RITSUMEIKAN UNIVERSITY

R-GIRO

Ritsumeikan
Global Innovation
Research Organization

RITSUMEIKAN GLOBAL INNOVATION RESEARCH ORGANIZATION

R-GIRO

RITSUMEIKAN
GLOBAL INNOVATION RESEARCH ORGANIZATION

Web: en.ritsumei.ac.jp/research/r-giro E-mail: r-giro@st.ritsumei.ac.jp

Office of Research Planning & Development
1 Nishinokyo-Suzaku-cho, Nakagyo-ku, Kyoto 604-8520, Japan
TEL: +81-75-813-8199
FAX: +81-75-813-8202

Research Office at Biwako-Kusatsu Campus
1-1-1 Noji-higashi, Kusatsu, Shiga 525-8577, Japan
TEL: +81-77-561-3412
FAX: +81-77-561-3955

Research Office at Kinugasa Campus
56-1 Toji-in Kitamachi, Kita-ku, Kyoto 603-8577, Japan
TEL: +81-75-465-8224
FAX: +81-75-465-8245

Research Office at Osaka Ibaraki Campus
2-150 Iwakura-cho, Ibaraki, Osaka 567-8570, Japan
TEL: +81-72-665-2570
FAX: +81-72-665-2579

2019.3

RITSUMEIKAN GLOBAL INNOVATION RESEARCH ORGANIZATION R-GIRO

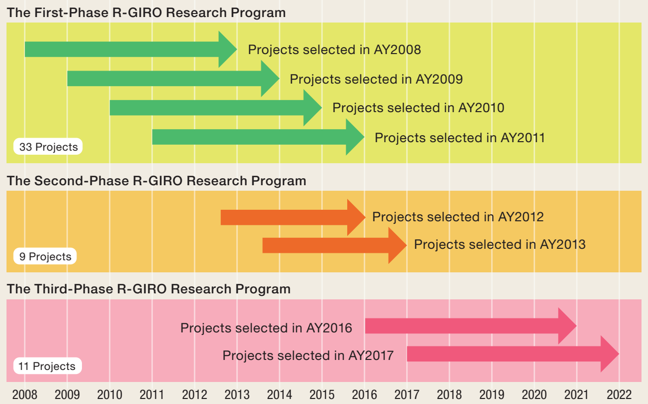
The Third-Phase R-GIRO Research Program

Formation of a Vital and Creative Human Society in Response to Declining Birthrate and Aging Population

The founding philosophy of the Ritsumeikan Global Innovation Research Organization (R-GIRO) is the pursuit of an flourishing and sustainable society. Ever since its foundation as a philosophy-driven organization in 2008, the R-GIRO has focused on the issues that need to be solved in order to form a society in symbiosis with nature, and has conducted activities through education and research.

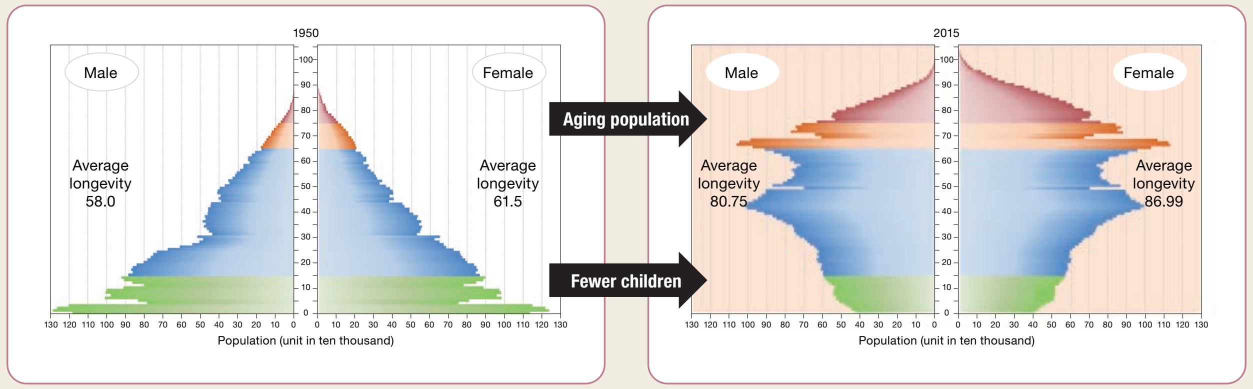
To date, based on its founding philosophy, R-GIRO has produced many research results. Recently, though, Japan and many other advanced countries have been facing the harsh reality of declining birthrates and aging populations. It is a matter of great urgency for Japan to seriously confront the issues arising from this reality in terms of not only policy but also research.

Based on such a background, we started the third-phase R-GIRO research program consisting of five research centers (Research Centers I to V) in AY2016. Focusing on the concept of "formation of a vital and creative human society in response to the declining birthrate and aging population," the research themes developed around these centers will approach solutions to the declining birthrate and aging population.



Research Center I
Formation of a society that provides younger generations with hopes and dreams, and the creation of a new culture

Research Center II
Science and technology to support an eco-friendly society capable of harmoniously coexisting with nature



Research Center III
Reinvigoration of production work by reforming the work environment

Research Center IV
Supporting a motivated life for elderly people and their entry into the labor force

Research Center V
Growth and sustainability of people and society on a global scale

Created from the Population Pyramid Image (National Institute of Population and Social Security Research) (http://www.ipss.go.jp.site-ad/TopPageData/1950.png, http://www.ipss.go.jp.site-ad/TopPageData/2015.png)

List of Projects of the Third-phase R-GIRO Research Program

Research Center	Research Project	Leader	College	Research Period	Page
I	Constructing Transdisciplinary Human Science for Evidence-based Human Services	Prof. Yuko Yato	College of Comprehensive Psychology	AY2016-2020	P3
II	New Technologies for Climate-Smart Agriculture	Prof. Hisaaki Mihara	College of Life Sciences	AY2016-2020	P5
II	Research Center for Everyday Smart Energy Innovation	Prof. Takashi Minemoto	College of Science and Engineering	AY2017-2021	P7
II	Development of Electronic and Photonic Materials Based on Organic and Biotic Resources	Prof. Hiromitsu Maeda	College of Life Sciences	AY2017-2021	P9
III	Robotics Innovation Based on Advanced Materials	Prof. Sadao Kawamura	College of Science and Engineering	AY2016-2020	P11
IV	Interdisciplinary Science and Technology for Activation of Living Organism	Prof. Satoshi Konishi	College of Science and Engineering	AY2016-2020	P13
IV	Systems Vision Sciences for Visual Function Regeneration	Prof. Katsunori Kitano	College of Information Science and Engineering	AY2016-2020	P15
IV	International and Interdisciplinary Research Center of Next-generation Artificial Intelligence and Semiotics	Prof. Tadahiro Taniguchi	College of Information Science and Engineering	AY2017-2021	P17
IV	Integration of Senses for Induction and Continuation of Exercise	Prof. Naruhiro Shiozawa	College of Sport and Health Science	AY2017-2021	P19
V	Restorative Justice in the Era of Decreasing Birthrates and an Aging Population	Assoc. Prof. Kosuke Wakabayashi	College of Comprehensive Psychology	AY2016-2020	P21
V	Research Center for a Sustainable Society Model Based on Long-term Demographic Analysis	Prof. Kenichi Yano	College of Letters	AY2017-2021	P23

Constructing Transdisciplinary Human Science for Evidence-based Human Services

Project leader

Yuko Yato (Center)
Professor, College of Comprehensive Psychology

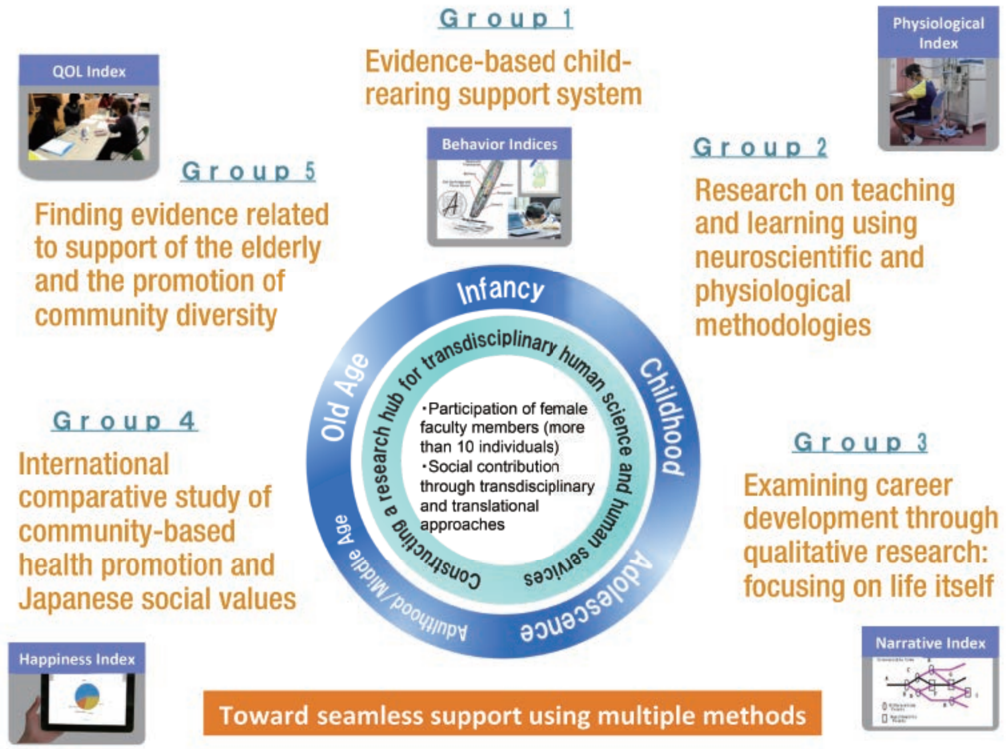
Group leaders

Tatsuya Sato (Left)
Professor, College of Comprehensive Psychology

Hanako Suzuki (Second from left)
Associate Professor, College of Comprehensive Psychology

Yuko Yasuda (Second from right)
Associate Professor, College of Comprehensive Psychology

Naoko Okamoto (Right)
Associate Professor, College of Social Sciences



Exploring new measures to provide seamless human services from infancy to old age

Aiming to seamlessly manage each stage of life from infancy to old age through integrated human science and social implementation

People face various difficulties at each stage of life, whether in infancy, childhood, adolescence, adulthood/middle age, or old age. This research project takes a transdisciplinary approach to study each of these stages of life, including development and learning processes, and understand their unique challenges. It seeks to find evidence-based measures to provide human services and means for their social implementation.

This research project not only focuses on the different stages of human life, but also explores measures to provide seamless services. In doing so, it examines issues such as developmental disorders and intellectual disabilities, which should be considered throughout life. Until now, there has been a dearth of flexible perspectives in the field of human services and developmental support owing to compartmentalization and fragmentation in academia. For example, researchers have not considered how a person who has experienced setbacks and failures at one point in life can recover at a subsequent stage. Such limited views have made it difficult to provide recovery support from a long-term perspective. However, in reality, childhood trauma can sometimes manifest during adolescence, or one's academic failures during childhood can usually affect one's future career development. A person's career development during adolescence can, in turn, shape the rest of his or her life. In this research project, each research group aims to provide new evidence and more effective support by thoroughly examining each stage of life and overcoming social and academic challenges, in addition to conducting original research projects.

Moreover, in addition to the method by which the research groups examine their participants and each stage of life, the research itself also takes an unprecedented approach by seamlessly integrating their research methods. By mutually sharing various research methods inseparable from the participants and their developmental stages, such as neuroscientific and physiological methods and qualitative research approaches that target individual participants, the research as a whole can bring to fruition integrated human science and its social implementation.

Accumulating evidence through the utilization of various research methods, such as neuroscientific and physiological methods, as well as qualitative and quantitative methods

For this research, the research groups were structured based on the following five life stages: infancy, childhood, adolescence, adulthood/middle age, and old age. While each group fully utilizes the latest research methods in their respective fields, the groups also proactively adopt research methods from other fields to accumulate evidence that can be put into practice.

Group Yato (Group 1 in the diagram), which focuses on infancy, deals with the social relationship between parents and children. It examines the social and physical environmental factors that influence the development of infants and caregivers' child-rearing behaviors. Highly accurate quantitative data are collected through various methods, such as behavioral observations, behavioral measurements, and physiological indexing, in order to find measures to provide evidence-based child-rearing support.

For example, infants between the ages of 6 and 36 months, along with their caregivers, are tracked using motion capture technology to measure their body movements, as well as the synchronicity between them and their caregivers. Another experiment also quantitatively captures each movement by analyzing drawing tasks performed by the infants using a digital pen. In addition to such research, which captures such activities, measurements based on physiological indices, such as saliva, are collected from the caregivers and infants. Furthermore, in addition to conducting web-based surveys on a national scale to collect quantitative data on the development of infants' sociability and difficulties in child-rearing, the group is also collaborating with a hospital to make behavioral observations of the fetus using ultrasound images. It aims to develop and socially implement a child-rearing support system that can detect early on the problems that occur in the relationship between parents and infants, thereby allowing for early intervention. For this purpose, the group uses various methods to quantify the social relationships between parents and their infants, and conducts a longitudinal survey of their environmental factors.

The next group, Group Okamoto (Group 2 in the diagram), focuses on childhood, with emphasis on conducting pedagogical research targeting both learners and educators. Their research attempts to determine the characteristics of teaching and learning activities by utilizing neuroscientific methods, such as brain activity measurements, and other physiological methods, such as eye tracking. The problem-solving process is divided into the following: the Individual Learning Condition, in which problem-solving is conducted alone by the learner; the Teaching–Learning Condition, in which the teacher provides appropriate advice to the learners as they try to solve a problem; and the Teaching–Collaborative Learning Condition, in which the learners collaboratively acquire problem-solving skills. In each of these behavioral processes, participants' brain activities are measured, and their eyes are tracked. The aim is to create models of teachers' advice and instructions based on the findings, in order to determine appropriate guidance and support and give back to the field of education.

The third group, Group Yasuda (Group 3 in the diagram), is conducting quantitative research by incorporating a *narrative* perspective with a focus on adolescence. Focusing on each individual and his or her unique and different life story is what characterizes the *narrative approach*. Using a qualitative approach methodology that involves Trajectory Equifinality Modeling (TEM), this group examines adolescents' career development and the accompanying support and education.

The fourth group, Group Sato (Group 4 in the diagram), studies quality of life (QOL) in adulthood/middle age. The novelty of this group's approach lies in their focus on the individuals involved. This perspective is based on the idea that an individual's criteria for his or her own sense of QOL are not necessarily shared by those who are of the same generation. Participants' QOL is measured using a method called the *Schedule for the Evaluation of Individual Quality of Life* (*SEIQoL*), in which the participants set for themselves the important items based on their understanding of their unique QOL. The findings are then used to develop a counseling tool designed to understand individuals' QOL. Moreover, this group is interested in improving QOL through the promotion of health and is engaged in investigating citizen-led health promotion activities in a certain area of Fukushima Prefecture.

Finally, Group Suzuki (Group 5 in the diagram) is examining the cognitive function of the elderly by using a brain-activity measuring apparatus. In particular, this group collects and analyzes multifaceted data on variables relating to the decline of motor functions, with the aim of creating a society friendlier toward the elderly. Moreover, Japan is not only experiencing a decline in birthrate and an increase in its aging population but also undergoing an internationalization process, creating a need for human services that relate to diversity. By conducting surveys on the mental health and wellness of people in foreign communities, considering the capacity to accept diverse cultures, and considering insights from international comparative studies, this group is attempting to lead the way toward creating a society that is more comfortable with people of different backgrounds.

Fostering female researchers through excellent research and a vision to establish a Lifelong Developmental Science and Mixed Research Methodology Center

As can be seen from the above discussion, there is no other available research that not only considers the relational aspects of the various stages of life and corresponding human development, but also fuses quantitative and qualitative research. This innovative approach aims to discover an entirely new evidence-based methodology for human services, in order to construct a framework for helping supporters, and to ultimately implement them in society. The research groups envision establishing a "Center for Lifelong Developmental Science and Mixed Research Methodology." The center will be designed to function as a hub for researchers and/or practitioners who wish to acquire knowledge on the various methodologies relating to human science and the requirements to help supporters.

Further, as the group strives to foster female researchers, which is a national priority, it has made it a policy to mostly appoint women as group leaders and researchers for current research projects. By involving female researchers who are active at the forefront of their field and by conducting groundbreaking research, the group aims to not only be an excellent role model, but also develop a foundation for improving the quality and capacity of future female researchers.

New Technologies for Climate-Smart Agriculture

Project leader

Hisaaki Mihara (Center)
Professor, College of Life Sciences

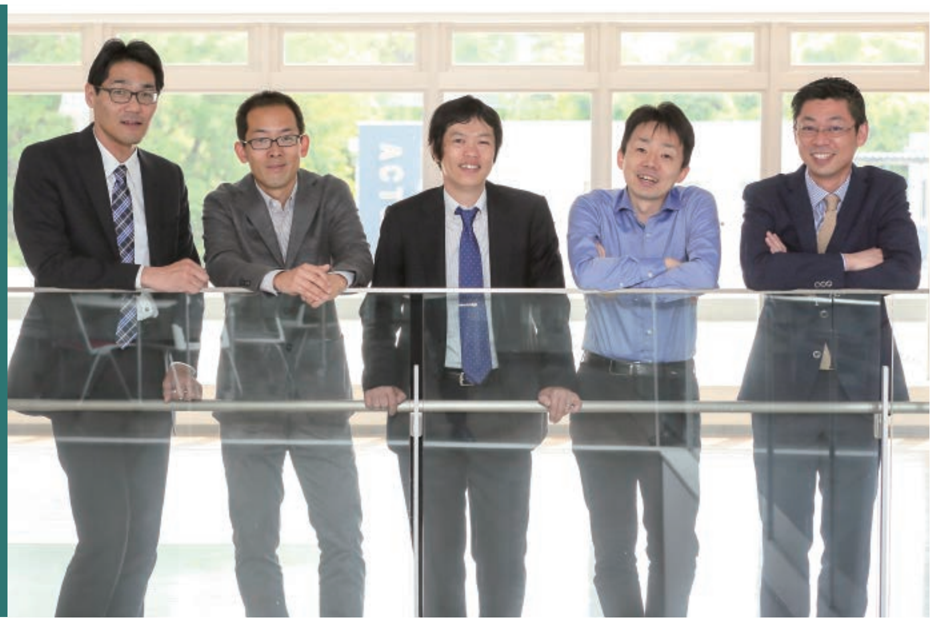
Group leaders

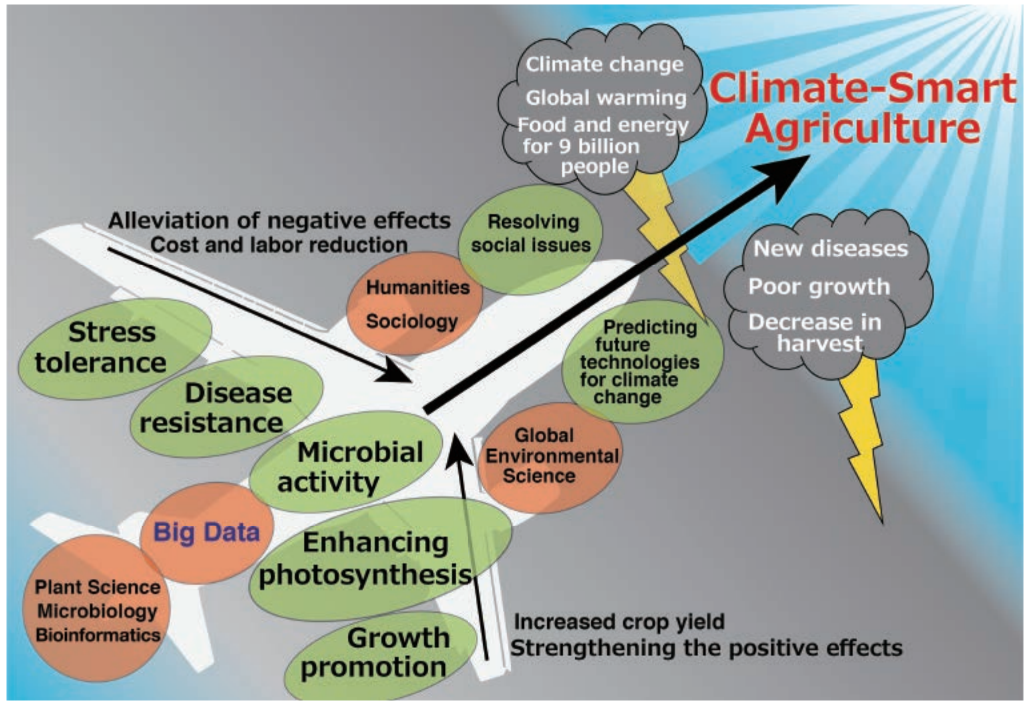
Takeshi Ishimizu (Left)
Associate Professor, College of Life Sciences

Atsushi Takeda (Second from left)
Professor, College of Life Sciences

Hiroyoshi Matsumura (Second from right)
Professor, College of Life Sciences

Yoichiro Fukao (Right)
Associate Professor, College of Life Sciences





Developing climate-smart next-generation agriculture that will sustain 9 billion people

Elucidating biological mechanisms related to the cultivation of crops with the goal of contributing to technological development that will support sustainable food production

Climate change, which includes events such as global warming and weather abnormalities, is now exerting a great influence on the growth of crops and their yield. It is predicted that the global population will reach 9 billion by the year 2050, and, as concerns about the impact of climate change grow, how to securely and sustainably provide food and energy has become a major concern. This research project is aimed at providing a solution to these concerns. The primary aim of the project is to contribute to the development of an agriculture system that is responsive to unpredictable climate changes, and that will perpetually and steadily sustain the food and energy needs of 9 billion people when that era arrives. This type of agriculture may be called *climate-smart agriculture*. As a foothold for such agriculture, the group is predicting the agri-biotechnology that will be needed in the future while actively developing new technologies based on the biological mechanisms involved in growing crops, while establishing a pathway by which they can be accepted by society in a sustainable manner.

Exploring the function of microorganisms and the molecular structures of plants for promoting plant growth and increasing their resistance to stress and diseases.

Joining the three different fields of botany with different perspectives—plant biochemistry related to plant growth, plant pathology related to plant immunity, and plant structural biology involving plant function at the molecular and atomic level—together with applied microbiology and plant bioinformatics, a major goal of this transdisciplinary research project is to develop new technologies.

First, Group Mihara, which specializes in applied microbiology, is researching and developing technology that will be beneficial in the *strengthening of the positive effects* (promoting growth) and *alleviation of the negative effects* (increase disease and stress-tolerance) by focusing on the various effects microorganisms have on plants.

Most of the previous studies related to soil microorganisms have focused on and limited their scope to the discovery of the indirect effects of the soil environment, for example, enriching and fertilizing the soil by turning organic materials, such as the fallen leaves, into inorganic materials. However, in recent years, accumulating evidence has indicated that microorganisms have a direct effect on plants as well. Therefore, this group started to focus on the fact that amino acids, such as lysine and pipecolic acids, may be involved in the communication between microorganisms and plants. The group is thus attempting to elucidate the mechanism of plant-microbe communication based on the metabolism of D-amino acid and pipecolic acid and apply the findings to the development of technology that will promote plant growth and confer resistance to pathogenic bacteria and stress.

Furthermore, the group has turned its attention to how microorganisms metabolize metals in the soil and is attempting to reveal the details of this metal-metabolizing system and its effects on plants. In collaboration with Group Ishimizu, which is investigating the impact of rare-earth elements on plants, the group aims to apply the findings for plant growth promotion.

The group is also planning to develop a safer and environmentally-friendlier microbial pesticide to help plants gain disease resistance.

Group Ishimizu aims to discover the plant growth promotion mechanism at the molecular level and to develop a growth promotion technology based on these findings. Using the sugar chain analysis method, which Ishimizu has developed and established over time, one such effort is directed towards the investigation of enzymes that are involved in the synthesis of cell wall polysaccharides directly involved in plant growth. Another area they have set their sights on as an external factor that also relates to plant growth is rare-earth elements. Because they discovered that plant growth is promoted when rare-earth elements are added to the soil, out of the 17 types of rare-earth elements, the group is working on finding the safest, easiest, and most effective element to maximize plant growth promotion. Additionally, the group is collaborating with Group Mihara in discovering this mechanism as they share and refer to their understanding of microbial metal metabolism.

Group Takeda is working on *alleviation of the negative factors* that prevent plant growth. With the advent of genome editing technology, it has now become possible to create plants that are resistant to diseases; however, there are still several hurdles that must be overcome. First, for each pathogen, it is necessary to clarify the mechanism of infection, and to determine the host factors necessary for infection. Subsequently, to establish a system that enables genome editing in the target plant species, the group is examining the infection mechanism and aiming to identify the host factors of a virus that infects bell pepper. In addition, with the use of genome editing, the group has tried to produce genome-edited peppers that the virus cannot infect. Finally, to ensure proper communication to consumers, the various issues relating to safety, regulations, and ethics need to be properly organized, and correct knowledge must be steadily disseminated to the public. Therefore, a specialist in international law is also participating in the project to ensure that the legal aspects of the theory rest on a rock-solid foundation. This legal specialist is also helping to remove any obstacles that may prevent propagation based on existing international norms and standards, including international environmental agreements, The United Nations Framework Convention on Climate Change treaty, and The Convention on Biological Diversity treaty.

The fourth group, Group Matsumura, is conducting basic research to provide plants with tolerance to environmental stress as a consequence of climate change, such as high temperature. More specifically, they are focusing on C4 plants such as corn, which shows tolerance to higher temperature, to elucidate the mechanism at the molecular level. The group is focusing on transgenic rice with DNA inserted from a C4 plant to improve its tolerance to heat stress. At the same time, the group is also testing methods for imbuing tropical plants with the ability to produce useful products while contributing towards the greening of the desert. For example, the tropical plant *Eucommia ulmoides* shows tolerance to higher temperatures, and, is therefore considered to be useful for greening the desert. In addition, *Eucommia ulmoides* accumulates a natural rubber that is useful for industrial applications. However, *Eucommia ulmoides*'s capacity for harboring natural rubber is rather poor, and its biosynthesis mechanism is still unknown. Therefore, this research aims to elucidate the molecular mechanism by which the tropical plant *Eucommia ulmoides* can store natural rubber at the atomic and molecular levels. Furthermore, based on these findings, the ultimate aim of this project is to create a tropical plant that will have high yields of natural rubber.

Finally, Group Fukao is researching methods for increasing crop yield by utilizing large-scale transcriptome data. As part of this undertaking, they are trying to improve rice quality and productivity by collecting gene expression data from rice fields, conducting a simulation analysis, and identifying the fields where immature white grains are likely to occur. In addition, as part of an effort to elucidate the mineral stress tolerance mechanisms, the group is trying to identify the genes that respond to zinc deficiency, with the hope of gaining a more comprehensive understanding of the zinc deficiency tolerance mechanisms in plants. Furthermore, the group is searching for a compound that will be tolerant against multiple stresses such as heat and mineral stress, by utilizing a large-scale chemical library. The aim is to modify such compounds into forms that can easily decompose, which will not only allow for the possibility of increasing the crop yield, but will also prevent yields from decreasing under stressed conditions. Moreover, the group intends to contribute to the improved productivity of future food production, based on predicting what impact future climate change will have on the growth of crops, through simulation analysis.

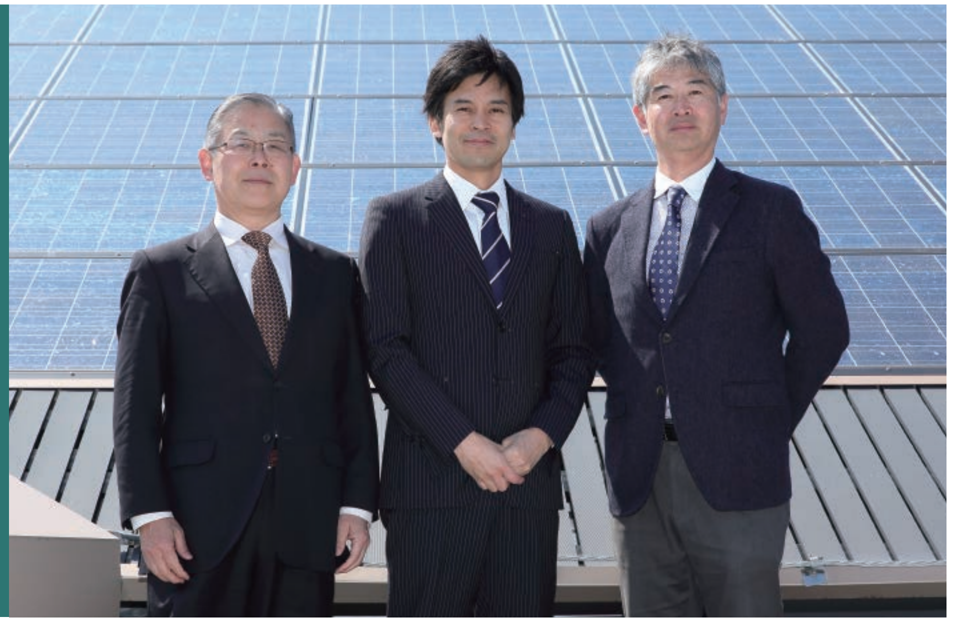
Predicting climate change at the global-level and exploring the sciences and technologies that will be required in our future

Based on the findings of basic research conducted by each of these groups, the research project as a whole will work in collaboration with farmers and corporations to refine such findings into a socially implementable technology. In addition, this research project is not looking only at current issues. The group is also working with researchers in climatology to explore the sciences and technologies that will be required in the future, as it looks to predict the state of global-level climate change by 2050 and beyond. The group believes in creating next-generation agri-biotechnology that will not be impacted by climate change or by complex and ever-changing social situations, based on scientific evidence, instead of relying only on past experiences as many have done. This mindset and effort will surely have a great impact that could be deemed the *agricultural revolution of the 21st century*.

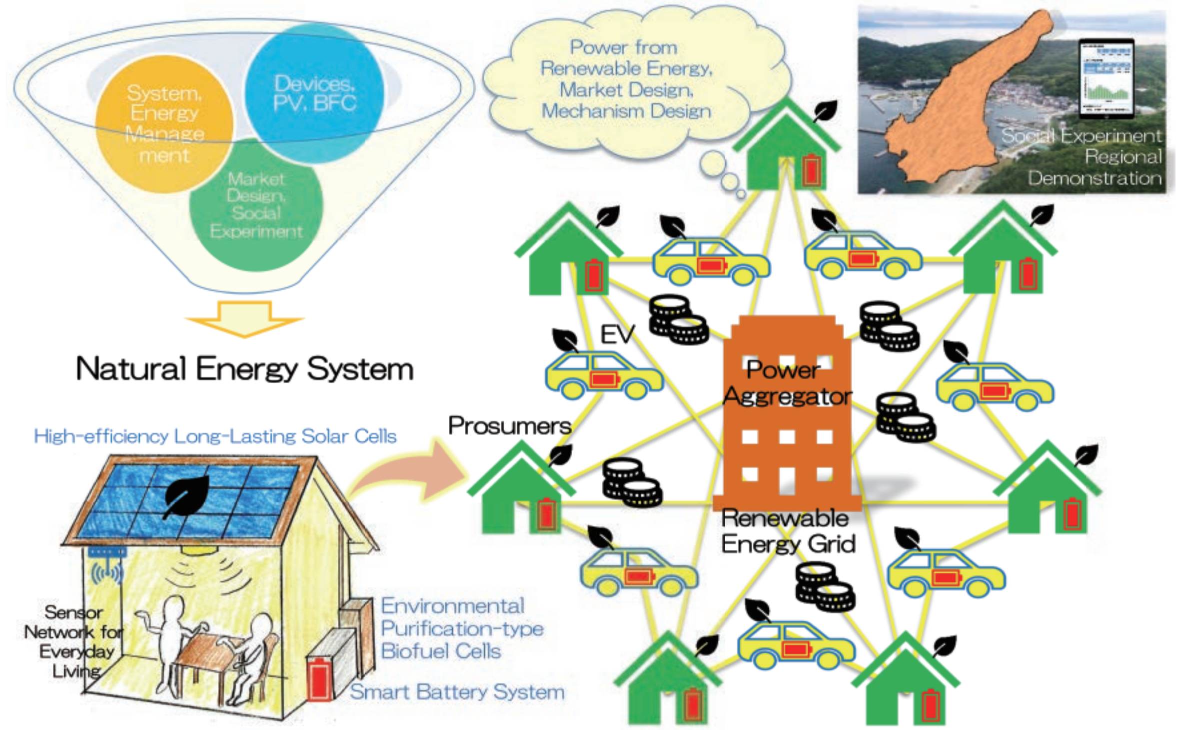
Research Center for Everyday Smart Energy Innovation

Project leader
Takashi Minemoto (Center)
Professor, College of Science and Engineering

Group leaders
Masahiro Fukui (Left)
Professor, College of Science and Engineering
Koji Shimada (Right)
Professor, College of Economics



Creating new devices, technologies, and social systems that allow for the *smartification of everyday living* using sustainable natural energy



Conducting technological and academic research to realize the *smartification of everyday living* using environmentally sustainable energy

In this research project, the members are conducting new technological and academic research, thus contributing to *a sustainable supply of environmentally symbiotic energy for everyday living*.

While issues related to the depletion of fossil fuel and environmental pollution caused by a global increase in energy demand are yet to be solved, the demand for sustainable, environmentally friendly energy sources is increasing. In this modern era, where the mechanization, informatization, and intelligentization of residences (and lifestyles) are emerging to not only assist seniors but also provide convenience and comfort to all, the efficient use of energy becomes a major issue. This research project intends to create a sustainable system using natural, symbiotic energy sources (clean energy) by employing technologies that are related to the intelligentization and optimal control of energy, in order to realize *an improvement in the quality of life*.

Specifically, attention has been given to solar power generation and biofuel cells as sources for sustainable energy. All the solutions, ranging from electric energy *generation* via natural energy conversion, to its storage and distribution for its *efficient use*, and a mechanism for borrowing and sharing this power via wide-scale power management and trading are being comprehensively researched with the goal of social implementation.

Comprehensive engagement in the creation of devices, energy management technologies, and social systems

To this end, three groups—energy conversion device development, energy management technology development, and energy innovation mechanism research—are researching their respective focus areas.

First, Group Minemoto is developing solar and biofuel cells as electrical energy conversion devices. The group's primary focus in this regard is the development of compound thin-film solar cells. Currently, approximately 90% of solar cells in the market are made of crystalline Si (silicon). However, because the production of Si is energy-intensive, there is a limit to its cost reduction potential. Therefore, Group Minemoto is choosing not to use silicon and instead developing Cu(In,Ga)(S,Se)2 based solar cells using elements and inorganic materials that are in abundance, such as copper (Cu), sulfur (S), indium (In), gallium (Ga), and selenium (Se). Cu(In,Ga)(S,Se)2 solar cells have already been proven to have a high conversion efficiency of 22% in lab experiments, and their commercial production is also underway. With the aim to reach the theoretical limit of 33% conversion efficiency, this group is working on improving the conversion efficiency by adjusting the electron affinity between the light absorption layer of the solar cell thin film (p-type semiconductor layer) and the (n-type) buffer layer, as well as by working on new material development such as a transparent electrode material. In addition, the group is developing solar cells, such as Cu2SnS3 and SnS, which do not use minor metals such as indium. Since this research group is envisioning a power transmission system that utilizes the mobility of automobiles, they are also developing coatable and thin-film panels with excellent flexibility, which can be applied to curved surfaces such as automobile rooftops. At the same time, the group is also developing biofuel cells, which use organic waste materials such as those from wood processing, to generate electricity.

Next, Group Fukui is in the process of developing a power storage system and a highly reliable and highly efficient intelligent power management system in order to *efficiently use* the generated power. Since the amount of energy that can be generated using natural sources is inconsistent depending on the weather or the time of day, it is indispensable to have a storage technology that allows for effective utilization of electricity. This group is thus engaged in developing a power storage device and, along with it, a small, high-efficiency DC converter to use electricity more efficiently. Additionally, to improve the safety, efficiency, and lifespan of such power storage and power converting devices, it is necessary to have a comprehensive battery management system for optimal control for both solar and biofuel cells alike. This group has also developed a technology that senses and controls the temperature and the power storage conditions inside the batteries, which is also capable of sensing the state of degradation and controlling it to avoid accidents caused by overheating. In addition, this highly reliable and highly efficient intelligent power maintenance management system includes an IoT device combining device sensors, communication, and the host computer.

The third group, Group Shimada, is researching how to create a *predictive energy management system*, which would be necessary after wide-scale implementation of renewable energy in a community, to ensure a steady supply of electricity. In addition, the group is designing a new trading market for renewable energy and researching how to implement it as a social system. First, from the perspective of system control, the group is trying to construct a statistical model that will be able to predict with high accuracy the demand for and amount of renewable energy that can be produced based on the weather and climate. Furthermore, the group is constructing an energy management algorithm that will utilize these predictions. This energy management system will make it possible to achieve local production and consumption of electricity by sharing and distributing it to and from the *prosumers* (homes and small businesses)—who are both producers and consumers of electricity—utilizing distributed power supplies (storage batteries) to secure backup energy and to create a buffer for surplus power to maintain a balance between supply and demand.

A large-scale implementation of renewable energy has issues such as an immature trading market and a lack of mechanisms to compensate for deficiencies in the backup power supply capacity. Therefore, it is necessary to create a trading market that incorporates trading between prosumers and wholesale power markets, which will act as a backup when there is a shortage in the power supply. This group is in the process of understanding prosumers' behavior based on regional weather conditions and the fluctuations in demand, in order to logically consider the optimal power trading mechanism. Furthermore, in locations where municipalities are promoting and taking charge of supplying electricity through renewable energy, such as in the cases of Miyama city in Fukuoka Prefecture and Awaji Island in Hyogo Prefecture, the group has implemented their findings from their theoretical studies in a demonstration experiment. Demonstrating the effectiveness of the mechanism design derived from theory in these regions brings them a step closer to social implementation.

Such unique research projects could not only lead to innovative device developments, but also to new technologies and academic fields yet unimagined.

Effective usage of clean energy is one of the most important global issues, and many advanced research institutes around the world are researching next-generation energy storage technologies and energy sources. However, there are no other known examples of research focusing on a concrete theme such as *the smartification of everyday living* in the context of a declining birthrate and an aging society, where a wide range of academic fields from science and engineering to humanities are coming together to research such a theme comprehensively, producing findings on a variety of subjects ranging from device development to energy management and social system designs. It is precisely for such uniqueness that the groups not only expect to see the creation of innovative designs and technologies but also the emergence of new technologies and academic fields that are yet to be imagined.

Development of Electronic and Photonic Materials Based on Organic and Biotic Resources

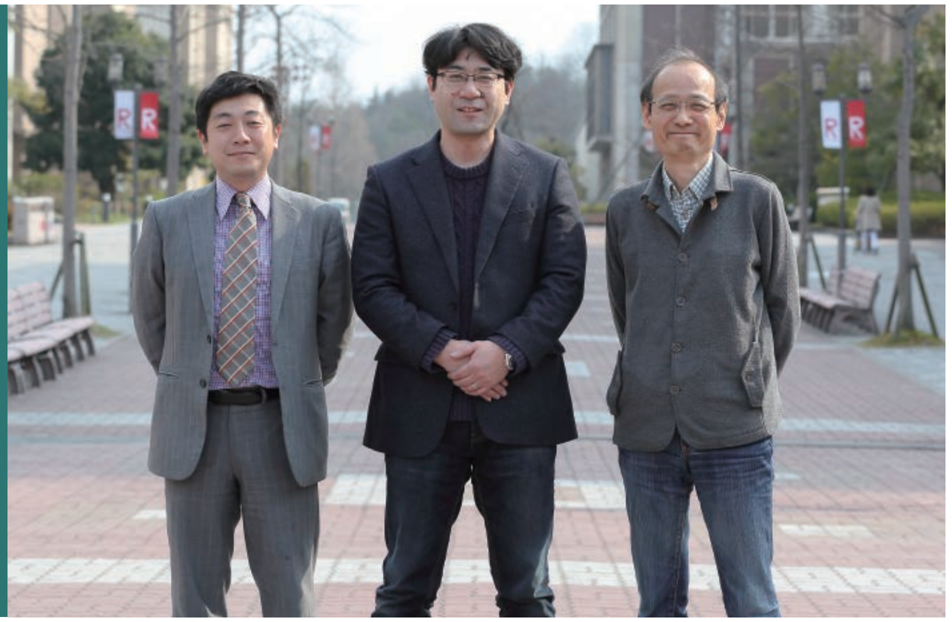
Project leader

Hiromitsu Maeda (Center)
Professor, College of Life Sciences

Group leaders

Toshifumi Dohi (Left)
Associate Professor, College of Pharmaceutical Sciences

Hitoshi Tamiaki (Right)
Professor, College of Life Sciences



Taking on the challenge of creating innovative organic materials that will advance science and technology research.

Creating new organic materials with new synthetic chemistry methods and developing innovative materials that will manifest new electronic and optical properties

Organic materials are widely used in society and industry, from everyday items such as medicines to electronics and advanced materials such as liquid crystals and semiconductors. In recent years, however, there has been growing excitement over the potential of new materials with electronic and photonic properties. Organic materials have several advantages compared to inorganic materials: organic materials can be designed and synthesized at the atomic and molecular levels, the conformations can be controlled easily, and their material costs are relatively low. In addition, currently, most organic resources that are used to prepare functional materials are derived from petroleum and coal. Therefore, the development of organic materials that can be synthesized more efficiently is anticipated, at the very least, to allow the effective utilization of limited fossil fuel and biotic resources. Above all, because all phenomena are based on appropriate atomic and molecular arrangement, the control of atoms and molecules in ordered forms could result in innovations that could solve many fundamental challenges facing humanity.

With this mission, the present research project focuses on synthetic chemistry and aims to create new organic materials that will act as the foundation for the development of functional materials with a range of physical properties, including electronic and electrooptical properties. With regard to the creation of new materials, the goal is to thoroughly examine a wide variety of methods for the precise arrangement of appropriate atoms, thus enabling the design and synthesis of new molecules, and, subsequently, the arrangement of molecules to form aggregates and higher-order structures for optimization as functional materials.

With *organic chemistry* as their common denominator, three research groups with different specialties will dynamically converge and collaborate to advance the research goals

In this research project, with organic chemistry as the common denominator, three groups, each with different specializations—physical organic chemistry, bio-organic chemistry, and synthetic organic chemistry—join to share and make use of each other's technologies and insights, aiming to produce results that the current model of research could not produce on its own.

For example, Group Maeda has been attempting to create a variety of new materials that exhibit electronic properties. Through organic synthesis, they have created π-electron ion pairs and have worked on the synthesis of molecules with π-electron systems, particularly focusing on pyrrole rings due to their ability to interact with ionic species. Among the various π-electron systems, negatively charged π-electron anions are difficult to synthesize and are highly reactive. In addition, the control of molecular assemblies is a significantly challenging subject.

Group Maeda has already designed and synthesized anion-responsive π-electronic systems, and succeeded in forming charge-stacked aggregates by using these species as pseudo π-electron anions, stacking them alternately with counter cations. Furthermore, Maeda has also made it possible to form assemblies based on arrangements of ionic species, where the same ionic species are stacked in parallel. In addition, he has found ways to adapt this into supramolecular gels and liquid crystals containing such assembled structures. Based on these successes, this group is now aiming to generate materials with new properties by incorporating the protocols offered by Group Dohi, that is, novel methods to form π-electronic molecular frameworks, and investigating a variety of synthetic routes and arrangements of various π-electronic molecules.

Group Tamiaki has used a variety of organic bonding methods to synthesize associative chlorophylls, and they are now using these associative properties in an attempt to create supramolecular nanofunctional materials. The nanostructures formed through self-assembly (self-association) will lead to breakthroughs in next-generation materials science.

Chlorophyll, which is Tamiaki's research focus, is a pigment molecule that functions as an antenna that absorbs and transmits light during plant photosynthesis. The group has investigated the light harvesting functions and energy transmission mechanism of photosynthesis and plans to utilize those characteristics to construct artificial photosynthesis systems; in this respect, Tamiaki is a world leader. To date, this group has developed a method to obtain a variety of chlorophyll J-aggregates systematically, as well as chlorophyll metal complexes. This group is now attempting to artificially synthesize novel associative chlorophylls based on the chlorophylls included in green anaerobic photosynthetic bacteria. In addition, by using the self-assembly (self-associability) of synthetic chlorophylls to control the degree of assemblies and their sizes and nanostructures, the group is developing self-assembling supramolecules with new physical properties. Such associative chlorophylls will lead to the development of supramolecular materials that exhibit new functions applicable to artificial photosynthesis systems, which has not been achieved to date.

Group Dohi has developed novel methods using π-conjugated molecules and aims to synthesize materials with new molecular frameworks. Currently, Dohi's lab is conducting advanced research into the development of organic synthesis methods using cross-coupling reactions. In particular, the group leads research into cross-coupling reactions that connect different aromatic rings. Thus far, the group has succeeded in the direct chemical conversion of phenols, alkylbenzene, and heteroaromatic rings by utilizing the unique properties of hypervalent iodine.

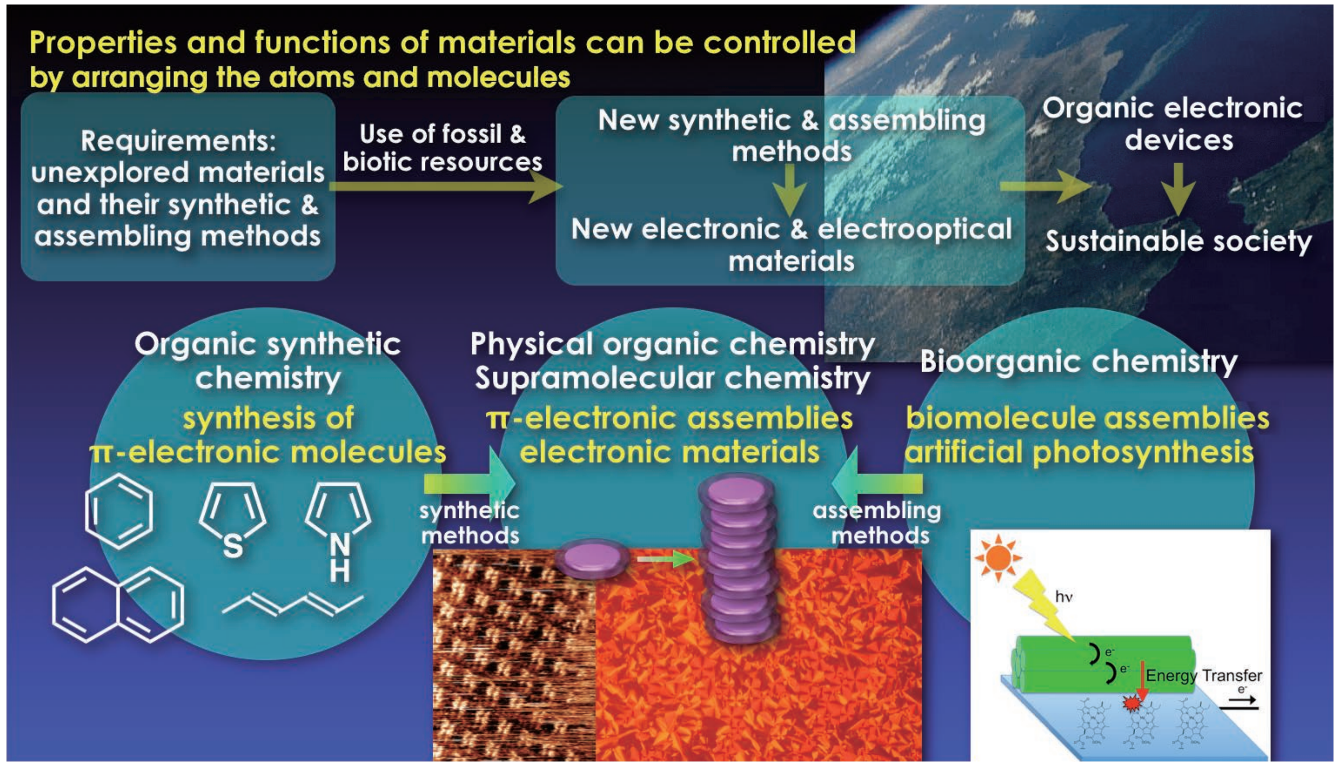
Building on these successes, Dohi is now attempting to synthesize new materials using new synthetic methods. The aim is to generate useful structures without the use of rare chemical resources such as rare metals, which have been considered indispensable in cross-coupling reactions. One such example is the development of the *iterative coupling method*, which controls the bonding of aromatic rings, where the bonding process is repeated successively. Thus, the focus is on the establishment of an easy method to synthesize highly structurally controlled mixed oligoarenes. This group will then provide these materials with new frameworks—which have been synthesized by the newly developed method—to Groups Maeda and Tamiaki as materials for further research.

The groups aim to create new organic materials based on novel principles, which will contribute to the advancement of science and technology and the development of industry

The intention is also to create a vast and varied library of materials and properties based on the research conducted by these three groups and to organize the information based on the correlations between the interactions (binding/association) of various materials at the atomic/molecular level and the resulting properties and functionalities.

Leadership in the field of science and technology, as well as the development of industry, can only be achieved if the scope of work is expanded beyond the improvement of the current functional materials to the creation of new materials based on entirely new principles and functionalities. To this end, it is necessary to be well versed in the chemical properties and uniqueness of materials and to conduct basic research into material development from the atomic and molecular levels upward.

Nowadays, the field of organic chemistry is compartmentalized, and convergence and collaboration are rare beyond the divisions of each respective specialty. In this research project, ideas will be generated through the close and dynamic collaboration of three fields of studies in a common and familiar environment. This close-knit collaboration is expected to lead to the creation and realization of new organic materials, whose properties will surpass those of currently available materials.



Robotics Innovation Based on Advanced Materials

Project leader

Sadao Kawamura (Third from left)
Professor, College of Science and Engineering

Group leaders

Shinichi Hirai (Left)
Professor, College of Science and Engineering

Osamu Tsutsumi (Second from left)
Professor, College of Life Sciences

Shima Okada (Third from right)
Associate Professor, College of Science and Engineering

Shugen Ma (Second from right)
Professor, College of Science and Engineering

Kazuhiro Shimonomura (Right)
Professor, College of Science and Engineering

Polymer Materials offer the possibility of soft, light, and small robots

The fields of robotics and materials engineering collaborate to create new robotics with new materials

Keeping pace with the development of computers over the last half of the 20th century, robotics has evolved at an accelerated rate. More than a million industrial robots are now in use and have become essential in the field of manufacturing. However, fundamental issues have also come to light regarding robotics, the most prominent of which is associated with robots made of rigid metallic materials. Structural materials, sensors, and actuators all use metals that result in the creation of robots that are hard, heavy, and large. Further, there are limits to the flexibility and smoothness of the movements of their joints. These drawbacks are preventing the implementation of robotics in a variety of fields. This research project aims to resolve these issues by reconstructing robotics itself from its basic theory through the introduction of advanced materials that will replace metallic materials and the revamping of the design mechanism, controls, and usage methods.

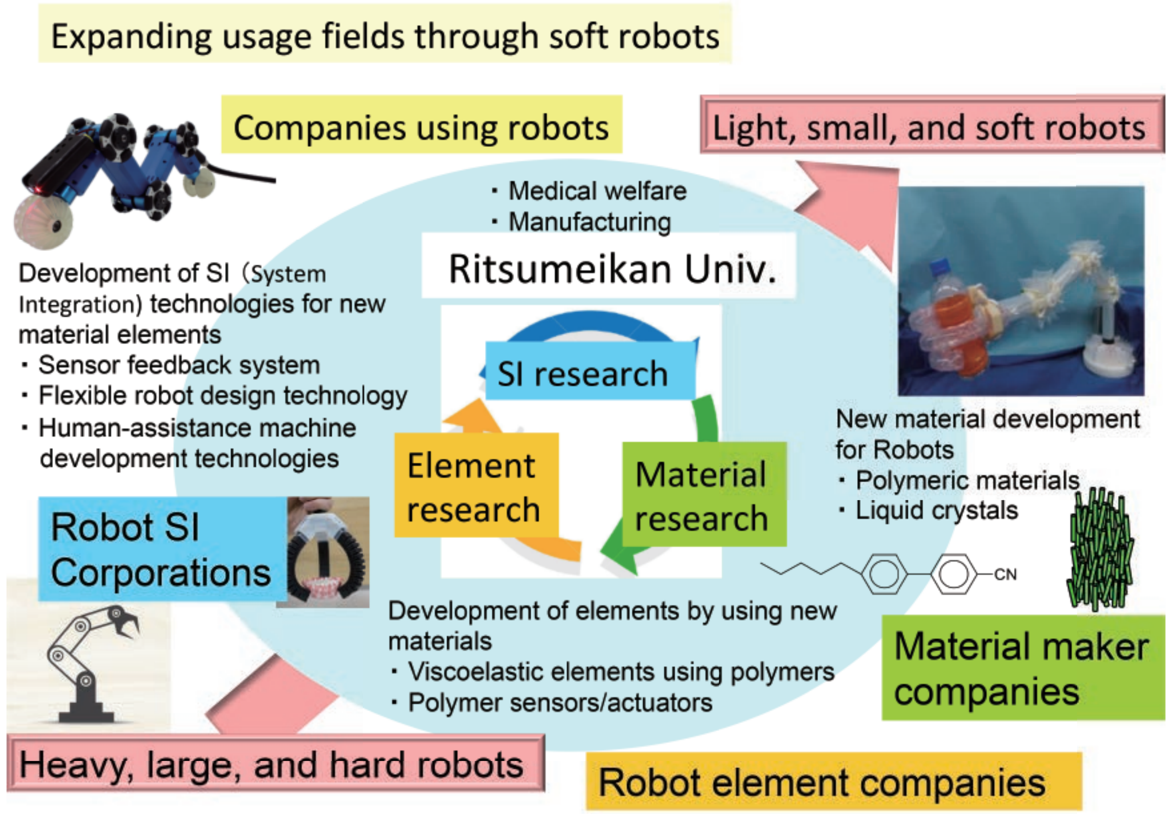
One of the advantages of this research project is that not only does the group include researchers from the robotics field, but, unlike in previous work, it also includes participating researchers from the field of materials engineering. Such collaborations will help in creating a new kind of robotics.

Developing soft actuators and small sensors from polymer materials that did not previously exist in the field of robotics

This research project is divided into six groups in order to conduct well planned research. Group Tsutsumi is responsible for the development and provision of new materials, which constitute the core of the R&D of each group. Tsutsumi has previously worked on polymers and molecular assemblies as the base materials to develop optical and electronic functional materials. Based on these past accomplishments, the group is progressing toward the development of organic materials that will contribute to weight reduction, miniaturization, and improved flexibility for robots. To this end, the group focuses on studying liquid crystals. Tsutsumi has utilized liquid crystals that, when stimulated, change their aggregated structure to develop a material that can change its luminescent color when an external stimulus is applied. Furthermore, it has developed a photoresponsive liquid crystal material using a photochromic compound. This group is now utilizing these technologies to develop nanoscale stress and pressure sensors, which may soon be mounted on robots. The group also intends to develop new viscoelastic polymer materials that improve the control performance of robot motion.

Then there is Group Kawamura, which is trying to create an all-plastic robot using a polymer material that is not commonly used in the robotics field. Kawamura has, for example, already developed a super-lightweight, plastic film-based, flexible, and inflatable air pressure operated robot arm by building upon its experience in developing metal-free mechanisms and control methodologies. This group is now trying to develop flexible contact and power sensors that utilize polyurethane and piezoelectric materials. They aim to eventually achieve precise positioning and force control by using polymeric materials to develop an all-plastic robot arm.

Next, Group Hirai is working on the development of soft actuators and robotic mechanisms using polymeric materials. Currently, the group is developing technology for food handling. To grasp foodstuffs that come in a variety of shapes and hardness, it is necessary to consider variations in shapes and positions. At the same time, precise control of the grasping force is required, so as not to crush the items. In addition to developing a method to absorb positioning errors, Hirai is exploring gripping methods suitable for grasping flexible objects. Using pressure-sensitive electrically conductive thread, whose electrical resistivity changes when tension and pressure are applied, this group is also working on the design and manufacturing of robotic hands that will be capable of grasping objects gently. If this can be achieved, the group will be able to contribute to the automation of processes at food processing sites, such as the handling of side dishes for bento boxes, which is still a manual process.



On the other hand, there is Group Ma, which has succeeded in developing hard metallic materials to create rather flexible robots, such as snake-like pipe inspection robots that can go through narrow environments, and mobile robots that can handle difficult terrains, including water, mud, and rubble. This group is now adding soft elements to the previous hard mechanical and metallic elements to explore new possibilities. The group is also trying to utilize new materials that have non-linear and viscoelastic properties, in order to improve functionality and environmental adaptability, reduce size and weight, and even remove the actuators themselves. Additionally, the group aims to establish a design theory that will be indispensable in manufacturing robots using new materials. In the future, the group would like to expand its potential to develop extremely compact and lightweight micromachines that can explore our inner body.

The fifth group is Group Shimonomura, which is attempting to apply soft and light advanced materials into a robotics system to achieve high performance. One area they have chosen to focus on is Unmanned Aerial Vehicles (UAV) and robotic hands. By collaborating with materials science researchers and applying cutting-edge, new materials into these projects, the group is attempting to develop lightweight robotic arms and hands that will be mountable on a UAV. Additionally, through the use of polymeric materials, the group aims to develop robotic hands with skin that can grasp the nature of its tasks or soft skin that can allow for smooth contact, enabling highly functional soft handling and manipulation.

Finally, Group Okada seeks to develop and apply human-support machine systems using soft-robotics technology, which takes full advantage of the developed advanced materials. First, the group is establishing the science and technology of human position and posture change by using soft robots. In particular, the group is focusing on sleep for practical use of its technologies by creating a polymer robot that can guide people toward comfortable sleep and promote and improve mental and physical health. Second, the group is also trying to solve the issue of the installation of sensors/actuators that relate to people-sensing. The group will link the research results of soft robotics conducted by the other groups to the development of human-support machines. Additionally, the group will be developing interfaces for intuitive operation in soft robotics technology by utilizing the results of the other groups. In this way, the group can further its development projects while closely collaborating with the other groups that are researching new materials, sensors, actuators, and soft robotics.

Create compact, light, and soft robots that do not yet exist and create new possibilities for the service, medical, and entertainment industries

The research project aims to drive a collaboration between the robotics engineering and materials engineering fields, which had not previously worked together, and thus develop new ideas and materials that would never arise in a single discipline, and to bring about innovation in the development of robots. Furthermore, through these research efforts, it aims to establish the science and technology of compact, light, and flexible robotic systems integration, which has yet to be realized globally, to expand potential usage beyond industrial robots to areas such as services, welfare, medical, life assistance, and entertainment, and to pursue its market development.

Interdisciplinary Science and Technology for Activation of Living Organisms

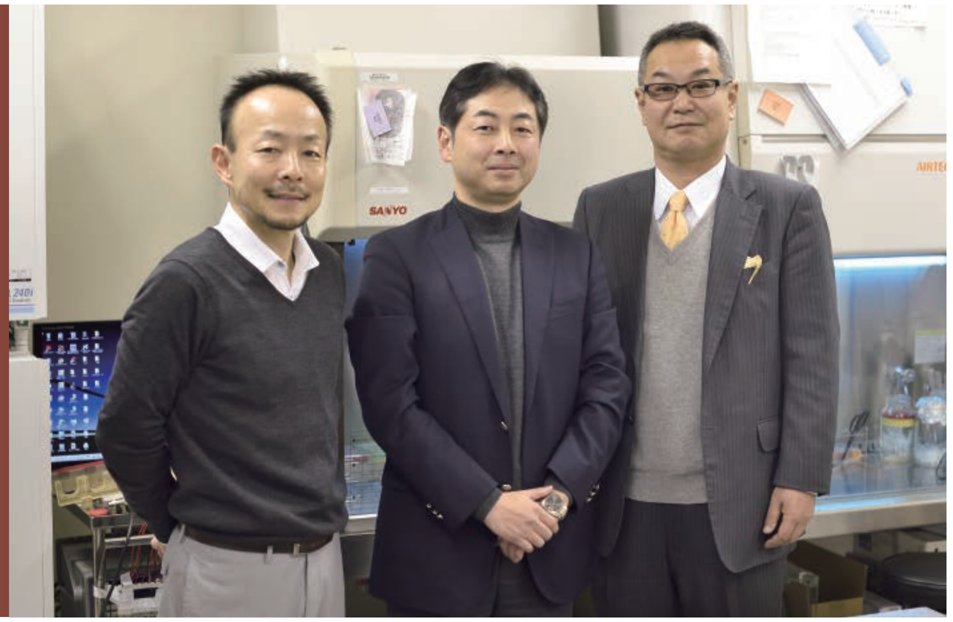
Project leader

Satoshi Konishi (Center)
Professor, College of Science and Engineering

Group leaders

Satoshi Fujita (Left)
Professor, College of Sport and Health Science

Takuya Fujita (Right)
Professor, College of Pharmaceutical Sciences



The fusion of engineering, pharmaceutical science, and physiology creates new technology for *activating the body*

Challenges in activation of the human body, focusing on *muscle function* and development of technology and tools for activating the body

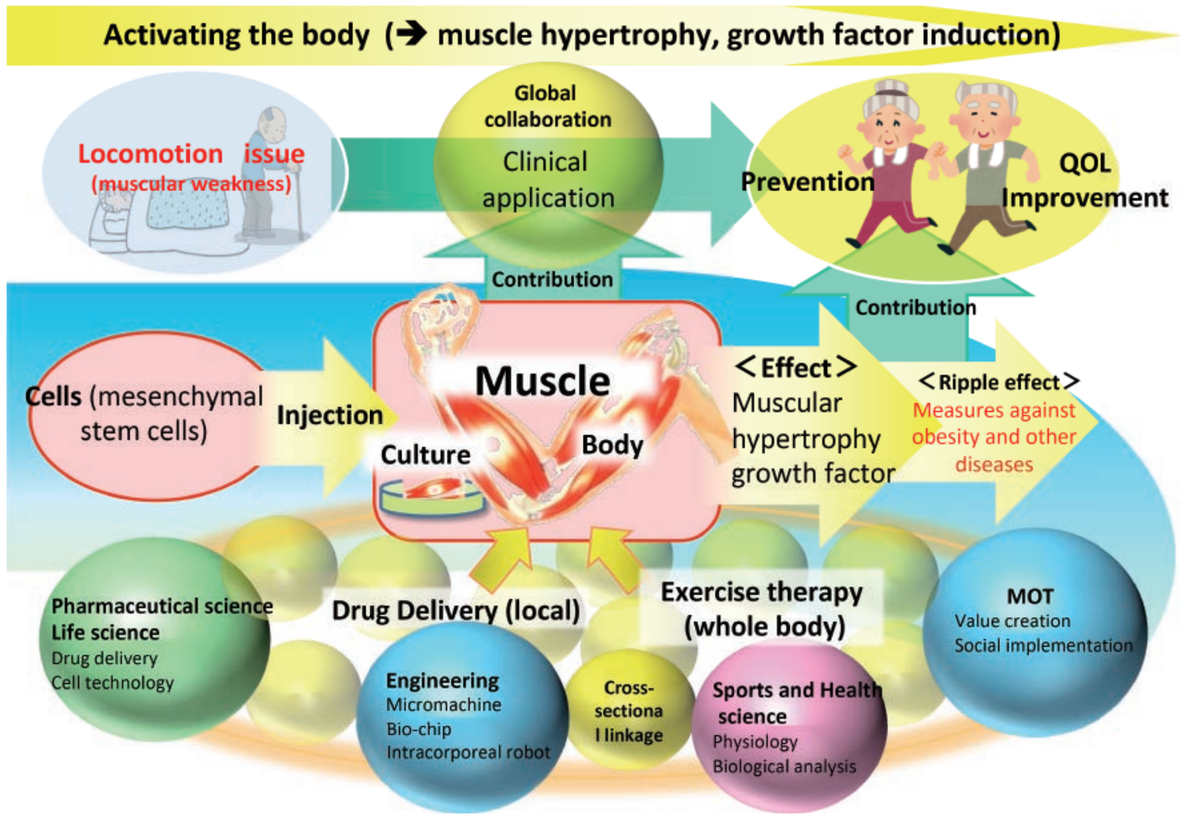
The goal of this research project is to *activate the human body*; to this end, the group is working toward understanding the science and technology of activation, as well as its social implementation. Because the current population is aging, specific attention has been given to *muscle function*. Decreases in skeletal muscle mass and muscle functions associated with aging are known as sarcopenia, which is not only a risk factor for fractures and becoming bedridden, but also causes serious lifestyle diseases such as diabetes and cardiac diseases. In this research project, while focusing on muscle functions, the group is also seeking methods for energizing the body and is engaged in the R&D of implementable technology. Implementing their research findings to prevent sarcopenia and lifestyle diseases may improve the quality of life of older adults and extend their healthy life expectancy. This will also contribute to reductions in medical and nursing care costs, which is a national concern. The group believes that, by implementing their state-of-the-art academic outcomes in the medical, drug discovery, and health fields, they will contribute to the industrial arena as well.

Developing technologies using genes, stem cells, and micromachines, while aiming to prevent sarcopenia

To activate the body, subjects can orally ingest or percutaneously absorb activating substances, such as medicines and supplements, or even inject these substances directly into the bloodstream or subcutaneous tissue. Recently, attention has focused on new methods such as gene therapy, in which genes are directly injected into the blood vessels and stem cells for direct application to the target sites. In this research project, a variety of methods, including exercise and nutritional intake, direct insertion of stem cells, and application of physical stimuli, will be examined to enlarge or grow skeletal muscles and myocardial muscles. Additionally, the group aims to develop the tools necessary for implementing unique methodologies involving the creative use of distinct technologies such as genes, stem cells, and micromachines. In these activities, three different fields—engineering, pharmacology, and physiology—are combined to overcome these difficult challenges.

First, Group Fujita (S.) is taking a physiological approach to discovering ways to maintain or grow muscles not only to prevent sarcopenia but also to prevent or improve various ailments associated with aging. In addition to the use of human and animal models, the group is also using cultured cells to examine the effect of motion stimulation on the skeletal muscles and the effect of dietary factors such as the use of functional foods on muscle enlargement, as well as the mechanisms of these effects. Additionally, using aged model animals, the group is evaluating the changes in skeletal muscle forms related to aging, as well as its impact on glucose and lipid metabolism and brain function, to determine the optimal exercise and nutritional interventions at the molecular level. The group is focusing on mesenchymal stem cells (MSCs) as an activation factor in the body. MSCs are stem cells that can differentiate into a variety of tissues, such as muscles, nerves, the pancreas, and fat. These cells may improve muscle functions and diabetes. By administering MSCs into the body of aged model animals, the group aims to determine their effects on the skeletal muscles, such as changes in morphology and alterations in glucose metabolism.

Additionally, clinical trials of human subjects are also planned. The group plans to analyze the blood and skeletal muscle tissues of young and old subjects while having the subjects exercise to improve their motor function and administering functional foods to them over the short and long terms. The group is attempting to determine the difference in responsiveness to activation stimuli, such as exercise and nutrition. By determining and providing guidance on the optimal combinations of exercises and nutrition, along with the introduction of stem cells, the group aims to drastically advance the prevention and improvement of sarcopenia and related diseases.



To promote the research of Group Fujita (S.) and enable its social implementation, appropriate tools must be developed. Group Fujita (T.) and Group Konishi have taken on this responsibility. From a pharmaceutical perspective, Group Fujita (T.) is engaged in researching delivery technology for carrying drugs, genes, or cells accurately to the target site in the body. In particular, using new methods to introduce genes and stem cells is necessary to develop a technology that will reliably deliver activating factors to target tissues in the body. The development of a delivery technology that introduces magnetism-imparted ribosomes into stem cells and carries the stem cells to the target tissue through magnetism is one such technology. Additionally, by combining the micromachine and drug delivery technology from Group Konishi, *in vivo* implantable nanodevices for genes and cell accumulation, as well as *in vivo* micromachines that provide external stimuli such as heat, pressure, or electromagnetic stimulation can be developed.

One area the group is focusing on is the development of a technology that utilizes MSCs. As described above, MSCs can differentiate to supplement and repair damaged tissues. Because MSCs are safer than iPS and ES cells, which have similar functions, many clinical trials have been and are being carried out. However, accumulation of the cells when transplanted to the target tissue is insufficient, and new technologies are being developed to promote the accumulation, production, and differentiation at the damaged site. Therefore, in collaboration with Group Konishi, they are researching not only a technology for delivering MSCs to the target tissue, but also the differentiation of these cells in the targeted tissue by developing a device for evaluating the optimal biological and environmental factors in an on-chip environment. Successful results would be a major breakthrough in overcoming the challenge of introducing MSCs.

Finally, Group Konishi is utilizing the potential it has nurtured over the years in sensors, micromachine, and micro-robotics research to develop drug delivery technology, intracorporeal micromachines, and minimally invasive activation tools. For example, Group Fujita (S.) is examining the difficulty of collecting samples in clinical studies. Because the collection of blood and skeletal muscle tissue is painful, subjects are resistant to these methods, and few institutions with specialized technologies can handle such samples. Thus, this group aims to develop a minimally invasive device and biosensing technologies for collecting biological specimens of blood and tissue, as well as the high-resolution analysis of specimens. Additionally, the group has experience in developing a micromachine embedded in the body to deliver genes to target tissues, and an artificial intestine-like on-chip life form. Based on its rich research experience, the group is collaborating with Group Fujita (T.) to develop a new drug delivery technology and intracorporeal micromachines.

Taking advantage of the *transdisciplinary* nature of this project, the group works to foster young researchers to bridge the medical, engineering, and pharmaceutical fields

As described above, the aim is to create devices and technologies for activating the body and to bring these methods to the social implementation stage.

Additionally, by taking advantage of the research project's *transdisciplinary* environment, the group aims to foster young talent with multiple specialties to bridge the gap between the medical, engineering, and pharmaceutical fields. The industrial world is currently aiming to extend technological development within a specialized field compared to traditional approaches. Rather, researchers are interested in the collaboration and convergence of different disciplines and fields to drive innovation. The group believes that, while each researcher specializes in a primary profession, there should also be attempts to gain secondary and tertiary specialties for collaborations with diverse fields. The group feels that fostering such young researchers is part of the responsibility of this research project.

Systems Vision Sciences for Visual Function Regeneration

Project leader

Katsunori Kitano (Center)
Professor, College of Information Science and Engineering

Group leaders

Teruhisa Kawamura (Left)
Associate Professor, College of Life Sciences

Chieko Koike (Right)
Professor, College of Pharmaceutical Sciences

Constructing a mathematical model to enable regeneration of the *eyes* through regenerative medical technology

Three fields—regenerative medicine, neuroscience, and information science—converge to reconstruct retinal function using iPS cells for the treatment of eye disease

The *eyes* (the retina) are part of the central nervous system and function to transmit visual information to the brain. In this research project, the group aims to reconstruct this retinal function using iPS cells. For this purpose, the members seek to understand the mechanism of visual information transmission and attempt to construct a mathematical model to advance visual regeneration technology.

With the aging of the population, retinal diseases, such as age-related macular degeneration, have increased year by year. Although retinal diseases do not lead directly to death, they significantly lower the quality of life (QOL) of those who are affected. Additionally, the patient's condition leads to an increase in social costs, such as medical and nursing care expenses. Therefore, the improvement of retinal regeneration technology has great social significance.

The first successful clinical application of iPS cells in a patient with reitina-related disease was recently reported. However, the reconstruction of the retina per se using iPS cells has not been achieved. If this could be accomplished, Japan could bring iPS cell technology to the forefront of medicine and further develop the field of regenerative medicine, which already has a competitive advantage, to make a huge impact on the world. With this research project, the group is joining forces to collaborate with the Institute of Physical and Chemical Research (RIKEN), which leads the world in retinal regeneration research for refining iPS cell purification technology. Additionally, in this project, the findings of iPS cell research are not being directly translated into clinical applications and empirical treatments. Rather, the group's intention is to generate a transdisciplinary effort, across the fields of information systems, systems biology, systems engineering, and systems phycology, to discover the retinal circuit formation and its mechanism and construct a mathematical model of the neural circuit that could be put to practical use during retinal treatment. Through such efforts, it will become possible to develop highly efficient, higher-quality regenerated retina.

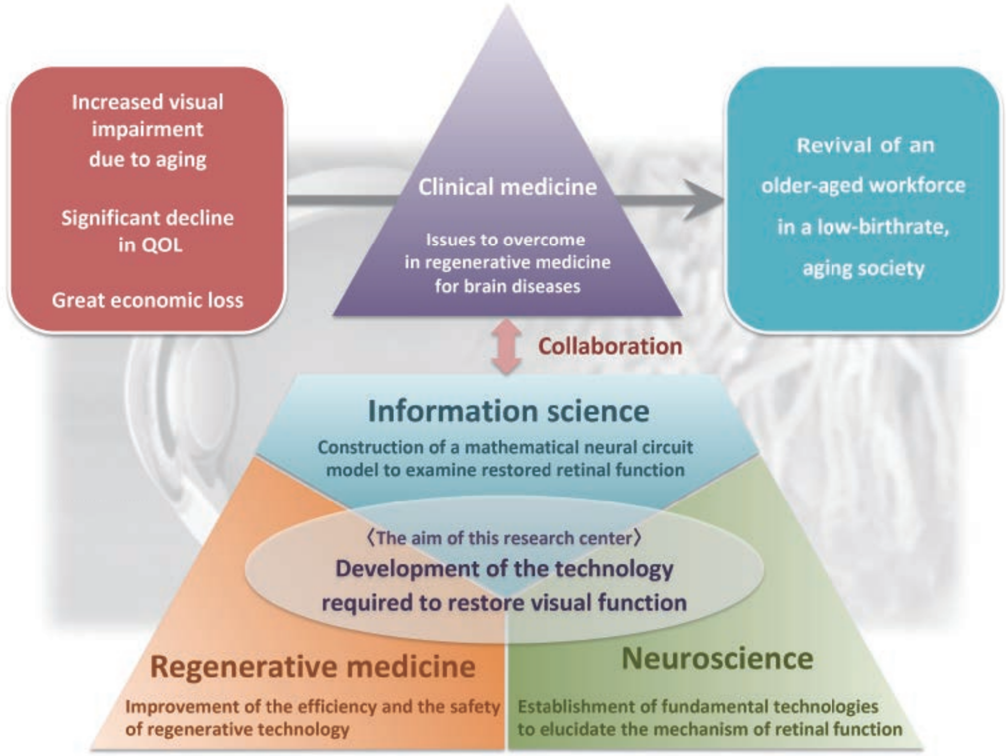
Regeneration of retinal tissue using iPS cells and analyzing retinal function to construct a retinal neuronal circuit simulation model

In this research, three groups—regenerative medicine, neuroscience, and information science—are collaborating. First, the regenerative medicine group is developing iPS cell establishment technology, and three-dimensional retinal tissue will be created based on these efforts. Next, the neuroscience group will use this tissue to analyze retinal function, and the findings from this effort will be transferred to the information science group, which will construct a retinal function simulation model.

First, Group Kawamura, which is responsible for regenerative medicine research, must overcome the problems in iPS cell establishment. Once they do, they will be able to establish iPS cells from a variety of animal species and create three-dimensional retinal tissue. The iPS cells establishment technology has, as of yet, not been completely established, as issues remain, such as safety risks, poor production efficiency, low differentiation ability, and risk of canceration. So far, Kawamura has found a unique methodology to analyze the iPS cell production process in detail. Taking advantage of these findings, the group analyzes iPS cell formation in collaboration with RIKEN, as they try to establish a high-quality and highly safe iPS cell line with low canceration risk. Such a cell line will achieve excellent induced differentiation in the optic nerve and will be developed into a fabrication technology. Next, using this technique, high-quality iPS cells will be produced from the somatic cells of humans and rodents (such as from mice and ground squirrels) and provided as research materials to other groups. Among these, ground squirrels have cone photoreceptor cells that occupy 70% of all visual cells. Cone photoreceptor cells convert optical information into nerve signals and are involved in capturing vivid colors. Studies on these cells will provide an extremely effective model for understanding human retinal functions.

Next, Group Koike, which specializes in neuroscience, is studying the cognitive response retinal circuit, between retinal tissue and where the optic nerves project, at a single cell level. The group is conducting a cross-hierarchical analysis of molecules in the tissues and then the individual, from the viewpoint that these molecules are the foundation of visual function. Indeed, for mammals, the retina is the only photosensitive organ. *Light*, which is the input stimulus, is converted into nerve signals by photoreceptor cells and then output (transmitted) to the brain through ganglion cells. As such, the retina is an ideal model to analyze the mechanism of information transmission through the synapses of the central nervous system, because the path from input stimulus to output stimulus can be easily traced. This group will study the molecular mechanism of synaptic formation in the central nervous system using iPS cell-derived retinas provided by Group Kawamura and photoreceptive cone cells, which are involved in capturing color. This group will determine, at the molecular level, the mechanism behind the formation of the synapses between bipolar cells, which are involved in the recognition of shapes. Then, using electrophysiological techniques, the group will analyze visual function from the cellular to the intercellular network level. Finally, this group will analyze visual behavior, using genetically modified mice and other model organisms and use the collected data to construct a mathematical model.

Finally, Group Kitano, which is led by informational science researchers, has constructed a model with three layers–the cellular, retinal circuit, and cognitive levels. The group aims to establish a detailed simulation model of visual mechanisms, specifically focusing on the parts of the visual system between where light enters and the central nerves. This group also aims to develop evaluation criteria that will allow their findings to be applied in medical and other fields. To this end, the group is trying to create a highly accurate photo potential conversion model, which will, at the cellular level, capture light response characteristics. In addition, the group will develop a retinal physiological function model that includes energy metabolism and maintains the biological environment. Then, at the retinal circuit level, the group aims to realize a model of the information pathways. This model will consist of the *vertical* information pathway, which primarily processes time elements, and the *horizontal* information pathway, which processes spatial elements. Group Kitano will establish a mathematical model that will provide a better understanding of the signal transmission characteristics of the pathway that converts optical signals into neural signals in the visual cells, which leads to ganglion cells, via bipolar cells. Through these efforts, the group will construct a retinal neural network simulation model. Then, at the cognitive level, the group will study healthy subjects and patients with eye diseases to formulate a visual environment evaluation index. This will be accomplished by quantifying the differences between the physical characteristics of visual information (light) and the cognitive characteristics related to how humans recognize visual information.



In addition to the impact of its research on retinal regeneration, the group's findings will provide a stepping-stone for the reconstruction of a central nerve system. The group wishes to contribute to regenerative medicine for other central nerve systems in the future.

A retinal blueprint is required in order to mathematically clarify retinal function and construct a simulation model of the retinal neuronal circuit. Additionally, by regenerating realistic retinal neuronal circuit tissue using iPS cells, the group aspires to develop a practical reconstructed retina with sufficient function and cost to be beneficial in the treatment of eye disease in the future.

Additionally, a mathematical model of retinal function would not only advance the understanding of the retina but also provide a great stepping-stone toward understanding the brain. The components of the central nervous system, including the brain, can only function after *circuits* are formed through synapses. Even if each cell was regenerated through iPS cells, the connection between each cell and the tissues is still not understood. If the proper circuits are not formed, it will not be possible to regenerate the brain. While research to discover the mechanisms of the brain is being carried out around the globe, Japan is a step or two behind the leading edge of this research. The group believes that their research will boost the development of this field in Japan and provide a pilot case that will contribute to the field of regenerative medicine, which aims to treat cranial nervous system damage and diseases.

International and Interdisciplinary Research Center of Next-generation Artificial Intelligence and Semiotics

Project leader

Tadahiro Taniguchi (Third from right)
Professor, College of Information Science and Engineering

Group leaders

Atsushi Aoyama (Left)
Professor, Graduate School of Technology Management

Takanobu Nishiura (Second from left)
Professor, College of Information Science and Engineering

Hiroshi Yoshida (Third from left)
Professor, Graduate School of Core Ethics and Frontier Sciences

Nobutaka Shimada (Second from right)
Professor, College of Information Science and Engineering

Takahiro Wada (Right)
Professor, College of Information Science and Engineering

Developing next-generation artificial intelligence (AI) that acquires knowledge by communicating with people

Tackling the challenge of developing artificial intelligence that learns from human-robot interactions. This approach is based on the philosophical theory of symbol emergence systems.

AI has undergone remarkable advancements over the past decade, and its use has found its way into a wide range of fields, from home applications to industrial applications. However, many challenges remain to be overcome.

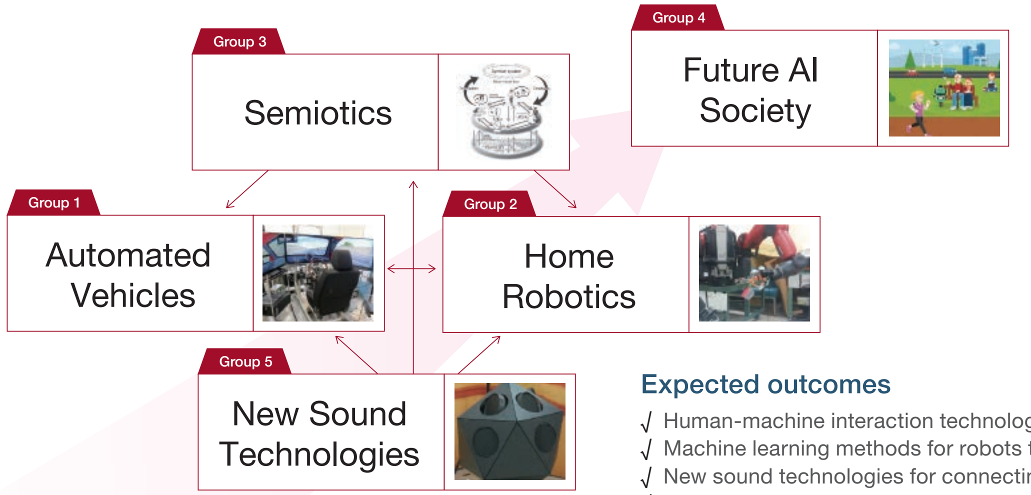
For example, it is now possible for AI to obtain global knowledge through machine learning, such as deep learning, so long as humans first provide what is called labeled data, or, in other words, correct information already attached to big data. However, there are limitations to this approach. Our living spaces, such as homes and offices, are filled with local knowledge. It is not easy or practical for people to keep feeding AI with such labeled data. Rather, robots that have found their way into homes and offices will need to obtain local knowledge through natural interactions with the environment, including interactions with humans. This research project is attempting to develop a revolutionary AI that can overcome these issues by expanding its knowledge through communications and interactions with humans.

The key to these issues is to have the AI understand the medium of human semiotic communication: symbols. For approximately 10 years, Taniguchi, who is the project leader, has been developing a theory of symbol emergence systems as a philosophical theory. Revolving around symbol emergence, which is its axis, the aim of this research project is to create a next-generation AI that will learn, cooperate, and harmonize through long-term communications with humans by using symbols as its medium, as well as through its environmental interactions.

Deepening the understanding of semiotics and seeking its potential applications for AI

For this project, the members have created five research groups. First, Group Wada is focusing on automated vehicles with the aim of developing safe and comfortable intelligent vehicles that can learn through interactions with humans. There are times when an autonomous driving system reaches its functional limitations, that is, when people are expected to take over the control of the vehicle from the system. It is also important to achieve automated driving in situations where the driver feels that autonomous driving is secure and comfortable. Therefore, this group is focusing its research on the relationship between humans and automated vehicles. To this end, a human machine interface that enables communication between the automated vehicle and the human driver has been developed as the foundational key technology. The team has proposed a shared authority mode, in which the human and the automated driving system are involved in the driving task simultaneously, by using haptic shared control as the low-level controller. This shared authority mode achieves a smooth control transition when it is used prior to the transfer of driving authority. The shared authority mode can also be used for mutual communication between the human and the vehicle automation system through haptic information. At the same time, the group is also developing a method to control the automated vehicle motion that considers a sense of security and comfort. For this purpose, the group is engaged in creating mathematical models of comfort related to human driving behavior and self-movement. In addition, the group is employing the same information to construct a driving control method that will not only be safe, but also feels safe and comfortable for people. In addition, the shared authority mode will allow the human driver to teach the AI the driving behavior that makes them feel safe and comfortable.

In addition, Group Shimada is engaged in the development of domestic service robots that are capable of voluntarily acquiring and adapting to environmental information based on symbol emergent systems. The group is developing a method for modeling the *process* of human tool-usage as a concept



Expected outcomes

- √ Human-machine interaction technologies for automated vehicles
- √ Machine learning methods for robots to acquire local knowledge
- √ New sound technologies for connecting human users and AI systems
- √ A new semiotics theory for explaining dynamic symbol systems, i.e., symbol emergence systems
- √ Business models and perspectives on well-being in future AI society

Establishing international and interdisciplinary research institutions to examine symbol emergence systems for the future AI society

that should be learned from observation of the co-occurrence of common shapes of parts and their own functions and induced operations. After this, they aim to transfer the obtained concept of tool usage into a robot so that the robot has the ability to manipulate tools in the same manner as a human. Furthermore, by applying the ability to learn functional concepts by observing humans, the group intends to develop partner robots that will model each individual mentality to provide appropriate care for the individual. In addition, the group is also putting effort into *the development of an AI that is capable of learning new vocabulary (symbols) through communication with humans*; this lies at the core of this project. One of the barriers between robot and human communication is that our *words (symbols)*, which constitute our communication medium, differ in meaning across cultures and contexts. This group has taken on the challenge through its research to develop a theory that will allow an AI to handle cultural and contextual human communications.

On the other hand, the Group Yoshida is working on fleshing out the symbol emergent systems theory from the standpoint of the field of humanities and sciences. As mentioned previously, when it comes to the meanings of symbols and concepts for humans compared to their meaning for an AI, there is a large gap between humans and existing machine learning approaches, as machines do not learn through physical interactions and communications with other humans. This group is exploring semiotics, which can be applied to next-generation AI by analyzing how humans interact with the real world through physical interactions and the generation of symbols and concepts. In particular, the focus is on images, where the AI will analyze an image (picture) as a signal system, which is transferred onto a flat surface depicting what humans are perceiving and experiencing in the world, in order to discover what images mean to humans. The other approach is to capture human cognition and actions within the framework of semiotics in a virtual environment, such as in games and simulators. The group is deepening its understanding of such symbols through such research as it seeks ways to transfer and apply this understanding to AI.

Next, Group Aoyama has turned its attention to the society that will be on the receiving end of the next-generation of AI and robots in order to determine how they should be socially implemented. The development of AI and robots is not only a considerable business opportunity, but, whether we like it or not, it also has the potential to transform the way humans work and live. Therefore, the group is analyzing and predicting how the next-generation of AI and robots should be implemented in accordance with corporate activities and human life, and, at the same time, evaluating the impact of its widespread adoption on an individuals' sense of purpose in life, capabilities, and sense of well-being. Through such efforts, the group is attempting to elucidate the conditions under which AI and robots can help in establishing a better society, and, with this, it is also attempting to present a roadmap for social implementation.

Finally, with the intent of materializing the symbol emergent systems theory at their forefront, Group Nishiura is supplementing each group's research technologically, acting as a booster to speed up the entire project. Because the main mediums for *symbolic* communications between humans and machines are based on sound symbolism, it is essential that the machines are equipped with technology that can accurately detect, perceive, and recognize the human voice if next-generation AI is to be realized. In addition to utilizing its own speech recognition, speech synthesis, and acoustic signal processing technologies in autonomous cars and domestic robot research, the group is providing its insights into sound symbolism from information science and engineering perspectives for humanistic research in the field of semiotics. In addition, the group receives feedback from each group during collaboration, and, through this, they are discovering new social issues, which, in turn, will lead to new technological developments related to sound symbolism.

Making an impact through the development of next-generation AI, which is important for future nursing care and life assistance robots in an aging society with a declining birthrate

In an aging society with a declining birthrate, it is expected that the necessity will further increase for nursing care and life assisting robots using next-generation AI that can autonomously gain local and personal knowledge through communications with people. The development of AI that considers the semiotic communication of both humans and machines would likely impact society considerably. In addition, this research project not only aims to give rise to a new academic field called *symbol emergence in robotics* with interdisciplinary organization spanning the fields of informatics, engineering, and humanities, but also intends to develop an international hub that will make academic contributions to fields such as information engineering and semiotics.

Integration of Senses for Induction and Continuation of Exercise

Project leader

Naruhiro Shiozawa (Center)
Professor, College of Sport and Health Science

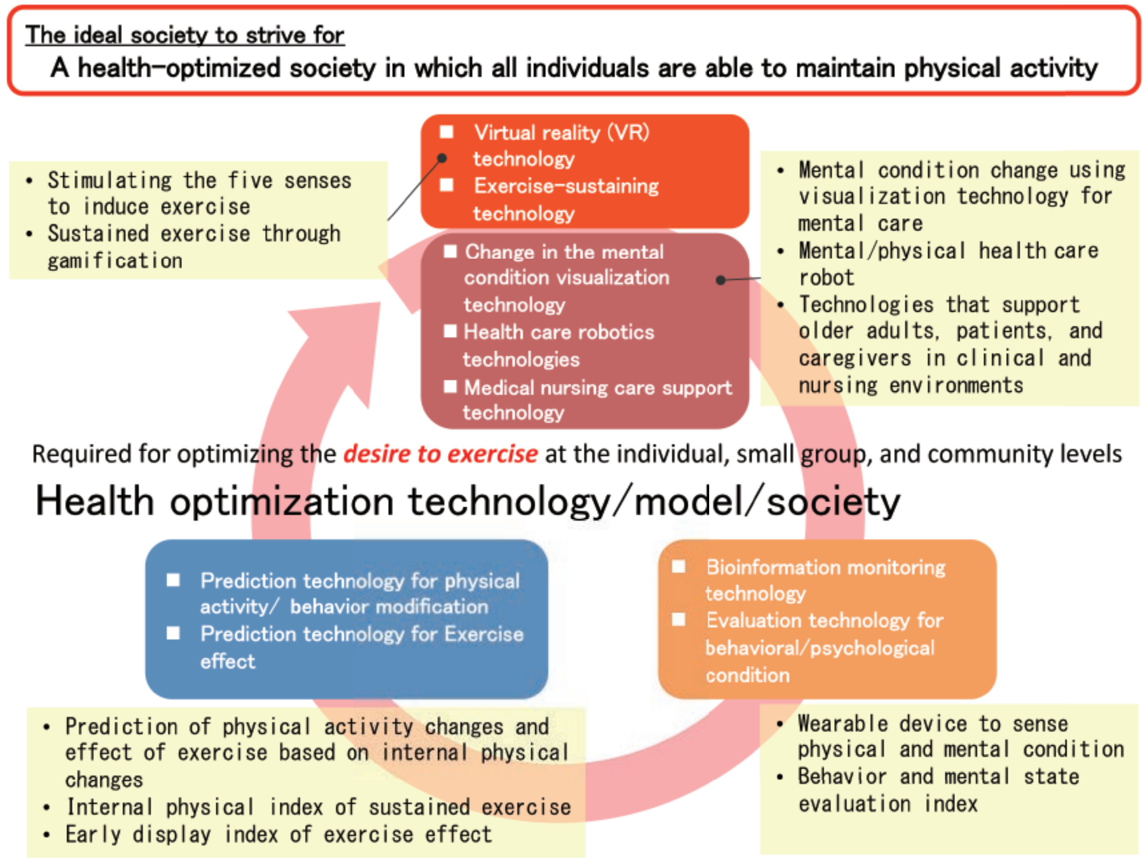
Group leaders

Jooho Lee (Left)
Professor, College of Information Science and Engineering

Motoyuki Iemitsu (Second from left)
Professor, College of Sport and Health Science

Tadao Isaka (Second from right)
Professor, College of Sport and Health Science

Tetsuo Yoshimoto (Right)
Professor, College of Business Administration



Stimulating visual, auditory, and olfactory senses to create an environment that encourages exercise

Creating a model that encourages voluntary starting and continuation exercise and its integration into the social system

There is an urgent need to maintain a healthy lifespan to keep the cost and burden of nursing and medical care low at a time when the birthrate is declining and the population is growing older. It is known that exercise and physical activity are important to maintain or improve health. However, while many individuals are aware that exercise is good for health, more than a few individuals find it difficult to put these thoughts into action. At the same time, it is also true that there are not enough programs or systems that could help transform such behavior in modern society. This research project attempts to solve this problem with a novel approach by inducing a change in the mindset and action of an individual, small group, or community, in order to promote the desire for voluntary exercise.

The desire to start or continue exercise is prompted by the interaction of the individual's internal (in vivo, that is physical) environment and the external (sensory or perceptual) environment. In this research project, the group has constructed a reference model that will control the physical and perceptual environment to induce voluntary initiation and continuation of exercise. This project aims to optimize the starting and continuation of exercise as a health activity from the individual level to the community level and ultimately to implement the activity as a social system.

Four groups—sensory environment, physical environment, action sensing, and ICT—are exploring the mechanism and methods of inducing the starting and continuation of exercise

For this research, four groups—each with their themes (sensory environment, physical environment, action sensing, and physical and mental care using ICT)—are working on elucidating the mechanism of exercise initiation and continuation, along with the establishment of its induction and evaluation methodologies.

First, Group Yoshimoto is focusing on controlling the sensory and perceptual environment related to vision (sight), audition (sound), and olfaction (smell) in an attempt to stimulate these three senses and induce voluntary initiation and continuation of exercise. The group has thus far developed an *olfactory display technology* that senses and visualizes the olfactory senses, a sound-image technology that controls acoustics and creates a *Sound Spot,* and a light-control technology called the *Media Experience*. In this group, research is being conducted on a Sensory Environment Control System that combines these technologies. The group is working on developing a non-contact, multimodal virtual reality (VR) system that works on the eyes, ears, and nose to control the sensory environment related to light, sound, and fragrance, to induce sustained exercise activity. The goal is to create integrated local perceptual VR environments—*unique spots for the enjoyment of exercise*—that can provide appropriate sensory stimulation to individuals or groups based on the type of exercise activities in which they plan to engage. In addition to the three senses, with their aim to advance their research on non-contact VR technology, the group is expanding its focus to include tactile sensation (wind), heat and cold sensation (temperature), and taste sensation. Ultimately, the group intends to integrate this into a spatial design, as it envisions social implementation.

Group Iemitsu focuses on the *physical environment*. This group is investigating how to promote and evaluate sustained exercise from the perspective of molecular biology, based on bioactive substances such as brain hormones and cytokines that are related to the continuation of physical activities. One reason that many individuals do not make exercise an ongoing habit is that it takes time to see the results. To see the results in a way that can be recognized from external appearance requires more than a few months of habitual exercise. However, motivation may be reduced and individuals may drop out from these activities. If people could perceive *the physical effects of exercise* in a shorter period, or even immediately, it would become easier to maintain motivation for exercise. Additionally, it would be possible to promote the initiation and continuation of exercise if the stimuli related to the reward system were activated. Therefore, this group has been conducting a comprehensive analysis of hormones and peptides, metabolic products, and gut bacteria in samples that are relatively easy to obtain, such as blood, saliva, and feces, to determine and identify potential markers of the effect of exercise. Furthermore, the group intends to use the findings to establish an effective system that could promote the induction of exercise and the monitoring of the effect of regular exercise, based on changes that occur in the body.

The third group, Group Isaka, focuses its research on health activity sensing technology. This group is using wearable sensing technology to catch changes in daily activities and psychological condition, for evaluation at an individual, small group, and community level. The group is developing SmartWare, a physical activity sensing device, based on research at Ritsumeikan University for the *Ministry of Education, Culture, Sports, Science and Technology (MEXT) Center of Innovation Science and Technology based Radical Innovation and Entrepreneurship Program (COI STREAM)*. Some sensors can be embedded and these sensors will monitor the heart rate and other biological information. Measurement criteria will be developed to establish a method for evaluating activity and psychological condition from the biological signals recorded by the SmartWare. The aim is to use this technology to determine the correlation between biological signals and changes in activity amount, in order to construct an optimal model of health behavior.

Finally, Group Lee is conducting research on physical and mental health, utilizing ICT to develop methods and technology to provide both *mental* and *physical* health care. The team has developed a technology to visualize the change in the *mental* state based on electronic medical records from counseling and data obtained from a near-infrared brain function imaging device, with the aim of using it in a robotic therapy system that provides mental support through interaction with robots. The team has also turned its attention to *physical* health care, aiming to develop care and nursing support technology informed by deep learning and machine learning. The system uses computer vision for long-term monitoring of elderly individuals and provides support with turning over or getting up, as well as quantitative measurement of treatments such as rehabilitation. The image processing technology, robotic technologies, and interactive technologies that are gained through the development of mental and physical health care support systems are then shared with the other three groups for use in advanced research.

To create a new academic field that integrates different systems and to contribute to the creation of a health-optimized society using exercise

To realize *a vital and creative human society in response to the declining birthrate and aging population*, it is necessary to create new social capital, revitalize local communities, and create living environments that are tailored to each individual, all based on the extension of a healthy lifespan. From this standpoint, *sustained healthy activities that are appropriate to society, locality, organization, or individuals*, which this research project advocates, hold an important meaning. The results and findings of this research project are likely to greatly contribute to the creation of a *health-optimized society*, which would realize health through the maximized utilization of exercise as a social technology.

In addition, this research project has made it possible to conduct unprecedented, cross-sectional and integrated research that combines sports science, biochemistry, acoustics, spatial studies, design studies, cosmetic science, psychology, and business administration. Through this innovative project, the group aims to establish a new academic field called *the study of the integration of senses for induction and continuation of exercise*.

Restorative Justice in the Era of Decreasing Birthrates and an Aging Population

Project leader

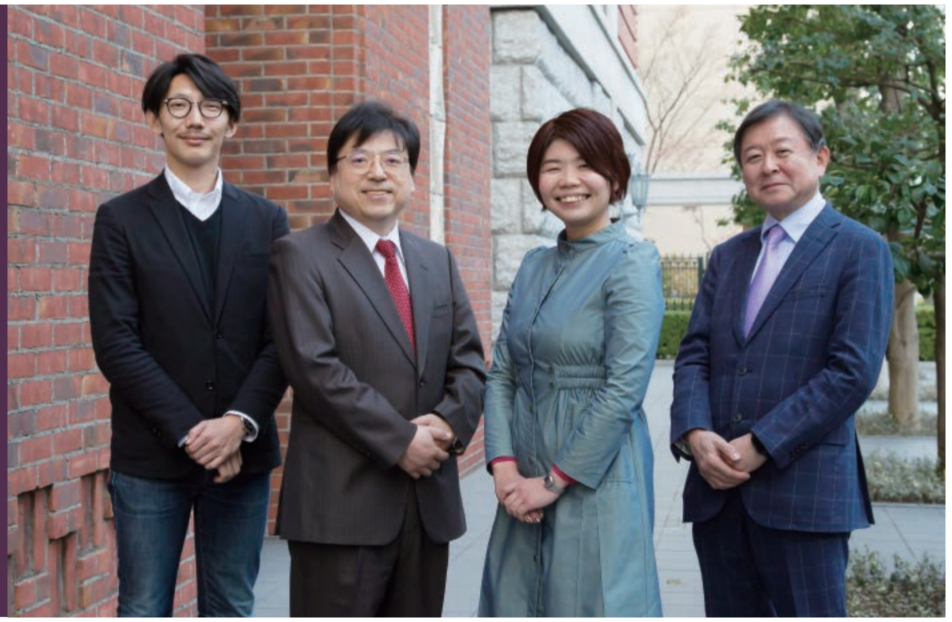
Kosuke Wakabayashi (Left)
Associate Professor, College of Comprehensive Psychology

Group leaders

Mitsuyuki Inaba (Second from left)
Professor, College of Policy Science

Chie Morihisa (Second from right)
Professor, College of Law

Katsumi Matsumoto (Right)
Professor, School of Law



Exploring the path of rehabilitation, crime deterrence, and recovery through the *restoration* of the relationship between people and society

Creating a new judicial and social system that draws from the thought processes of *restorative justice* and is more in line with an aging society

Family structure and lifestyle have become more diversified in this era of declining birthrates and aging populations. The present social foundations must be supported by theories that were based on a general perception of human being that have been supplemented or supplanted by new research; the traditional theories cannot offer proper assistance or support for our future society. While the reality is that our current judicial and social systems are unable to keep pace with these sudden changes, it is becoming necessary to design a new system that appropriately responds in an era of decreasing birthrates and an aging population. This response needs to be for both the elderly population, who now form the majority, and children, who form the minority in a low-birthrate, aging society. Centering on justice (jurisprudence and practice), diverse disciplines from fields such as psychology, policy science, sociology, information engineering, medical science, and social welfare science have converged for this research project with the aim of resolving these contemporary judicial issues and contributing towards a fair judicial and social system.

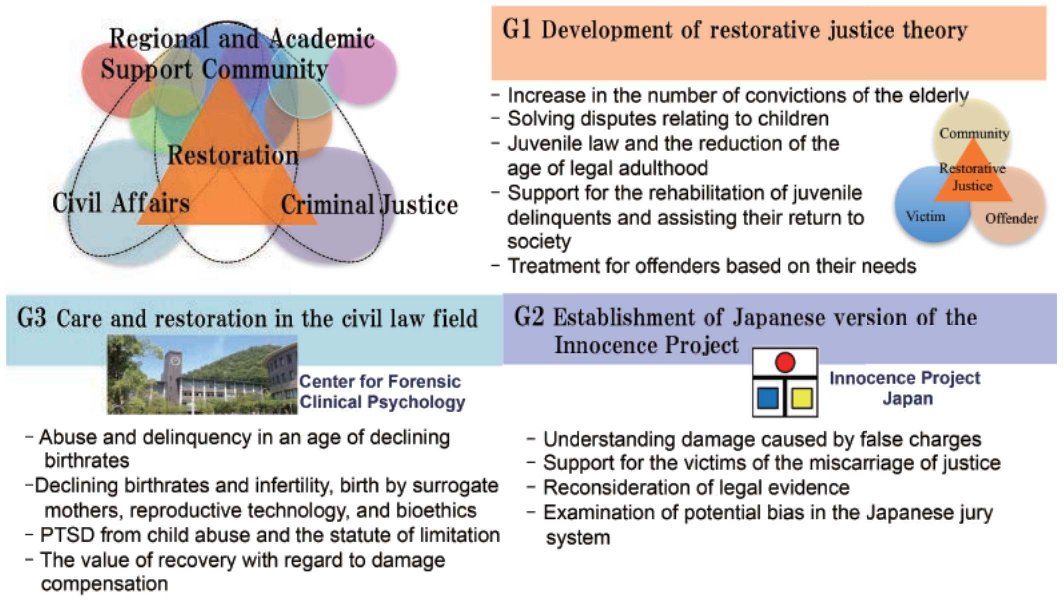
The common ground that holds together this transdisciplinary research project is the philosophy of *restorative justice*. The idea behind restorative justice is that, in relation to the damage caused by a crime, the offender (either the criminal or a perpetrator of an offense) can repair their relationship with the victim and others in the community. It is through restoration acts that both the perpetrator and the victim can recover, leading to the rehabilitation of the perpetrator and promoting the deterrence of new crimes. In traditional Japanese criminal justice procedures, the response was simply a unilateral and limited punishment against the crime committed. The idea behind this emanates from a judicial view of humanity, which is that “all actions taken by an individual should be the responsibility of that individual.” However, in reality, people can adapt the responsibility for people's behavior to their society. Therefore, if the offender committed a crime because of mental, social, or interpersonal issues, then for that person, punishment alone would not lead to their rehabilitation or prevent a repeated offense. If we can prevent crime by providing welfare assistance or by restoring human relationships with those around offenders, and can prevent offenders from repeating their offense, this will eventually lead to a reduction in criminal damages and bring relief to victims. Therefore, by perceiving the responsibility of human behavior within the framework of *relationships*, with *restoration* as its focus, this research project aims to create *a new judicial and social system that closely aligns with an aging society with low birthrates*.

Proceeding with research and practice in applying restorative justice as part of an effort to prevent criminal and civil cases, as well as miscarriages of justice from occurring

Three groups are conducting this research; the first group is focusing on constructing a restorative justice theory in Japan with the aim of implementation, and the other two groups, one from the criminal justice system and the other from the civil justice system, are investigating the restorative approach.

In the first group, Group Morihisa is working towards applying and deploying the restorative justice theory within the Japanese legal system. Up until now, Morihisa has investigated the effectiveness of restorative justice in cases with intellectual, mental, and physical disabilities, or those who are labeled as *difficult people to detain*, and, in this way, enriched his theoretical research on the application of restorative justice in the Japanese legal system. Thus far, this group

Restoration of the relationship between law, people, and society



Children and the elderly: aiming to establish a system that does not simply judge and punish, but rather one that supports people willing to start over.

has used the findings of the theoretical study, to attempt to apply restorative justice to Japanese society. In particular, the focus has been on juvenile crime, and, while engaging in the rehabilitation of juvenile delinquents and aiding them to return to society, they have been considering concrete ways on how to permeate restorative justice into the Japanese legal process. The group will consider not only the judicial process but also social welfare, which should be structured so that people will not turn to crime. Alternatively, when someone does commit a crime and is sent to prison, how should the offender treatment and judicial welfare system collaborate during different phases such as incarceration or treatment? In the future, the group hopes to establish methods to support the practitioners and supporters who work on restorative justice. The group is led by Morihisa, a criminologist. Joining this effort are researchers from the disciplines of psychology and sociology, as well as other practitioners such as attorneys and probation officers, who are all conducting research with social implementation in mind.

Group Matsumoto aims to develop and apply restorative justice, which originates from the criminal justice system, in the civil justice field. Considering the low-birthrate and aging population, their emphasis is on children and older aged adults with a primary focus on “recovery from damage”; they have explored “the prevention of and recovery from sexual abuse during childhood,” “child welfare after divorce,” and “the prevention of and recovery from consumer victimization for the elderly.” In each case, they have paid particular consideration to care and restoration, and their goal has been to develop specific recommendations. In the field of civil law, the thought of restorative justice has rarely been considered. However, more judgments are being passed many years after the crime against perpetrators who must pay victims who suffered from childhood sexual abuse. Subsequently, the discussion has shifted from whether or not there should be a liability for damages over an incident that occurred at a limited, particular point in time, to the need to consider care and restoration with the conception of *the passage of time*. Matsumoto has been researching the *statutes of limitations* related to PTSD damage. In light of such research, the group is exploring the question of what is needed for those who have suffered to *truly recover*. Specifically, for a potential adaptation within the Japanese system, the group has investigated prior cases in Korea and Germany, where restorative justice has already gained traction within the civil justice systems. Furthermore, they have investigated cases of consumer harm against the elderly to discuss its effects and measures.

The third group, Group Inaba, is taking a much more comprehensive perspective to reconsider the fundamental issues of Japan’s contemporary criminal justice system. Specifically, they have focused their attention on the victims of a miscarriage of justice in order to consider whether there were any biases in decision-making processes, in the investigative methods, or in the criminal procedures. They are also examining the judicial processes to examine the causes of the injustice, and, at the same time, they are developing a legal and social system that could mitigate these. One such exploration, led by Inaba, uses informatics to take measurements to prevent false accusations by reducing bias in the interrogation processes. The group is developing a system to find any *unnatural transitions in the statements* made during the long interrogation process by using a computer to analyze all the statements and identify any confessions made under duress. Using a variety of methods, including information technology, the group aims to create scientific appraisals and improve the investigative techniques that could contribute towards the prevention of miscarriages of justice.

Additionally, the Miscarriage of Justice Relief Center that the group leader Inaba established has begun offering relief to those who have fallen victim to miscarriages of justice, and part of this center’s activities is a collaboration with the activities of the current research project. Going forward, the aim is to connect to the Innocence Project, which is a global project based in the United States, and, through its network, investigate different nations’ attempts at preventing miscarriages of justice.

Contributing towards the fostering of young researchers and practitioners who will put into practice new judicial and social systems

The ultimate goal of this research project is to make the reformation of the judicial and social systems in Japan a reality by implementing its findings. For this to happen, it is essential to train researchers and practitioners who will implement these changes and practice them within the judicial and social systems. The group feels that a project such as this, where multiple disciplines converge to deal with a variety of judicial matters, will also help foster and train young researchers and practitioners who will be able to implement and practice new judicial standards going forward.

Research Center for a Sustainable Society Model Based on Long-Term Demographic Analysis

Project leader

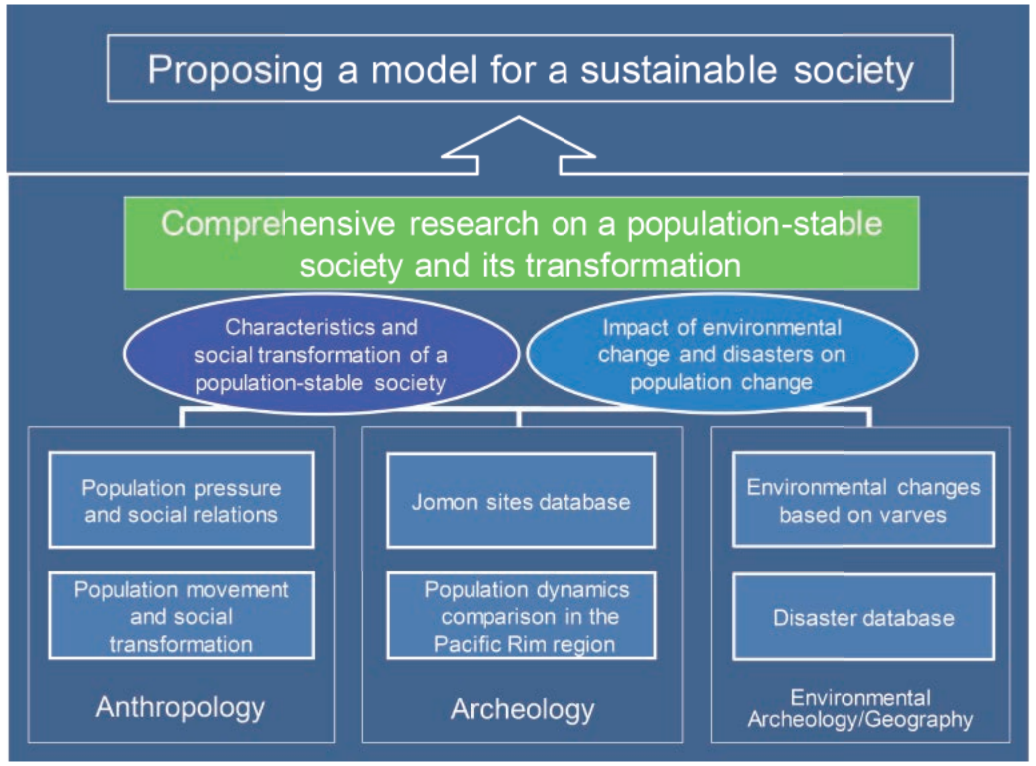
Kenichi Yano (Right)
Professor, College of Letters

Group leaders

Sayaka Ogawa (Left)
Associate Professor, Graduate School of Core Ethics and Frontier Sciences

Manabu Takahashi (Second from left)
Professor, College of Letters

Yoshinori Yasuda (Second from right)
Professor, Kinugasa Research Organization



Approaching the modern population problem from a 10,000-year historical perspective

Constructing a social model of a future world with a stabilized population based on over 10,000 years of demographic information

Many parts of the world are facing a variety of issues due to an unprecedented situation caused by a low birthrate and an aging society. Among these issues, that which pertains to the population is particularly noteworthy. While Japan is facing a hitherto unprecedented low birthrate with an aging population, at the global level, many countries are experiencing a population explosion. No solution has yet been identified for these population issues, given the overwhelming gap between these two situations. Through an examination of history, this research project aims to find evidence that may reveal the answer to such questions.

The current population issue can be described as a situation in which humanity has hit a wall after relying on scientific development to get this far. The present research project considers the possibility that, especially at a time like this, it may be necessary to find solutions that extend beyond modern day thinking. Thus, the project turns its attention to societies that existed before the time period in which the human population increased so dramatically. Considering the long-term population dynamics of over 10,000 years from the perspective of civilization theory, a group of researchers has analyzed the changes in life and society that were concurrent with the change in population numbers, along with the relationship these populations had with the environment and any disasters that occurred. Based on the findings, the group is trying to construct a sustainable social model wherein the future world population will not only stop growing but will instead begin to reduce or stabilize.

Comprehensive research across the fields of archeology, cultural anthropology, and geology to reveal the demographic history of Japan and the world

Comprehensive academic research is being conducted using approaches from four fields to address the research topic; these fields are environmental archeology, cultural anthropology, archeology, and disaster geography.

Group Yasuda, which is responsible for the environmental archaeological research, is trying to discover the changes in the ecosystems and their various effects by analyzing samples of annual sediments collected from various parts of the Pacific Rim; in particular, the group members are focusing on samples from many places across Japan and Latin America. Yasuda and his group have discovered thin, micron-level annual sedimentary layers known as varves at the bottom of Lake Suigetsu in Fukui Prefecture. By analyzing the pollen and diatoms included in each of these varves, it has become possible to understand the climate changes, earthquakes, flooding, and other disasters, as well as the environmental changes of the past, at seasonal and annual levels. In addition to the samples collected from Lake Suigetsu, this group also collected varves from Megata in Akita Prefecture and Lake Odawara in Aomori Prefecture and then expanded their scope to include the Pacific Rim, the Laguna de Guatavita in Colombia, a lake near the Seibal ruins in Guatemala, Bolivia, Peru, and Bali in Indonesia. The group has analyzed the fine sediment structures using high-resolution digital images to identify data that indicates environmental changes; group members also conducted DNA analysis of remains in the sediment to determine which organisms lived in or around the water at that time, thus enabling them to understand which animals and plants thrived and which went into decline. Based on such analysis, the group aims to discover which environmental changes had an impact on Japanese demographics, on the thriving or extinction of organisms, and on the rise and fall of civilizations around the Pacific Rim. Using these research findings, the group aims to challenge the approach of Western-style civilization, which prospered through its offensive stance against nature, and to construct a sustainable social model in which humans and nature can coexist.

Next, there is Group Ogawa (formerly Group Watanabe), which is examining the impact of population change on society from the perspective of cultural anthropology. For their research, the group members have adapted the research findings of Claude Lévi-Strauss, a 20th-century anthropologist, as the source of their most important guidelines. Back in the 1950s, Lévi-Strauss was already concerned about the various issues that could arise from an increase in the population, and, through the study of marriage rituals, he debated how demographics could influence the social relationships of humans. This group is thus examining the findings based on Lévi-Strauss's structural analysis of marriages and kinship. Further, by conducting field research, the group is revealing the effect of social factors and climate changes on social life in non-urban small-scale societies and how demographics, such as those of migration, change in response. The group is also collecting and reading articles from ethnic magazines published in small-scale societies, such as those from the natives and aborigines of Latin America and Canada. Through analysis of these articles, written by those who have maintained a civilization with values that differ from those of modern day societies, the group is trying to glean hints that could inform the potential dynamics of macro-scale world civilization, as well as ideas that would contribute to the construction of a population-stable society.

Next, Group Yano, which is conducting archeological research, is analyzing the demographics of long-term population-stable societies by drawing from Yano's *Archaeological Sites Database*. Yano has been working on the *Archaeological Sites Database*, which summarizes a number of ruins from the Jomon Period. Thus far, he has created a database of Jomon ruins from a total of 10 prefectures—six prefectures around the Kinki area and four more from Mie, Aichi, Gifu, and Fukui Prefectures. By expanding this ruins database and comparing the resource usage, types of residence, and ceremonies during the time of population change to those of times in which there was stability, the group hopes to reveal the relationship between population change, resource quantity, and social structures. Particular focus is placed on the period in which the same culture was maintained for approximately 10,000 years, between the Jomon Period and the Yayoi Period, in order to analyze the fluctuations in the population across the Japanese archipelago. Since there is no other example of a culture that has survived for over 10,000 years, the team members expect to obtain rare research data from their examination of this period. Moreover, there is no other known study that endeavors to grasp changes in one particular demographic over a 10,000-year period. As a globally unique demographic study, this research is expected to become quite influential not only within the field of archeology but also in population studies and other fields related to population. The group aims to expand the Archeological Sites Database and elucidate the demographic changes in the Japanese archipelago between the Paleolithic age and the Yayoi period, spanning approximately 30,000 years.

Finally, Group Takahashi is researching the impact of environmental changes and disasters on demographics from the perspective of disaster geography. By using Group Yasuda's research findings on varves and Yano's *Archaeological Sites Database*, the group is following the 10,000-year history of natural disasters, including climate change, earthquakes, tsunamis, volcanic eruptions, and flooding, and elucidates how these have affected the demographics in the Pacific Rim, including Japan. At the same time, the group is seeking to discover the underlying mechanisms that determine how natural disasters strike in Japan and in the Pacific Rim regions in order to decide how damage could be minimized. Thus far, Takahashi has found that the size of the impact of natural changes is related to the location of the dwellings and the number of people in a given population. That is, as the population increases, people start to move into areas that are vulnerable to natural changes, and this increases the impact of the damage during a disaster. This group is revisiting the remaining tribal knowledge related to natural changes in areas across Japan and the Pacific Rim, which tend to face many natural disasters. In addition, by analyzing how people use the land and studying the living population in this modern era, the group intends to disseminate information related to preventing natural changes from becoming disasters or at least limiting their damage.

Adopting a novel approach to modern-day population issues with the intent to construct and propose a model for an ideal future society

By pursuing a new approach to modern population problems through research in these four fields, the ultimate goal is to clarify the advantages and dangers of a *sustainable society* to be used as a fundamental guideline for our future world and to build and advocate an ideal model for future societies.

Furthermore, through this groundbreaking research, in which our current day is viewed from a perspective informed by over 10,000 years of history, the researchers hope to generate significant academic results that will contribute to both the humanities and the natural sciences.

First-Phase R-GIRO Research Program

The First-Phase R-GIRO Research Program for Specific Research Areas was inaugurated in April 2008, with a focus on six natural science areas that need to be urgently addressed: environment, energy, food supply, materials and resources, medical treatment and health, and safety and security.

In 2009, several new research areas were added from a humanities and social sciences perspective: human life and value, peace and governance, and Japanese and regional studies. Also included was a new research area which integrates arts, humanities and sciences. Research project proposals in a total of ten research areas were invited on campus and selected over the course of four years beginning in October 2008. With the aim of promoting research on safety and security as an effort to contribute to recovery and reconstruction from the Great East Japan Earthquake, another two research projects were adopted in 2013.

*This First-Phase R-GIRO Research Program was completed in AY2015.

Research Areas	Research Project	Leader	College	Research Period
Environment	Establishment of Cell Line from Rare Species Lives in Lake Biwa and Their Application as Biosensor	Prof. Tatsuyuki Takada	College of Pharmaceutical Sciences	AY2010-2014
	Supreme Collateral Utilization System toward Efficient Material Cycle: Microbial Recovery of Phosphate and Rare Metals	Prof. Tadayuki Imanaka	College of Life Sciences	AY2009-2013
	Development of High Power Deep UV Semiconductor Light Emitting Diodes and the Device Application to Solve Bio and Environmental Issues	Prof. Yoshinobu Aoyagi	R-GIRO	AY2008-2011
	Basic Technology Development and Strategic Innovations towards a Low-Carbon Society	Prof. Zhou Weisheng	College of Policy Science	AY2008-2012
Energy	Application of Solid Oxide Electrolyte Cell to the Energy and/or the Environmental Device	Prof. Yoshinobu Yoshihara	College of Science and Engineering	AY2008-2012
	Development of High Efficiency Multijunction Thin Film Solar Cells for Energy Security	Prof. Hideyuki Takakura	College of Science and Engineering	AY2009-2013
Food supply	Construction of Food Production System Based on Symbiosis Material Circulation Society	Prof. Motoki Kubo	College of Life Sciences	AY2008-2012
	Improvement in Agricultural Production by Developing Advanced Technology for Breeding, Cultivation, and Disease Prevention by Application of Microorganisms	Assoc. Prof. Hisaaki Mihara	College of Life Sciences	AY2010-2014
Materials & resources	Environment-Friendly Photoactive Materials Based on Naturally Occurring Tetrapyrroles	Prof. Hitoshi Taniaki	College of Pharmaceutical Sciences	AY2009-2013
	Formation of Functional Soft Materials Based on Elemental Resources	Assoc. Prof. Hiromitsu Maeda	College of Pharmaceutical Sciences	AY2008-2012
	Development of Organic-Inorganic Hybrid Nano Materials and Control of Their Organized Structures	Assoc. Prof. Osamu Tsutsumi	College of Life Sciences	AY2008-2012
	Engineering Materials Research Project for Sustainable Development	Prof. Kei Ameyama	College of Science and Engineering	AY2008-2012
Medical treatment & health	Research for Drug Development and Useful Functional Organic Molecule Creation Based on Sustainable Advanced Synthesis	Prof. Yasuyuki Kita	College of Pharmaceutical Sciences	AY2009-2013
	Integrative Study for Elucidating the Mechanisms of the Protein Folding and the Protein Folding Diseases	Prof. Minoru Kato	College of Pharmaceutical Sciences	AY2009-2013
	Drug Development using a Gene Regulation Mechanism by Natural Antisense Transcripts	Prof. Mikio Nishizawa	College of Life Sciences	AY2008-2012
	Pioneering Studies of Regenerative Medicine by Glycotechnology	Prof. Hidenao Toyoda	College of Pharmaceutical Sciences	AY2008-2012
	Fusion between MEMS and BME on Multiple-Scale	Prof. Satoshi Konishi	College of Science and Engineering	AY2008-2012
	IRT-Based Haptic Collaborative Virtual Environment for Tele Surgery Training through Ultra-realistic Communication	Prof. Hiromi Tanaka	College of Information Science and Engineering	AY2009-2013
	Digital Atlases of Human Anatomy and Computer Assisted Diagnostic System	Prof. Yen-Wei Chen	College of Information Science and Engineering	AY2008-2012
	Development of Biosimulators and Analysis Tools	Prof. Akinori Noma	College of Life Sciences	AY2008-2012
	Integrated Research of Sports and Health Innovations	Prof. Tadao Isaka	College of Sport and Health Science	AY2010-2014
Safety & security	Invisible, Secure, Safe and Dependable Platform to Support Our Lives	Assoc. Prof. Koichi Mouri	College of Information Science and Engineering	AY2009-2013
	Nowcasting System for Disaster Mitigation in Lake Biwa	Prof. John C. WELLS	College of Science and Engineering	AY2013-2015
	Sharing Information System for Disaster Prevention by Using One-Segment Broadcasting That is Utilizing White Space	Prof. Koichi Hosoi	College of Image Arts And Sciences	AY2013-2015
Human life & value	Learner's Science as an Application of Science for Human Services Creating a New Discipline	Prof. Akira Mochizuki	College of Letters	AY2010-2014
	Frontier of Applied Illusionology	Prof. Akiyoshi Kitaoka	College of Letters	AY2009-2013
	Constructing the Center for Law and Psychology	Prof. Tatsuya Sato	College of Letters	AY2009-2013
	Social Studies on Barrier Free Access to Digital Books	Prof. Yoko Matsubara*1	Graduate School of Core Ethics and Frontier Sciences	AY2011-2015
Peace & governance	Towards New Peace Studies : A Study of Reconciliatory Governance and Sustainable Peace Building in Post-Conflict Areas	Prof. Jun Honna	College of International Relations	AY2010-2014
	Mutual Understanding and Collaboration between Northeast Asia, Korea and Japan - from a Viewpoint of Peace Making	Prof. Makoto Katsumura*2	College of Policy Science	AY2009-2013
	Asbestos Disaster and the Policy Science of Relief, Compensation and Prevention System	Prof. Hiroyuki Mori	College of Policy Science	AY2009-2013
Japanese & regional studies	World Wide Co-Ownership on the Materials of Japanese Art and Culture by Digital Archiving	Prof. Ryo Akama	College of Letters	AY2009-2013
	Forced Removal, Incarceration, and Repatriation of the Overseas Japanese during World War II and the Post-War Reconstruction of the Japanese Society	Prof. Hiroshi Yoneyama	College of Letters	AY2010-2014
	Digital Museum of Kyoto	Prof. Keiji Yano	College of Letters	AY2009-2013
Integrated research	A Trial R&D Project of Human Dimensions Programme on Global Environmental Change Based on Local Carbon Sequestration Systems through Cool Vegetable Agriculture	Prof. Hidehiko Kanegae	College of Policy Science	AY2010-2014

The job titles and affiliations are from the time of the original report.

*1: As of AY2012, Professor Yoko Matsubara (Graduate School of Core Ethics and Frontier Sciences) has replaced Professor Shinya Tateiwa (Graduate School of Core Ethics and Frontier Sciences).

*2: As of AY2012, Professor Makoto Katsumura (College of Policy Science) has replaced Professor Nobuhiko Katsurajima (College of Letters).

Second-Phase R-GIRO Research Program

To further advance research toward the realization of R-GIRO's basic philosophy, the results obtained from the First-Phase R-GIRO Research Program for Specific Research Areas were analyzed. Subsequently, the Second-Phase R-GIRO Research Program for COE Formation was launched to create a unique interdisciplinary research center, taking full advantage of Ritsumeikan University's strong cross-functional and interdisciplinary approaches.

The Second-Phase R-GIRO Research Program, which covers 10 research areas, similar to in the First-Phase R-GIRO Research Program, invited unique interdisciplinary research project proposals, including those featuring a combination of natural sciences and humanities/social sciences, from within Ritsumeikan University, and adopted nine projects across seven research centers.

*This Second-Phase R-GIRO Research Program was completed in AY2016.

Research Areas	Research Project	Leader	College	Research Period
Environment	Research Center for Water and Waste Reclamation and Recycle Systems in Asia and Pacific Region	Prof. Jun Nakajima	College of Science and Engineering	AY2013-2016
Energy	Multi-Scale Research Center of Photovoltaics for Energy Security	Assoc. Prof. Takashi Minemoto	College of Science and Engineering	AY2012-2015
Food supply	Research Center for New Food Production System with Value-added Chain of Agriculture and Fishery: Creation of Food-Agriculture Linkage Model and Local-based Experimental Research	Prof. Toyohiko Matsubara	College of Economics	AY2012-2015
State-of-the-art health care	Research Center for "Monozukuri" Science and Technology toward Medical and Health Innovation	Assoc. Prof. Satoshi Konishi	College of Science and Engineering	AY2012-2015
	Research on Next Generation e-Health Based on Integration of IT, Medicine, Nursing and Health Care	Prof. Yen-Wei Chen	College of Information Science and Engineering	AY2012-2015
	Space Innovation Center for Health Promotion Society	Prof. Tadao Isaka	College of Sport and Health Science	AY2013-2016
Human life and value	Center for Forensic Clinical Psychology	Prof. Mitsuyuki Inaba	College of Policy Science	AY2012-2015
Peace and governance	Ritsumeikan Research Center for Japan's International Peace Cooperation Policies (R-JIPCoP)	Prof. Jun Honna	College of International Relations	AY2013-2016
Japanese and regional studies	Construction of Pan-Pacific Civilization Study towards the Creation of New Relation between Men and Nature	Prof. Manabu Takahashi	College of Letters	AY2013-2016

The job titles and affiliations are from the time of the original report.