms. A liquid-liquid phase separation (LLPS) condensate is one of the MEB examples.

For the cross-scale measurement, we combine multiple techniques, including cryo-electron tomography, super-resolution imaging, intracellular NMR, and intracellular atomic force microscopy (AFM). Computational science is also used to integrate and interpret experimental data. The aims of our research area include, but are not limited to, the following three biological and medical areas: "The polarity of cell and development," "The shape and topology of membranes", and "Structural abnormalities and quality control of proteins that cause diseases." We want to create new frameworks of cell biology that answer how highly ordered and functional structures are built from the random MEBs by analyzing these fundamental phenomena by cross-scale measurements.

In the last two years, a virtual "Cross-scale cell measurement center" has already been in operation, in which two groups, A01=Technical and A02=Biological, collaborate with each other. Therefore, in the current call for proposals, applicants should understand ***open science***, in which research data is shared among this research area, while we respect the contribution of individual researchers.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

(A01) Technology group: we expect applications from researchers developing unique technologies for analyzing intracellular molecular structures and dynamics at the mesoscale level. Technologies not covered by the planned research group, e.g., quantitative proteome, labeling techniques that can be applied to multiple intracellular cross-scale visualization, technologies to deliver and control large molecules such as proteins and nucleic acids inside cells, technologies that can be linked with the technologies in the planned research (e.g. Super-resolution microscopy and cryo-electron microscopy in the same field of view), and analysis of intracellular structural dynamics using other light sources such as X-rays. The examples listed here are only examples; researchers with methods other than those listed above are also expected to apply.

As research in the area progresses, we need researchers who can apply computational science to meso-complexes. Examples include computational science to analyze data obtained from cross-scale observations (e.g., cryo-electron tomography data) and large-scale simulation studies on MEBs using supercomputers such as Fugaku. In the case of the computational science, in order to broaden the scope of the program, we call for <u>two proposals</u> from individuals or small groups up to 2-million-yen annual budget. Groups of normal size may also apply with a maximum of 4 million yen.

In both cases, the grant applicant should clearly explain the advantages and uniqueness of their technologies, and how the technologies contribute to the elucidation of the MEBs.

(A02) Biology group: we expect applications from researchers aiming to elucidate the mechanisms of fundamental phenomena in cells from the viewpoint of intracellular molecular structure dynamics. Example areas include, not limited to, cell differentiation, reprogramming, cell cycle control, cell-cell communication, immunological synapse, and LLPS. We also expect applications from researchers who aim to elucidate disease mechanisms from the viewpoint of intracellular molecular structure dynamics.

The grant applicant should clearly explain what kind of MEBs is expected to be observed by the above methods and what can be concluded from the observation.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Technology group	Computational science: 2 All technology: 4	2 4
A02	Biology group	4	10

Research Outline of Research Areas

Life Science Innovation Driven by Supersulfide Biology
https://supersulfide-proj.com/english/en-index.html

Number of Research Area	:	21A303	Term of Project :	FYFY2021-2025
Head Investigator	:	MOTOHASHI Hozumi		
Research Institution	:	Tohoku University, Institute of Development, Aging and Cancer		

1. Details of Research Area

Sulfur has been an essential element for living organisms on the earth during the long history of evolution. Unique chemical properties of sulfur include redox-sensitive nature and ability to catenate only by itself. The latter allows generation of a wide variety of sulfur-containing molecules that are rather fragile due to the former. We define "supersulfides" as metabolites and proteins possessing sulfur catenation.

Because supersulfides are so sensitive to redox perturbation and easily degraded or altered during the sample processing, their presence in biological contexts has been overlooked for a long time. Thanks to a recent technical advancement in the analytical chemistry, substantial amount of supersulfides, such as glutathione persulfide and cysteine persulfide, have been found in various organisms. Low-molecular weight supersulfides are now recognized as universal metabolites and play critical roles in energy production, antioxidant function, and anti-inflammatory function. Supersulfidated proteins are expected to be involved in the protein folding, proteostasis regulation, and regulation of protein functions. Based on these emerging biological functions of sulfur, we aim at creating and establishing innovative sulfur biology by further clarifying chemical, physical and biological characteristics of supersulfides and interdisciplinary research network among wide range of scientific fields, including chemistry, physics, geoscience, biology, mathematics and so on.

Here are three goals of our Research Area.

1) Development of quantification methods for supersulfides in terms of high sensitivity, high fidelity, and high reproducibility.
2) Discovery of life principles from a viewpoint of supersulfides in electron transfer and signal transduction.
3) Application of supersulfides for contribution to the SDGs

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

We welcome all research focusing on sulfur-containing metabolites and proteins for reevaluation of biological function of sulfur by cooperating with Planned Research Group members. Young investigators and women investigators are strongly encouraged to apply for the Publicly Offered Research.

Specific topic examples in each Research Group are as follows.

Research Group A01) Clarification of structure and properties of supersulfides from the viewpoint of inorganic and organic chemistry, biochemical analysis of interaction between sulfur and metal (iron, zinc, molybdenum, etc.), functional analysis of supersulfide-synthesizing enzymes and supersulfidated proteins, and development of new methodologies for quantification and synthesis of supersulfides.

Research Group A02) Analysis of electron transfer inside and outside of organisms via sulfur, clarification of redox reactions involving supersulfides and their significance, discovery of new homeostasis regulation utilizing sulfur, and clarification of relations between sulfur and other free radicals (reactive oxygen species, nitrogen species, etc.).

Research Group A03) Clarification of functional significance of sulfur-containing metabolites and proteins in signal transduction, mechanisms of supersulfide synthesis from the viewpoint of genetic and epigenetic regulation, and regulation of sulfur-metabolizing enzyme activities at protein levels.

Research Group B01) Interdisciplinary research on sulfur, such as sulfur cycle at global scale, roles of environmental biogenic sulfur, molecular evolution of aminoacyl-tRNA synthetase, sulfur utilization by living organisms during the evolution, is highly welcome. Other creative proposals are encouraged to be applied.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Analysis, quantification, and visualization of supersulfides	2	5
A02	Electron flux mediated by supersulfides	2	5
A03	Signal transduction utilizing supersulfides	2	5
B01	Interdisciplinary research on sulfur biology	3	5

Research Outline of Research Areas

Biology of non-domain biopolymer
https://www.nondomain.org

Number of Research Area	:	21A304	Term of Project :	FY2021-2025
Head Investigator	:	NAKAGAWA Shinichi		
Research Institution	:	Hokkaido University, Faculty of Pharmaceutical Sciences		

1. Details of Research Area

In recent years, there have been increasing reports of biopolymers such as long noncoding RNAs and intrinsically disordered proteins that play critical physiological roles without possessing conserved functional domains across species. These molecules share the common characteristic of not forming specific three-dimensional structures, suggesting they function through unique molecular mechanisms that diverge from the traditional molecular biology doctrine - where the primary sequence dictates structure, and structure determines function. In this research area, we define RNAs and proteins whose functions are difficult to predict from their primary sequences as 'non-domain biopolymers'. We aim to advance a hierarchical, cross-sectional analysis, from physiological function to molecular action mechanisms, to elucidate new strategies organisms use to acquire functionality without a high dependence on primary sequences. We are excited to launch our group grant for this project and warmly encourage applications from interested researchers.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In this open call for research, we anticipate analyses of "novel" non-domain biopolymers independently discovered by applicants. However, we also encourage research focusing on particular regions or domains of "known" molecules, where functions are difficult to predict from primary sequences. These include poorly characterized peptides translated from untranslated regions of mRNA and intrinsically disordered regions of proteins with low sequence conservation across species. Further, we are interested in studies on originally discovered reaction fields, structures, and molecular condensates formed by non-domain biopolymers. We also look forward to new approaches for elucidating the molecular mechanisms of non-domain polymers, such as deep mutagenesis and the development of various measurement technologies.

In the A01 Physiological Function Unit, we solicit projects that verify the physiological functions of non-domain biopolymers at the individual animal level. While mice and fruit flies are used as model organisms in our planned research, we are open to research proposals using not only common model organisms such as bacteria, yeast, Arabidopsis, nematodes, and zebrafish, but also various non-model organisms.

The A02 Cellular Function Unit seeks research proposals to elucidate the functions of non-domain biopolymers using molecular biological methods and biochemical techniques involving cultured cells. Additionally, we welcome research topics that identify new non-domain biopolymers using large-scale screening technologies like CRISPR libraries, perform deep mutagenesis analyses of known molecules, and design new functional non-domain biopolymers.

The A03 Molecular Mechanism Unit invites research topics that clarify the detailed molecular mechanisms at play when non-domain biopolymers function. Additionally, this unit welcomes projects that elucidate the behavior of non-domain biopolymers from a soft matter physics perspective, and projects that analyze common sequence characteristics in non-domain biopolymers using bioinformatics and deep learning techniques.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Analyses of the physiological functions of nondomain biopolymer at individual animal level	4	18
A02	Analyses of the functions of nondomain biopolymer at the cellular level		
A03	Analyses of the functions of nondomain biopolymer at the molecular and atomic levels		

Research Outline of Research Areas

Understanding multicellular autonomy by competitive cell-cell communications
http://www.multicellular-autonomy.lif.kyoto-u.ac.jp/en/

Number of Research Area	:	21A305	Term of Project :	FY2021-2025
Head Investigator	:	IGAKI Tatsushi		
Research Institution	:	Kyoto University, Graduate School of Biostudies		

1. Details of Research Area

A critical difference between multicellular living organisms and non-living thing is that the former has 'autonomy'. A multicellular system can spontaneously construct tissues and organs and optimize its structure and function by itself. Such characteristic of the multicellular system is emerged only when cells are grouped together, and it is a unique natural phenomenon that reduces entropy (randomness). While the mechanism by which a cell population spontaneously creates a structure is gradually being clarified, the mechanism by which a cell population optimizes its own structure and function is still elusive. Recent advances in single-cell analysis technology have identified that there are 'variations' in various cell populations within the animal and that these variations are eliminated over time. In addition, when cells with slightly different properties or status are emerged in a cell population, 'unfit' cells are actively eliminated from the population through cell-cell interactions, a phenomenon called 'cell competition'. Cell competition is a context-dependent cell elimination whereby slightly abnormal cells that can survive on their own are eliminated from the population when coexisting with normal cells, thereby optimizing the structure and function of the cell population. In this research area, we will approach one of the greatest mysteries of life, the multicellular autonomy, by studying competitive cell-cell communications. To achieve this, we will strongly promote research on cell competition in various model systems and physiological processes, and dramatically advance our understanding of competitive cell-cell communication and its physiological roles. We will also promote interdisciplinary research in the research area to understand how multicellular autonomy is created by competitive cell-cell communications.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In this research area, we aim to comprehensively understand competitive cell-cell communications and elucidate the principle that autonomy is created in multicellular systems. In the planned research, in addition to approaches that have strongly promoted cell competition researches (which include genetic, biochemical, and cell biological analyses using *Drosophila*, cultured mammalian cells, mice, and zebrafish), we will promote constructive approaches such as synthetic biology and development of spatial omics technology to understand competitive cell-cell communications. Therefore, for the publicly offered researches, we will call for proposals not only for researches on various cell competition phenomena that complement and strengthen the planned researches but also on competitive cell-cell communications that do not fall within the category of cell competition. We also call for researches that aim to elucidate the principle by which competitive cell-cell communication creates multicellular autonomy and optimizes multicellular structure or function. In addition, we expect research proposals on competitive cell-cell communication or the phenomenon in which the structure and function of multicellular systems are autonomously optimized using model organisms, cutting-edge technologies, mechanobiology, mathematical analysis, or data analysis methods that are not covered by the planned research. We also expect proposals that strengthen theoretical approaches to understand how competitive cell-cell communication creates multicellular autonomy, synthetic approaches to reconstruct multicellular autonomy, and any approaches to clarify the impact of cell competition on various biological and pathological phenomena. In addition to researches on competitive cell-cell communication in animal development, tissue repair, and regeneration, cell competition researches in the context of various temporal changes such as diseases and animal aging are also expected, if it matches the goals and directions of the research area. While aiming to accelerate the research area and achieve goals through collaboration with the planned researches, we also expect challenging research proposals that seek to find new questions or dramatically develop and transform the research area. We look forward to applications from young researchers and female researchers who will lead future cell competition and multicellular autonomy researches.

In this research area, in order to eliminate the barriers among different specialties, we have set only A01 as the research group. Therefore, all the publicly offered researches belong to A01. In order to achieve the above goals, we have set the upper limit of the amount of the publicly offered research budget to 4.5 million yen per year for 16 research proposals.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Understanding multicellular autonomy by competitive cell-cell communications	4.5	16

Research Outline of Research Areas

Shin-biology regulated by protein lifetime
https://www.proteinlifetime.jp

Number of Research Area	:	23A301	Term of Project :	FY2023-2027
Head Investigator	:	MURATA Shigeo		
Research Institution	:	The University of Tokyo, Graduate School of Pharmaceutical Sciences		

1. Details of Research Area

Proteins are vital to living organisms, and the functions of cells and tissues are determined by the proteome, which consists of thousands of different proteins. Protein synthesis follows genetic information, but the correlation between mRNA, translation, and protein levels is weak. Post-translational regulation, especially proteolysis, plays a critical role. Proteins vary in lifetime, from minutes to years. Existing laws explain some protein lifetimes, but most remain elusive. The regulation of individual protein lifetime is extensively studied in key biological events, but only limited aspects of protein dynamics are observed. During major functional transformations, protein composition undergoes significant reconfiguration, affecting degradation and synthesis. The mechanisms behind selective and large-scale proteolysis in biological and pathological contexts are unknown. To unravel these mysteries, we'll explore new principles of protein lifetime regulation, establish techniques for in-depth lifetime measurements, and elucidate regulatory mechanisms that drive compositional changes. We'll integrate sequence, modification, and 3D structure information to study protein lifetime regulation factors. We'll also develop technologies for precise protein lifetime control and methods to manipulate cellular and tissue functions. This interdisciplinary research aims to understand, measure, and manipulate protein lifetime mechanisms to achieve a deep understanding of biological phenomena and pathological conditions.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

Research Group A01 seeks a new understanding of life phenomena through the comprehensive measurement of protein lifetime and the investigation of regulatory mechanisms. While the planned research will focus on cellular senescence, neural stem cell differentiation, and Moyamoya disease, publicly offered research is encouraged to address other life phenomena and disease mechanisms involving protein lifetime regulation. This research area will study the large-scale regulation of protein populations rather than individual proteins. Research Group A02 aims to uncover novel molecular mechanisms that determine protein lifetime. The planned research will focus on the ubiquitin-proteasome and autophagy-lysosome systems in eukaryotic cells, particularly on branched ubiquitin chains, ubiquitin chain discrimination, and the enhancement of degradation by liquid-liquid phase separation. Publicly offered research is not limited to these systems but should investigate diverse substrates and lifetime determination mechanisms that involve significant changes in protein composition rather than a regulatory system for a specific substrate. Research Group A03 aims to develop tools for in-depth measurement and computational analysis of protein half-lives and for controlling the lifetimes of target proteins. The planned research includes the establishment of high-resolution measurement techniques, the analysis of the correlation between lifetime and proteoforms, and the further development of techniques such as auxin-degron and PROTACs for protein lifetime control. Proposals should introduce new methods and tools for measurement, control, information analysis, and mathematical analysis of protein lifetimes, using diverse approaches such as synthetic biology, analytical chemistry, informatics, organic chemistry, and computational science. Administrative Group has established mass spectrometry and information analysis teams. We invite publicly offered research that synergizes with planned research and contributes to the development of this research area. Diverse and highly original research by young and female investigators is encouraged.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Biology of Protein Lifetime Dynamics	4	7
A02	Mechanisms of Protein Lifetime Determination	4	6
A03	Measurement and Control of Protein Lifetime	4	4

Research Outline of Research Areas

Integration of extracellular information by multimodal ECM activity
https://www.multimodal-ecm.com/

Number of Research Area	:	23A302	Term of Project :	FY2023-2027
Head Investigator	:	FUJIWARA Hironobu		
Research Institution	:	RIKEN Center for Biosystems Dynamics Research		

1. Details of Research Area

Multicellular organism's structures and functions are complex but tightly organized. Although they emerge from the interplay between cells and the extracellular matrix (ECM), biological research has largely focused on cells, neglecting the ECM as just a 'static scaffold'. However, recent advancements in ECM measurement and manipulation techniques have begun to unveil that the ECM is far more dynamic than previously thought, providing cells with a wide range of biochemical (e.g., composition, adhesive and soluble signals) and physical (e.g., adhesion, viscoelasticity, geometry) information. This information collectively constitute 'multimodal spatiotemporal information' within the ECM. We anticipate that the ECM plays a pivotal role in establishing and integrating different biological scales and, thus, in governing dynamic and ordered multicellular phenomena, such as self-organization and morphogenesis. This research area aims to harness the expertise of experimental biologists, polymer materials engineers, and mathematical/data scientists to better understand and control the dynamics and multimodal information encoded within the ECM through interdisciplinary and holistic approaches. By unravelling the dynamic operating principles of the ECM, we endeavour to transform the current cell-centric framework of biology.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The insufficient exploration of the ECM's dynamics and multimodal information stems from visualization challenges and struggles to decouple the ECM's diverse biochemical and physical parameters. Thus, this research area aims to achieve a greater understanding of the ECM through studies in the following three research groups: 'Operating principles of the ECM-multicellular dynamic unit (A01)', 'Manipulation of extracellular information by designer matrices (A02)', and 'Mathematical and data science for ECM-multicellular systems (A03)'. We invite proposals for Publicly Offered Research focused on any multicellular organisms and ECMs. We welcome proposals that a) complement the planned research, b) aim to be developed in collaboration with the planned research, or c) explore new concepts with innovative perspectives or methods. We plan to select 12 experimental research projects with a funding limit of 4 million yen each and 4 theoretical research projects with a funding limit of 3 million yen each. Young and female researchers are especially encouraged to apply.

Research Group A01 aims to investigate the mechanisms underlying the dynamics of the ECM in governing multicellular systems. We prioritize studies that extend beyond the static analysis of individual ECM molecules and strive for a comprehensive quantitative understanding of the spatiotemporal interactions between cells and the ECM. Potential research areas include the ECM dynamics (e.g., production, movement, activity, degradation) that regulate processes like morphogenesis, tissue regeneration, fibrosis, cancer development, and evolution. We also welcome proposals that examine the cross-scale dynamics of the ECM from the micro to macro scales, investigate the regulatory mechanisms of the ECM-cell interface, and explore the interplay between the ECM and soluble factors.

Research Group A02 invites proposals for the development of designer matrices, including reconstituted ECM, artificial ECM, and synthetic polymer hydrogels, capable of decoupling, integrating, and manipulating individual ECM parameters. We encourage proposals that aim to manipulate cell populations in conjunction with culture systems (e.g., organoids) and contribute to a greater understanding of the emergent functions of the assembly of ECM molecules. We also welcome proposals for measuring, visualizing and manipulating the mechanical properties and components of the ECM.

Research Group A03 seeks proposals focused on the use of mathematical and data science in the study of ECM-multicellular interactions. This includes the development of methodologies aimed at acquiring, quantifying, and integrating multidimensional data related to the ECM and cells, such as gene expression, spatial distribution, proteome, mechanical properties, and dynamics. We also encourage the development of innovative mathematical models of ECM-multicellular interactions alongside a simulation-based analysis. The above examples are intended only as illustrations. We welcome all proposals that align with the research area's objectives.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Operating principles of the ECM-multicellular dynamic unit	Experimental research: 4 Theoretical research: 3	12 4
A02	Manipulation of extracellular information by designer matrices		
A03	Mathematical and data science for ECM-multicellular systems		

Research Outline of Research Areas

Hibernation biology 2.0: understanding regulated hypometabolism and its function
https://hibernationbiology.jp

Number of Research Area	:	23A303	Term of Project :	FY2023-2027
Head Investigator	:	YAMAGUCHI Yoshifumi		
Research Institution	:	Institute of Low Temperature Science, Hokkaido University		

1. Details of Research Area

Most mammals are homeotherms that keep their core body temperature within a narrow body temperature range of 37°C. If the core body temperature continues to deviate from the range, a breakdown of systemic homeostasis occurs, leading to death. On the other hand, some mammals called hibernators can achieve hibernation, during which basal metabolisms and core body temperature become very low under conditions such as cold or starvation when a food, a source of body heat production, is insufficient. During hibernation and torpor, animals can maintain homeostasis and survive for a long period of time. Elucidating the mechanism of hibernation will lead to the clarification of the mechanism of whole-body homeostasis under extreme hypothermia, which could not be approached in non-hibernators such as humans, and has the potential to expand and spread to various fields. Recently, hibernation research is entering a new stage with the spread of genetic modification techniques in mammalian hibernators and the identification of neurons that induce a hibernation-like hypometabolic state in non-hibernators. This research area aims to take advantage of these breakthroughs and elucidate the mechanisms of induction and adaptation of "hibernation/torpor " and to derive new knowledge on the mechanism of "extended homeostasis," the mechanism by which homeostasis is maintained despite extreme low core body temperature.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

A wide range of research to deepen our understanding of the principles of hibernation and torpor in mammals is invited in each research category from A01 to A03. In addition to research that uses mammalian hibernators (e.g., hamsters and chipmunks), we are also seeking research that draws a picture of the essence of hibernation by comparing hibernation diversity, and research on the mechanisms that induce hibernation-like low metabolism and hypothermia in mice a hibernation-like hypometabolism (e.g. QIH: Q neurons-Induced Hypometabolism and hypothermia). Research that contributes to an understanding of the extended homeostasis observed during hibernation and torpor, not only with regard to central regulation, but also with regard to the nature of peripheral organs and the systemic organ connections with the central nervous system, is also welcome. Proposals from young and female researchers are also welcome in order to promote the future development of research in this area and to encourage research from diverse perspectives.

A01 Molecular and Neural Basis for Hibernation: Proposals are invited to examine the functions of genes, molecules, and neural circuits predicted to be involved in the control of hibernation and torpor. Although hamsters will be used as a model hibernator in this area, interspecies comparisons will be an important element in understanding the principles of hibernation. We welcome studies on torpor and hibernation-like low metabolism models in mice, as well as proposals related to the control and significance of hibernation and torpor in poikilotherms, which should contribute to our understanding of homeostasis mechanisms in mammals through comparative verification.
A02 Biological Responses Induced by Hibernation: Proposals are invited to elucidate the responses to the biological environment such as hypometabolism and hypothermia induced by hibernation and torpor, and their mechanisms at the cellular, tissue, or individual level using techniques from molecular biology, biochemistry, or neuroscience. Research that pursues not only the response in mammalian hibernators, but also the low temperature response and its mechanisms in non-hibernators such as mice and humans, as well as in organisms for which comparative physiological verification is possible, is included in this section.
A03: Elemental Technologies for Hibernation Research: Proposals are invited to introduce or propose emerging technologies and methods necessary to elucidate the mechanisms of hypometabolism induction, low temperature response, and stress tolerance that occur during hibernation and torpor. We also welcome research proposals that appropriately address problem setting in hibernation research, even for existing experimental techniques and methodologies that have not been addressed in hibernation research due to difficulties in their application at low temperatures or in mammalian hibernators.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Molecular and Neural Basis for Hibernation	4.3	7
A02	Biological Responses Induced by Hibernation		7
A03	Elemental Technologies for Hibernation Research		2

Research Outline of Research Areas

Dynamic reproductive lifespan: Life-long changes and fluctuations in germ cell function and risk for next generation
https://reproductivelifespan.jp/en/

Number of Research Area	:	23A304	Term of Project :	FY2023-2027
Head Investigator	:	KITAJIMA Tomoya		
Research Institution	:	RIKEN Center for Biosystems Dynamics Research		

1. Details of Research Area

This research area aims to elucidate the dynamic nature of the reproductive lifespan by clarifying the changes and fluctuations of germ cell functions and properties across the lifespan. Traditionally, the reproductive lifespan has been defined as a period during which an individual has the ability to produce the next generation. This is based on a qualitative view in which an individual's reproductive capacity is turned on and off in a binary manner at physiological turning points. However, as recent technological innovations have quantitatively analyzed germ cell functions and properties at the cellular level, it has become clear that they can change and fluctuate throughout life in terms of reproductive capacity and risk to the next generation. In this research area, we will quantitatively characterize such changes and fluctuations in germ cells across the entire lifespan and elucidate their underlying mechanisms.

Our particular interest includes changes and fluctuations in germ cell function and the risk to the next generation throughout the adult stage. For example, in mammalian females, oocytes enter a dormant state after production and remain non-proliferative throughout the adult stage. However, as life progresses, functions such as chromosome segregation deteriorate, leading to infertility and miscarriage, and increasing the risk of aneuploidies in the next generation. In males, however, sperm stem cells acquire the ability to suppress genomic mutations, continue to proliferate, and produce numerous sperm throughout the adult stage. However, the risk of transmitting mutations to the next generation increases with age. Not limited to these examples, germ cell function and risks to the next generation change and fluctuate from various perspectives, and these changes and fluctuations shape a dynamic reproductive lifespan with the processes of "acquisition, maintenance, adjustment, and deterioration" in life. This research area brings together research and technological development focusing on "acquisition" during the developmental and juvenile stages, "maintenance and adjustment" during the adult stages, and "deterioration" during the aging stages, to conduct germ cell research throughout the entire life span, with the goal of elucidating the dynamic reproductive life span.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

Researches that focus on changes and fluctuations in germ cell function (A01) and risk to the next generation (A02) across the lifespan, as well as the development of technologies to facilitate these researches (A03), are eligible. We welcome research proposals that bring new approaches and perspectives not found in existing germ cell research, as well as research that takes advantage of technologies that have been developed in the field of germ cell research to date. While this research area is a group that gathers to elucidate the dynamic reproductive lifespan, it is intended to be a place where outstanding individual research can be enhanced through collaboration within the research area, and proposals based on open ideas that contribute to this concept are encouraged. In addition, as this research area seeks to promote diversity in human resources, proposals from young scientists and women scientists are strongly encouraged.

The following is a list of examples of research that we expect to see, but proposals are not limited to these, as long as a proposal contributes to the goals of this research area.

- Research to elucidate the dynamic changes and fluctuations in germ cells by taking advantage of mammalian or non-mammalian animal models.
- Research to elucidate cellular changes and mechanisms using techniques such as *in vitro* germ cell reconstitution and live imaging.
- Research that focuses on the fundamental processes of the reproductive cycle, such as germ cell differentiation, meiosis, and fertilization.
- Research that focuses on the environment and mechanical control of germ cells.
- Research focusing on the dynamics of long-term turnover of molecules and cells during the reproductive lifespan.
- Research that focuses on the effects of external factors, such as nutrition, on germ cell function and risk to the next generation.
- Research that focuses on risk factors inherited by the next generation, not limited to the genome itself.
- Research that develops or utilizes engineering and informatics technologies such as device fabrication and artificial intelligence, as well as original technologies.
- Research that theoretically elucidates the reproductive lifespan using quantitative data at the cellular level.
- Research to elucidate basic germ cell functions related to the reproductive lifespan of primates, including humans.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Reproductive lifespan by germ cell function	4	15
A02	Reproductive lifespan for next generation		
A03	Technology development for reproductive lifespan research		

Research Outline of Research Areas

Photosynthesis ubiquity: Supramolecular complexes and their regulations to enable photosynthesis all around the globe
https://www.photosynthesis-ubiquity.jp/en/

Number of Research Area	:	23A305	Term of Project :	FY2023-2027
Head Investigator	:	KURISU Genji		
Research Institution	:	Osaka University, Institute for Protein Research		

1. Details of Research Area

Photosynthesis is one of the most important topics in plant science, as it is an excellent light-driven chemical reaction in very diverse conditions from the tropics to the poles. Photosynthetic organisms cover the globe overcoming not only high or low light, but also dynamically changing light conditions, which embodies the concept of "photosynthesis everywhere". Thus, if we can address how photosynthetic organisms have adapted to diverse light conditions and understand and verify the principle of photosynthetic adaptation to diverse light environments, not only high academic impact but also pervasive social effects, such as the potential application to global warming or climate changes, will be expected.

The latest scientific research in plant biochemistry, plant physiology, and structural biology, elucidated that photosynthetic organisms have evolved specific proteins or the combination to adapt to their environments by diversifying light-harvesting antenna and its regulation system, without changing the core molecular apparatuses on the thylakoid membrane. Furthermore, these adaptations are thought to be strengthened by optimizing the regulation of gene expression, thylakoid membrane structure, and electron transfer activity. In other words, it is now becoming clear that it is important to understand environmental adaptation in photosynthesis based on the functional analysis and structural studies of various types of supramolecular protein complexes. However, it has not yet been accomplished to link the supramolecular complex structures, which are dynamically formed on the thylakoid membranes in response to environmental changes, and the physiology of various photosynthetic organisms. In this Research Area, leading scientists in structural biology, plant physiology, and biochemistry, team up with researchers in information science to tackle how the supramolecular complexes express their structural and functional features to accomplish the ubiquitous photosynthesis.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

For Publicly Offered Research, we seek for research proposals that cover biological diversity of environmental responses using non-model organisms (Research Group B01) and that pursue unique measurement techniques such as the development of new structural and functional analysis methods (Research Group B02) to fill the gaps in Planned Research Groups.

In Research Group B01, we will actively select research proposals using species that are not be covered by the Planned Research but expected to serve as important keystones in studying the principle of photosynthetic adaptation to diverse light environments. The strength of photosynthesis and plant/algal research in our country lies in the wealth of human resources who work with a wide range of photosynthetic organisms and make use of each characteristic to achieve high-quality results. Unfortunately, however, there are many researchers who are not sufficiently well funded despite their high-quality researches. Therefore, in Research Group B01, we would like to encourage the participation of researchers who work with characteristic materials in a wide range of lineages, such as "Cyanobacteria in extreme environments", "Glaucophyta, one of the earliest divergent eukaryotic algal lineages without light-harvesting antennae of LHC", "Bangiophyceae, red algae with a hybrid light-harvesting antennae of LHC and PBS", and "Prasinophytes and streptophyte algae known for their characteristic physiological functions", which are important for investigating the principle of photosynthetic adaptation.

In Research Group B02, we will actively pursue research proposals that address the development of new methods for analyzing supramolecular functions based on the emerging atomic-level information. For example, vibrational spectroscopy such as Rama/IR or ultrafast spectroscopy, as well as new method development for molecular simulation using computational chemistry are expected to be applied.

In addition, we especially expect young researchers in Category II to actively apply for the program, since it is important for this Research Area to provide an appropriate environment of which they can take advantage for networking in early stages of their careers. In both B01 and B02, we expect active applications from young and female researchers.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
B01	Structural and environmental adaptation of supramolecules	Category I: 5	10
B02	New techniques to analyze structures/functions of supramolecules	Category II: 3	10

Research Outline of Research Areas

Hierarchical Bio-Navigation Integrating Cyber-Physical Space

https://bio-navigation.jp/en/

Number of Research Area	:	21A401	Term of Project :	FY2021-2025
Head Investigator	:	HASHIMOTO Koichi		
Research Institution	:	Tohoku University, Graduate School of Information Sciences		

1. Details of Research Area

Our world is filled with the movements of living things, including humans and artificial objects. In this Research Area, we define "navigation" (how to reach a destination) as individual-level behaviors focusing on movements; "interaction" as behaviors that influence other individuals and the environment; and "hierarchical navigation" as behaviors that allow individuals and groups to reach a destination hierarchically. Hierarchical navigation is the primary mechanism supporting biological and human society. We will develop engineering and information techniques to identify the essential components of hierarchical navigation and their causal relationships. We aim to transform the methods and techniques used to solve problems involving the behavior of organisms, thereby creating a new academic field: "hierarchical bio-navigation." We will develop or use existing fundamental technologies for behavior measurement, quantification, intervention, and modeling and automate these technologies to expand our knowledge of hierarchical bio-navigation. In addition, we will integrate these technologies to create an AI-driven experimental logging robot ("χ logbot"), in which AI is used to select intervention strategies autonomously, and a new experimental methodology called "seamless CPS" (CPS: Cyber-Physical System) is implemented. These will enable a comprehensive understanding of hierarchical navigation.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The Planned Research falls within two groups. Research Group A01 will collect and analyze data on hierarchical navigation in the real world, create models, and conduct interventions to improve our understanding of the relationship between the environment, biological information, behavior, and other factors. Research Group A02 will develop modeling approaches and use engineering techniques for measurement and intervention to develop technologies for the χ logbot. We will build an academic community integrating biology, engineering, and informatics with the Planned Research. To this end, the call for Publicly Offered Research is open to a wide range of research related to hierarchical navigation. This complements our Planned Research and fusion research spanning fields related to the area.

Research Group A01 invites research proposals in zoology (mammalogy, ornithology, herpetology, etc.), animal behavior, ecology, neuroethology, neuroscience, and fields related to hierarchical navigation in various species. We solicit wide-ranging research on the individual- and population-level movement of insects, migratory birds, fish, and other animals with excellent navigation skills. Examples include herd dynamics, decision-making in organisms moving in groups, and migration studies of fishery species, pest animals, and invasive species of high social importance. For mice and other model animals, high-precision analysis at the cellular level using biogenetics and other techniques is expected. Particular emphasis will be placed on research using the χ logbot and intradisciplinary fusion research with the concept of sharing navigation data within the Research Area and collaborating with engineering and information science researchers.

Research Group A02, in collaboration with Research Group A01, invites engineering, information science, and related research on measurement and intervention in hierarchical navigation. Examples include research on technologies fundamental to the χ logbot, such as robotics, measurement, and control technologies with high accuracy and over longer lengths of time in various environments. Research on information technologies is also solicited, e.g., exploratory AI research, mathematical, statistical, and machine learning models for hierarchical navigation, and research on analyzing, designing, and planning human and object movements using sensors and cameras, including IoT. We welcome proposals to share the developed technology through software releases or lectures. While applicants are not required to have prior experience with animal data, we encourage them to present a clear vision of contribution to addressing issues within this Research Area.

Please refer to the Research Area's website for details on each Research Group and the χ logbot/seamless CPS. For Publicly Offered Research, we intend to offer joint use of the χ logbot, technical workshops, support for young researchers, and support for overseas travel expenses if necessary.

3. Research Group, Upper Limit of Annual Budget, and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Research proposals on hierarchical bio-navigation in related fields, such as ecology and neuroscience	3	10
A02	Research proposals on hierarchical bio-navigation in related fields, such as engineering and information science	3	10

Research Outline of Research Areas

Advanced mechanics of cell behavior shapes formal algorithm of protozoan smartness awoken in diorama conditions.
http://diorama-ethology.jp/

Number of Research Area	:	21A402	Term of Project : FY2021-2025
Head Investigator	:	NAKAGAKI Toshiyuki	
Research Institution	:	Hokkaido University, Research Institute for Electronic Science	

1. Details of Research Area

Intelligence broadly describes an ability to adapt to the environment. In this sense, single-celled organisms like protists (eukaryotic unicellular organisms) have a prototype of intelligence, or rather they can demonstrate skillful behavior in complex field environments due to their sophisticated evolution over hundreds of millions of years. This behavioral ability seems to be inherited as 'single-cellular' behavior in multicellular organisms (sperm motility during fertilization, cell motility in the internal environment, etc.).

In this Research Area, we define 'proto-intelligence' as the fundamental adaptability to the environment that single-celled organisms potentially possess. We name such artificial conditions as 'diorama environments', where organisms can show their potential proto-intelligence. Diorama environments may mimic the complexity of a habitat but in a setup designed for testing proto-intelligence. For example, one such instance is that of an amoeboid organism of slime mold, which displays the ability to find the shortest path in a maze of diorama environments.

Since the mechanisms of proto-intelligence can often be formulated using coupled kinetic equations of cell motion and the environment, such environment-coupled mechanics will be thoroughly applied. We will challenge and advance the algorithms (heuristics) of proto-intelligence. 'Ethological dynamics in diorama environments' is short for the full name of this research project.

The Planned Research consists of four groups (diorama ethology, diorama implementation, mechanical modeling, algorithmic evaluation). Firstly, this focuses on the two main areas of (1) single sperm behavior (the smallest scale) and (2) collective motion of a red tide (the largest scale) in order to survey a wide range of scale for ethological dynamics. Secondly, the scope of investigation will be expanded to include the behavior of various other organisms (e.g. ciliates and algae). In Publicly Offered Research, we expect that the proposed research area will be applied to a wide range of species, enabling the establishment of ethological dynamics in diorama environments through active research exchanges between the research groups within the Research Area.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The call for proposals is seeking skillful assessments of cell movement and behavior in various species. In this way, we seek to establish ethological dynamics of proto-intelligence across the species. Planned Research Groups may propose technical support (advanced measuring instruments and technologies, and advanced methods for mechanical modeling and simulation) for possible collaboration with Publicly Offered Research. Joint research and research exchanges between Publicly Offered Research groups are strongly encouraged.

In Research Group A01, the call is for cell biological and ethological research on smart adaptive behaviors under diorama environments, field environments, the internal environment of multicellular organisms, or industrial environments (bio-reactor, etc). The main target is single-celled eukaryotes (protists), but single-cellular behaviors found in multicellular organisms and prokaryotic behaviors are also included. In Research Group A02, the call is for research on technologies and methods that contribute to the creation of a diorama environment. Expected subjects are, for example, measurement engineering and micro-engineering, technology for measuring cell behavior with high temporal and spatial resolution, development of software for visualizing and analyzing cell behavior, development of methods for applying complex physical stimuli to cells, methods of collecting and culturing protists from a field environment, and development of microscope for observing cell behavior within a field environment, etc

In Research Group B01, the call is for biophysical and applied-mathematical research. Expected subjects are not only excellent mathematical model of cell behavior, and simulation with high temporal and spatial resolution, but also, for example, mathematical models dealing with the interaction of multiple species, simulation technology with the aim of assimilation with experimental data, and kinetic research on intracellular machines that control cell behavior. In Research Group B02, the call is for research on information science and comparative cognitive science. Expected subjects are not only excellent research proposals on the algorithm of proto-intelligence in a diorama environment, but also, for example, research on environmental adaptation, learning and evolution in cellular organisms, and research on proto-intelligence in comparative cognitive psychology.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	studies on skillful cell behavior in diorama environments	3	20
A02	studies on creation of diorama environments and measurement		
B01	studies on mechanical modeling for skillful cell behavior	2	6
B02	studies on algorithm evaluation of photo-intelligence		

Research Outline of Research Areas

Digital biosphere: integrated biospheric science for mitigating global environmental change
https://digital-biosphere.jp/en

Number of Research Area	:	21A403	Term of Project :	FY2021-2025
Head Investigator	:	ITO Akihiko		
Research Institution	:	University of Tokyo, Graduate School of Life and Agricultural Sciences		

1. Details of Research Area

Preventing global environmental change is an urgent issue for human sustainable society, and so various countermeasures have been proposed and deployed. Facilitating biospheric functions such as CO_2 assimilation and biomass production is expected to make contributions to mitigation, but our understanding, data, and models are far from sufficient.

This Research Area aims at establishing a new research field of integrated biospheric science by re-organizing findings of relevant areas, and thereby at presenting a new countermeasure to prevent critical global environmental impacts. Research members conduct a wide variety of basic studies and related applications to overcome barriers associated with scale gaps spanning from micro to macro scales of biological systems and global biodiversity and heterogeneity. This Research Area is composed of three categories of Research Group: A) investigation of mechanisms of biospheric functions, B) observation of biospheric functions under changing global environment, and C) development of a new model, called Digital Biosphere. Through intimate collaborations and simulations with the integrated model, this Research Area conducts a quantitative assessment of important mitigation-related indices such as CO_2 fixation, biomass production, and required land extent.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

In the second-half research period, participation of Publicly Offered Research that compensates for gap areas of the Research Area and contributes to integration into the Digital Biosphere, especially by model development, is expected. The Research Area expects diverse and collaborative applications from biosphere-related scientific fields such as ecology, Earth sciences, applicative fields such as agronomy, forestry, and fishery, integration of big-data from the biosphere with machine learning, technological support of model development, and comprehensive assessment across the biosphere and human society.

Research Group A04 conducts studies related to the Planned Research A, i.e., mechanisms of CO_2 fixation and biomass supply. Since the Planned Research investigates forest, vegetation, and soil microbes, the publicly offered research is expected to conduct studies on other mechanisms, such as blue carbon accumulation in coastal area and functional response to short- to long-term environmental variations. Also, a proposal on the relationship between biodiversity and functions is anticipated.

Research Group B03 conducts studies related to the Planned Research B, i.e., broad-scale observation of biospheric function. The Planned Research performs micrometeorological measurements and high-resolution remote sensing, and we expect participation of many sites to cover a wide spatial extent. Applications of long-term monitoring by utilizing existing sites and integrated data synthesis by participating intensive field campaign and manipulative experiments are expected.

Research Group C03 conducts studies related to the Planned Research C, i.e., biospheric modeling and mitigation options. The Planned Research develops a high-resolution model 'Digital Biosphere' and assesses climatic feedback using the Earth system model. The publicly offered research is expected to make contributions to these model studies and to facilitate intimate collaborations with the Research Groups of A and B. Proposals on improvement of simulation effectiveness with data-driven models and on examination of mitigation options taking account of socioeconomic factors are expected.

The Research Area plans to adopt three categories of the Publicly Offered Research: studies about high-priority topics and integration with the Administrative Group at 8 million yen per year (about 2 projects), developing research topics at 4 million yen per year (about 9 projects), and emerging (beyond the Research Area) topics at 2 million yen per year (about 14 projects). Applications from young and/or diverse researchers are strongly encouraged.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A04	Studies on mechanisms of biospheric functions	8 [high priority/integration]	2
B03	Studies on monitoring by observations	4 [developing]	9
C03	Studies on modeling and mitigation options	2 [emerging]	14

Research Outline of Research Areas

Plant Climate Feedbacks
https://www.plant-climate-feedback.com

Number of Research Area	:	23A401	Term of Project :	FY2023-2027
Head Investigator	:	SATAKE Akiko		
Research Institution	:	Kyushu University		

1. Details of Research Area

Climate change not only affects seasonal activity of plants, but it is also impacted by it as plants alter atmospheric composition and climatic processes. In addition to CO2 fixation and evapotranspiration, plants affect global climate by emission of biogenic volatile organic compounds (BVOCs) that comprise a large variety of molecules differing in size and physicochemical properties. BVOC have been shown to influence solar radiation and rainfall through the formation and growth of secondary organic aerosols, and contribute to tropospheric ozone production. BVOC emissions are one of the phenological traits that show pronounced diurnal and seasonal variation, and their seasonal emission behavior will have important implications for the future global environment However, there are many challenges to be overcome in elucidating the dynamic feedback between plant phenology and climate, such as large uncertainties associated with the estimates of BVOC emission and how BVOC emissions respond to future environmental change. Our aim is to address the intricate relationship between plant seasonal activity and climate This endeavor involves the establishment of a novel field "plant climate feedback," which integrates disciplines such as mathematical biology, plant molecular biology, ecology, atmospheric chemistry, and climate modeling. To achieve our objectives, we have formed two distinct research sections within our planned research group: "Regulatory Mechanisms" and "Feedback." In the "Regulatory Mechanisms" section, we unravel the genetic regulatory mechanisms that govern crucial plant phenological processes, including BVOC release, flowering, and leaf development. will develop predictive models to better understand how individual plants respond to climate change. In the "Feedback" section, we develop BVOCs monitoring method and climate prediction models to extend our understanding from individual plant-level responses to encompass population and broad-scale levels. By doing so, we aim to capture a comprehensive picture of the feedback mechanisms between plants, and we are also establishing the Plant Climate Integration Center, which will have strong organizational support in advanced measurement techniques, modeling capabilities, and field research assistance. This center will provide a robust framework for collaboration and enable seamless integration of expertise from various disciplines.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The research scope in this field ranges from genes to ecosystems to climate. A multidimensional approach is necessary to effectively analyze the multilevel data obtained, and it is crucial to enrich areas beyond the capabilities of the research teams through participation in Publicly Offered Research. The followings are examples of the projects. A01: Experimental and Monitoring Research (Biological Systems). This research focuses on observing plant phenological changes and stress tolerance in response to climate change and elucidating control mechanisms. It includes research on biosynthesis genes of terpene compounds and low molecular weight phenols related to BVOCs, as well as molecular mechanisms related to the accumulation and release of BVOCs, including methane. The project encourages proposals that analyze interactions between organisms and ecosystems, considering dynamic changes in gene expression. Additionally, it welcomes research that incorporates phytoclimatic feedback concepts into paleoclimatic and paleontological studies. B01: Experimental and Monitoring Research (Ecosystem, Atmospheric Science, Climate). This research seeks six proposals related to phytoclimatic feedbacks driven by molecules other than BVOCs. It also includes ecosystem observation using innovative devices such as automated remote observation systems for species identification, biomass and phenology observation, and technology development to enhance BVOC and aerosol measurements. The projects encompass the development of advanced technologies for BVOC and aerosol measurement. C01: Data Analyses and Modeling. This category focuses on data analysis and modeling and will accept five proposals. It seeks the development of new methods for analyzing large-scale, multilevel, and high-dimensional data. It also encourages the development of new biodiversity models that consider genetic diversity and theoretical research that mathematically models feedbacks between plants and climate to predict future scenarios. Since this category primarily involves data analysis and modeling, with no experimental expenses required, the maximum funding limit for applications is set at 2 million yen, lower than the other categories. In addition to BVOCs, research on other molecules, various plant species, and regions is also welcomed.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
A01	Experiment and monitoring (Biological systems)	4	7
B01	Experiment and monitoring (Ecosystem, Atmospheric Science, Climate)	4	6
C01	Data analyses and modeling	2	5

Research Outline of Research Areas

Extension and validation of unified theories of prediction and action
https://unifiedtheory.jp/en/

Number of Research Area	:	23A402	Term of Project :	FY2023-2027
Head Investigator	:	ISOMURA Takuya		
Research Institution	:	RIKEN Center for Brain Science		

1. Details of Research Area

Elucidating the computational principle of the brain and implementing it in artificial intelligence (AI) is the greatest frontier of natural and computational sciences. Although AI has achieved great success by gaining inspiration from neuroscience (e.g., feature extraction and reinforcement learning), a significant gap still exists between human intelligence and AI.

The brain constructs a 'generative model' that expresses the dynamics of external states to enable prediction and action to minimise future risks. The Bayesian brain hypothesis and the free-energy principle have been proposed to account for the perception, learning, and action of biological organisms. However, the neuronal bases underlying these theories are yet to be elucidated, given the difficulty in linking them with the corresponding biological phenomena. Recent developments in experimental techniques have enabled the identification of cell types and the acquisition of high-precision, large-scale data covering multiple layers and regions. Furthermore, reverse engineering of generative models has enabled the mapping of neural circuit quantities to quantities in generative models in a one-to-one manner. These developments have made it practical to identify generative models from experimental data, which will facilitate an understanding of the brain and mind.

Based on these progresses, this project aims to use state-of-the-art techniques to measure highly accurate, large-scale neuronal activity data from the brains of various animals and reverse engineer generative models from these data, to develop a unified theory of the brain and empirically test its validity. We will measure the neural activity related to the prediction of the external world and behaviour in various species—including fish, rodents, monkeys, and humans—and test whether generative models constructed from empirical data can predict brain activity, behaviour, and learning in animals. By integrating theoretical and experimental research, this project will develop a unified theory of the brain that can explain perceptual prediction and the planning and generation of behaviour in a unified manner, paving the way for the development of AI with human-like thinking and early diagnostic methods for psychiatric disorders.

2. Call for Proposals and Expectations for Publicly Offered Research, etc.

The principal investigators of the Planned Research are researchers in the fields of computational neuroscience, information theory, machine learning (Group A), and in neuroscience, neurophysiology, and psychiatry (Group B). However, to develop and verify a unified theory of prediction and action, it is necessary to combine innovative ideas from diverse perspectives with original techniques and theories in a complementary manner. Therefore, research proposals will be recruited from a wide range of fields. Emphasis will be placed on proposals that involve the necessary data science to link theory and experiments, and on the magnitude of the synergistic effect of collaborations between Publicly Offered and Planned Research. For example, we encourage applications from theoretical researchers who are willing to test their original theory empirically with data from the Planned Research, and experimental researchers who deal with functions and measurement scales that are not handled in the Planned Research or who have unique technologies for measuring and controlling biological targets narrowed down in Planned Research. We believe that Publicly Offered research conducted by multitalented researchers will play an extremely important role in the development of this research area. In particular, we expect active applications from young and female researchers with flexible and new perspectives. Research proposals of up to JPY 10, 5, and 3 million per year are invited.

C01: Theoretical research on unified theory—We invite proposals that will lead to the construction of a unified theory of the brain, proposals for theories with an original perspective targeting specific brain functions related to prediction and action, and proposals that will test theories by analysing data measured by the Planned Research and utilizing existing databases. We also emphasise AI applications and invite proposals that include ideas that could lead to the development of next-generation AI; for example, implementing energy-efficient computation using spiking neural networks.

C02: Experimental research on unification theory—We invite proposals with highly original measurement techniques and analysis methods to acquire highly accurate, large-scale neural activity in the brain related to prediction and behaviour in animals or humans. A specialised biological background is not a requirement for applicants. Proposals involving a variety of animal species will be obtained. Proposals focusing on the control and manipulation of biological information to verify theoretical predictions by examining causal relationships will also be invited.

3. Research Group, Upper Limit of Annual Budget and Number of research projects scheduled to be selected

Research Group Number	Research Group	Upper Limit of Annual Budget (Million yen)	Number of research projects scheduled to be selected
C01	Theoretical research on unified theory	10	4
C02	Experimental research on unified theory	5 3	7 5