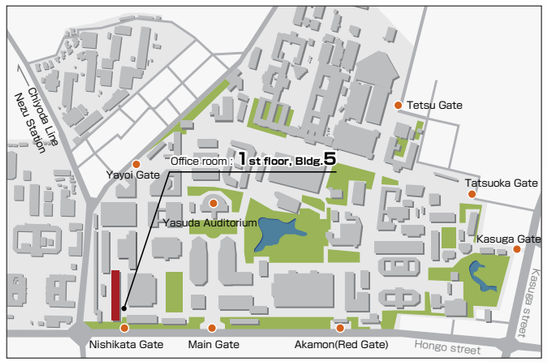
BIO×ENG



Department of Bioengineering,
School of Engineering,
The University of Tokyo

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Published in 2023

bioengineering
THE UNIVERSITY OF TOKYO

Department of Bioengineering,
School of Engineering,
The University of Tokyo

BIO×ENG

INTEGRATION for INNOVATION

Connecting Engineering with Life Sciences and Medicine

bioengineering
THE UNIVERSITY OF TOKYO

Development of innovative medical systems through elucidation and manipulation of the interactions of materials and systems with living bodies

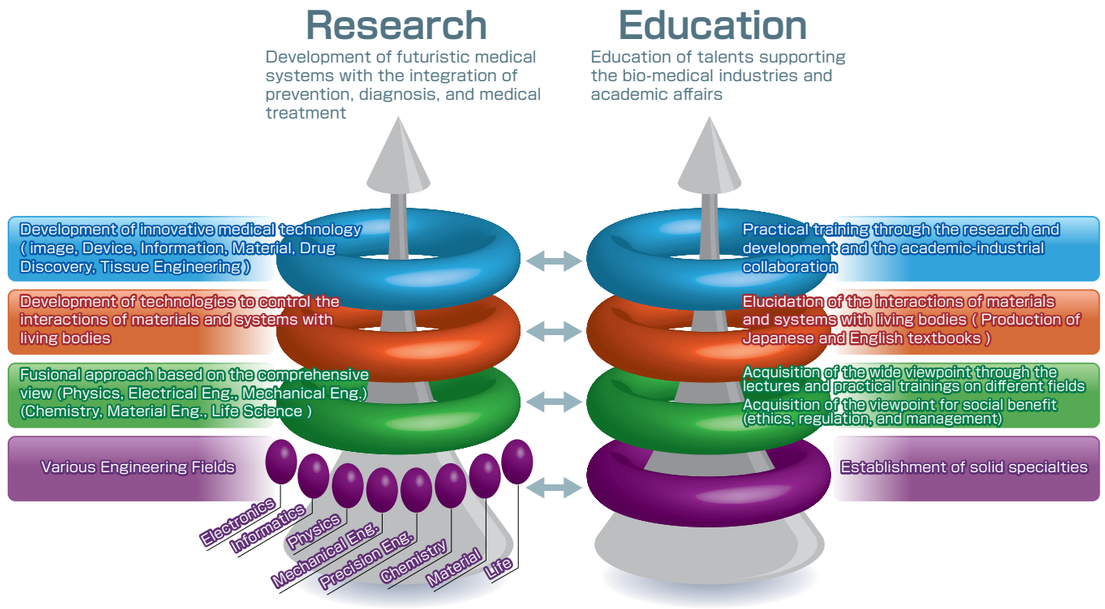
Head of the Department of Bioengineering
Professor Masaki SEKINO

Over 15 years have passed since its establishment in 2006, and the Department of Bioengineering has become well known both domestically and internationally. Until then, most bioengineering research was conducted in specific laboratories within existing departments, but with the establishment of the Department of Bioengineering, we organized related faculty members across existing departments and started the Department of Bioengineering as an extremely innovative department that integrates disciplines ranging from physics to chemistry. Since then, we have attracted excellent students with a high sense of purpose from all over the world, and we are very happy to see that many excellent human resources and research results have been produced.

Because bioengineering research covers a very wide range of subjects, it is almost necessary to integrate various academic disciplines and the latest life science knowledge in order to succeed. It is natural that a strong sense of purpose, a broad perspective, and a high level of expertise through daily research and self-improvement are also required. The Department of Bioengineering provides students with the opportunity to learn and grow in this way. Nowadays since its establishment, we are proud to say that we have successfully brought together outstanding students, young and mid-career faculty members who are extremely active, and senior faculty members with extensive experience in integrating different fields, including biotechnology, to create new value.

Modern society is becoming increasingly complex, and the future is not always a simple extension of the present. It is important to continuously update one's high level of expertise through daily study and research, but in addition to that, it its further important to draw a roadmap to reach one's ultimate goal and the image of society in which it will be utilized, sometimes through backcasting. This will not only identify short- and medium-term bottlenecks and streamline the solution process, but it will also make it possible to discover medium- and long-term issues that need to be addressed in order to realize the ultimate goal. On the other hand, especially in the life sciences, breakthroughs that overturn the conventional wisdom often change the conventional way of doing things in a short period of time. However, if we have drawn up our own roadmap to the ultimate goal, we will be able to calmly assess the value of the discovery and deal with it.

The 21st century is truly the century of life science. There are still many unknowns about our bodies, and life science is advancing rapidly to elucidate them. However, an engineering perspective is indispensable to make these results useful to society, and this is exactly what bioengineering is all about. We hope that students will acquire a broad perspective that enables them to deal with many complex problems, as well as problem-solving and problem-finding abilities through their studies in this department.



Principles on research and education in Department of Bioengineering

FIELDS

Multidisciplinary Engineering in Life Science and Medicine

6 FIELDS

"6 fields form the core of the Department of Bioengineering: Mechanobioengineering, Bioelectronics, Biodevices, Chemical Bioengineering, Biomaterials, and Bioimaging".

Mechanobioengineering

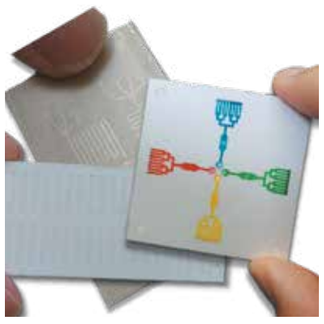
In this field, we research advanced medical support technologies that combine mechanical engineering and biotechnology. Specifically, the development of medical diagnostic and surgery support robots based on advanced information technologies and control technologies; contrast studies for malignancy imaging by applying fluids containing microelements - such as molecules and bubbles - to the phenomena of macro fluids; a noninvasive tumor therapy and lithotrity system using ultrasound; development of DNA handling technologies based on microfabrication, micro measurement technologies and nano/micro mechatronics; and the development of technologies for mechanical stress loading with high accuracy and 3D fabrication technology for organs.

Bioelectronics

The field of bioelectronics investigates the mechanism of biological electric signal and information processing with the emphasis on distributed representation, parallel processing, and plasticity. Biologically-inspired (bio mimetic) devices, bio chips and nano pharmacologic sensors based on bimolecular and electronics have also been constructed. Bioelectronics fuses extraction/modeling of biological architecture with the implementation of electronic devices by top down (self organization system) and bottom up (semi conducting technology, for example) nanotechnology. Furthermore, bio nanotechnology supported by micro fabrication technique and nano-micro mechatronics is studied. Diagnosis, treatment and measurement system for bio-related materials and organisms are studied based on photonics and precision engineering. We are also performing researches of bio imaging with terahertz spectroscopy.

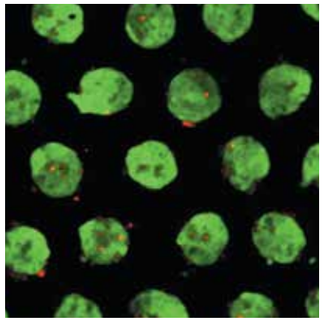
Biodevices

In the field of medicine and life sciences, development of new analytical devices has brought a lot of discovery and innovation. In this field, based on the understanding of the interactions of materials and systems with living bodies, we study and develop a variety of devices for inspecting states of the living body, organs, cells, proteins and genes. Currently advanced microsystems for biology and medicine (referred to as biochips, micro total-analysis-systems, Lab-on-a-chips, Organ-on-a-chips) are being investigated intensively. Analytical chemistry, biomolecule manipulation and controlling, device fabrication technology and materials development, and so forth are the core technology of biodevices.



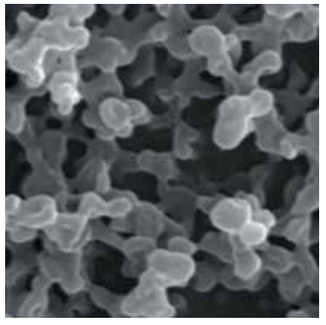
Chemical Bioengineering

The behaviors of biosystems are well-regulated and controlled by the interactions among various functional molecules such as DNA, RNA and proteins in different hierarchies such as cells, tissues and organs. On the firm basis on chemistry, the research in the chemical bioengineering field is focused on the structure and functions of these biomolecules, and on the mechanisms for regulating and controlling the biosystems through such molecules. The research is also focused on the innovative technology development for design, synthesis and control of high performance cells, tissues and organs through artificial designing, alteration, modification and systematization of functional biomolecules. Finally, we aim at applying these technologies to the medical treatment field.



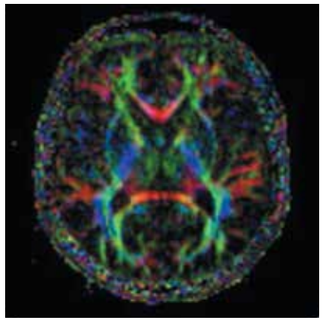
Biomaterials

By controlling the interactions of materials with living bodies, we attempt to create high-performance innovative biomaterials that act directly on cells, tissues and organs to control their activities. By mimicking the structure and function of the natural viruses, we create delivery systems that contain drugs and genes and precisely convey them to the target tissues and lesions. By mimicking the structure and function of the biomembrane, we design coating materials that prevent non-specific adhesion of proteins and cells to surfaces. By precisely controlling the 3D shape on various scales, we develop structural biomaterials with extremely superior properties.



Bioimaging

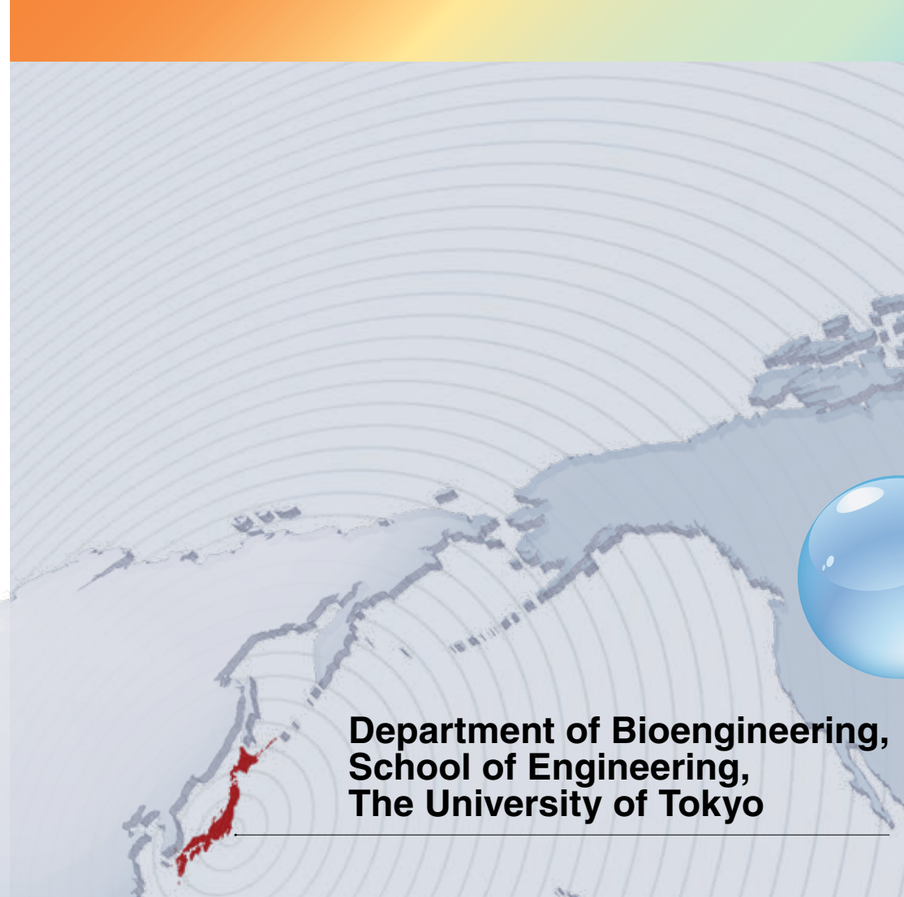
Aiming to achieve advanced medical treatments, we have been investigating and developing the imaging technologies for medical diagnosis, therapies, surgeries, and bio-function analysis. Our programs based on the disciplines of quantum physics, biological science and physics, system engineering and the information science of medical and cell imaging, and provides bio-imaging technologies for structural, functional, metabolic and molecular analyses, and also bio-simulating technologies.



NET
WORK

Global Network for Cutting-edge Research

The Department of Bioengineering, The University of Tokyo, promotes global education and research programs. Current programs include the China-Korean special program for the acceptance of Chinese and Korean students for doctoral course, an English-based master program from the Global 30 Project (International Bio-Engineering Program (IBP)) for outstanding students around the world, short-term study abroad programs between Western universities and research institutions (Global COE (Centers of Excellence), Center for Medical System Innovation (CMSI), etc.). In this way, the Department of Bioengineering aims to foster professionals who can contribute globally.



**Department of Bioengineering,
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The University of Tokyo**

Europe

- Imperial College London
- University of Gothenburg
- Swiss Federal Institute of Technology
- University of Cambridge
- Uppsala University
- Royal Institute of Technology
- University of Ulm
- Ludwig Maximilian University of Munich
- University of Lyon
- University of Twente
- Université de Rennes 1
- Karolinska Institutet
- Stockholms Universitet
- University of Technology of Compiègne

Asia

- Seoul National University
- Yonsei University
- Tsinghua University
- National University of Singapore
- Indian Institutes of Technology
- Nanyang Technological University

North America

- Stanford University
- Harvard University
- The University of Texas at Austin
- Massachusetts Institute of Technology
- University of California, Los Angeles
- University of Toronto
- The University of Utah
- University of Rochester
- Duke University
- Clemson University
- University of Florida

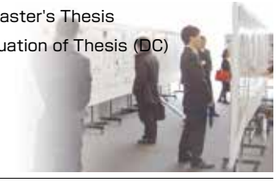
Asia

South America

- Pontificia Universidad Católica de Chile
- Universidad Nacional Autonoma de Mexico
- Universidade Federal de Minas Gerais

Campus Life

	April Entrance	September Entrance
4 Apr	Entrance Orientation Start of Summer Semester Entrance Ceremony	
5 May	Examination Guidance for Graduate School May Festival	Examination Guidance for Graduate School May Festival
6 Jun		Submission of Doctoral Thesis
7 Jul	Middle Term Evaluation of Thesis (MC)	Middle Term Evaluation of Thesis (DC)
8 Aug	Entrance Examination	Submission on Master's Thesis Entrance Examination
9 Sep		Graduation Ceremony
10 Oct	Start of Winter Semester	Entrance Orientation Start of Winter Semester Entrance Ceremony
11 Nov		
12 Dec	Submission of Doctoral Thesis Open Meeting with Industrial Society	Open Meeting with Industrial Society
1 Jan		
2 Feb	Submission on Master's Thesis Middle Term Evaluation of Thesis (DC)	Middle Term Evaluation of Thesis (MC)
3 Mar	Graduation Ceremony	



Message from International Students

Bioengineering combines biological science and traditional engineering to improve our life

GAO, Panpan

- *Nationality:China*
- *Biodevices*
  Miyake laboratory
- *1st Year Doctor Student*

How amazing it will be if we can break the wall between life science and engineering, and how can we make it? Bioengineering should be the answer. Bioengineering is an interdisciplinary field that introduces engineering methods to biological science to develop new technologies for our daily life. When I was a master student in Miyake Lab, I was developing the microdevice to monitor the plant's physiological condition, which could be applied for smart farming in the future. Thanks to the great opportunities provided by the department, I could participate in many international conferences and visit other laboratories oversea to share my research works with researchers worldwide. And now as a Ph.D. student, I am working on a creative project for designing the wearable device for the healthcare system.

In Bioengineering, you will be exposed to many opportunities to join state-of-the-art researches and inspiring lectures. And with the help of the resources and platform offered by the department, your innovative idea can make a real contribution to our society.

The Department of Bioengineering teaches how to create innovative solutions

VALENCIANO BELLIDO, Sandra

- *Nationality: Spain*
- *Chemicalbioengineering*
  Tsumoto laboratory
- *1st Year Doctor Student*

Bioengineering is the perfect combination of two different fields. The powerful tools of engineering applied with the broad knowledge of biology enables the creativity towards innovative solutions and the discovery of novel and revolutionary techniques and devices. By mixing together such different fields, it is possible to contrast diverse ideas and to see a problem from different perspectives, which is the key to successful solutions.

Bioengineering department offers the opportunity to learn from multidisciplinary fields, from device engineering to material science and protein engineering, which is the specialization of Tsumoto laboratory. However, our department provides much more. It presents a wide variety of lessons in English, facilitating the contribution of many international students. The array of different lessons from Engineering and Biology related disciplines together with the contribution of international students maximizes the possibilities of great collaborations. For me, this department has shown me to see the problems from different frames of mind and to be able to create original novel solutions. I have been able to create a network of multidisciplinary specialists to potentially collaborate with, and moreover, to create a group of friends. You are welcome to Bioengineering.

Admission Capacity and Requirements for Completion

Admission Capacity

[Master's Course] Admission Capacity: 24 / Master of Engineering
[Doctoral Course] Admission Capacity: 12 / Doctor of Engineering

Requirements for Completion

[Master's Course] Students are requested to obtain over 30 credits to complete the program.
First, a minimum of 15 credits (7 lectures) must be acquired through the compulsory subjects.
Second, a minimum of 7 credits (4 lectures) must be acquired through the semi-compulsory subjects.
And third, a minimum of 7 credits must be acquired through the optional subjects.

[Doctoral Course] To obtain a minimum of 20 credits including the 20 credits for Bioengineering Seminar 2 (A), Bioengineering Seminar 2 (B), Advanced Experiments on Bioengineering 2, Advanced Research on Bioengineering 2.

List of Course

Master's Course: Compulsory Subject

- Bioengineering Seminar 1(A)・1(B)
- Advanced Experiments on Bioengineering 1
- Advanced Research on Bioengineering 1
- Bioengineering exercise for social implementation 1
- Bioengineering Summer Experiments A
- Basic Biology

Master's Course: Semi-Compulsory Subject

- Overview of Bioengineering 1
- Overview of Mechano Bioengineering 1 *
- Overview of Mechano Bioengineering 2
- Basic Bioelectronics
- Overview of Bioelectronics
- Overview of Biodevices 1 *
- Overview of Biodevices 2
- Overview of Chemical Bioengineering
- Overview of Biomaterials 1 *
- Overview of Biomaterials 2
- Overview of Bioimaging 1 *
- Overview of Bioimaging 2

Master's Course: Optional Subject

- Advanced Lectures on Regenerative Medicine *
- Protein Engineering *
- Advanced Biomaterials
- Advanced Biodevices
- Biomanipulation Engineering *
- Brain Electronics *
- Advanced Bio-Electronics *
- Medical Precision Engineering *
- Applied Microfluidic Systems *
- Advanced Lectures on Bioimage Processing *
- Advanced Course on Biosignal Processing *
- Biological Reaction Engineering 1
- Radiation Biology
- Overview of Biomedical Engineering *
- Human Anatomy *
- Human Physiology *
- Human Pathology *
- Overview on Clinical Medicine *
- Presentation and writing in bioengineering
- Multiscale Biosystems Engineering
- Biofluid Mechanics *
- Biosensor Engineering

Doctoral Course: Compulsory Subject

- Bioengineering Seminar 2(A)・2(B)
- Advanced Experiments on Bioengineering 2
- Advanced Research on Bioengineering 2

Doctoral Course: Optional Subject

- Bioengineering exercise for social implementation 2
- Overview of Bioengineering 2
- Bioengineering Summer Experiments B
- Biological Reaction Engineering 2

*A Japanese lecture

Graduate Careers

Master

Employing Companies
Accenture Japan Ltd.
Asahi Kasei Corporation
Ajinomoto Co., Inc.
Astellas Pharma Inc.
Amazon.com
Iwaki Seiyaku Co., Ltd.
USHIO INC.
Eisai Co., Ltd.
NTT DATA Corporation
LG Electronics Incorporated
Olympus Corporation
Kao Corporation
Canon Inc.
KYOCERA Corporation
KYOWA HAKKO BIO CO., LTD.
KONICA MINOLTA, INC.
GE Healthcare Japan Corporation
SYSMEX CORPORATION
Shiseido Company, Ltd
SHIMADZU CORPORATION
Johnson & Johnson K.K.
Sony Corporation
SoftBank Corp.
DAIICHI SANKYO COMPANY, LIMITED
Taisho Pharmaceutical Co., Ltd.
Takeda Pharmaceutical Company Limited.
CHUGAI PHARMACEUTICAL CO., LTD.
TEIJIN LIMITED
TERUMO CORPORATION
Tokyo Electron Limited
Tokyo Electric Power Company Holdings, Inc.
TOSHIBA CORPORATION
TORAY PEF PRODUCTS,INC.
Towa Pharmaceutical Co., Ltd.
TOYOTA MOTOR CORPORATION
NIKKISO CO., LTD.
NIPPON CARBIDE INDUSTRIES CO.,INC.
JAPAN TOBACCO INC.
PHC Holdings Corporation
HIKARI ALPHAX INC.
Hitachi, Ltd.
Hitachi Zosen Corporation
Hitachi High-Technologies Corporation
Pfizer Japan Inc.
Fujifilm Corporation
Brains Technology, Inc.
Mitsui E&S Machinery Co., Ltd.
Mitsubishi Heavy Industries, Ltd.
Murata Manufacturing Co., Ltd.
Ricoh Co., Ltd.

…… and others

Doctor

Employing Companies
Pharmaceuticals and Medical Devices Agency
Kao Corporation
KANEKA CORPORATION
Center for iPS Cell Research and Application, Kyoto University
National Cerebral and Cardiovascular Center Hospital
GE Healthcare Japan
SYSMEX CORPORATION
Sichuan University
Mitsubishi Tanabe Pharma Corporation
CHUGAI PHARMACEUTICAL CO., LTD.
TEIJIN LIMITED
TERUMO CORPORATION
Tokyo Medical and Dental University
University of Tokyo
Tosoh Corporation
TORAY PEF PRODUCTS, INC.
Microsoft Japan Co., Ltd.
Panasonic Corporation
Hitachi, Ltd.
Pfizer Japan Inc.
HOGY MEDICAL CO.,LTD.
Institute of Physical and Chemical Research
Lily MedTech Inc.
Harvard Medical School, Boston Children Hospital
Stevanato Group

…… and others

Mechanobioengineering

Professor

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[**Subjects of Research**]

- Bio-inspired robotics: Systems inspired by living things
- Micro-nano robotics: System integration using micro-nano fabrication and MEMS devices
- Bio-medical applications: Sensors & actuators for emerging functions and intelligence
- Milli, micro, and nanoscale robots inside the human body for health and medical care
- Organo-machine having superior functions of organisms and operating stably in vitro

[**Field of Study**]
Robotics, Micro-nano Mechatronics, MEMS, System Integration, Medical Engineering

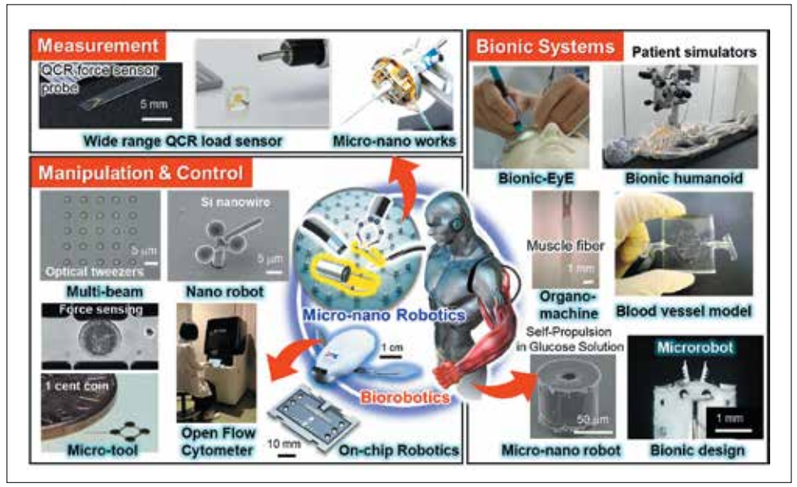
Biorobotics based on Micro-nano Mechatronics

Investigate the excellent functions of living things, learn from living things, and create mechanical systems with new functions.

Research Objective

How can we realize a completely new mechanical system that transcends conventional performance? In addition to the approach of advanced integration based on the understanding of physicochemical phenomena in the micro/nano domain, the approach of learning from the wisdom acquired by living things can be considered. In this laboratory, based on design thinking that focuses on living organisms, such as knowing the mechanism of living organisms, imitating the functions of living organisms, and utilizing the abilities of living organisms, we are working on the functions necessary to create innovative biomechanical systems. Fundamental research and applied research on mechanical elements, system design, control, intelligence, and system integration are conducted. Applications include medical and welfare robots, service robots, regenerative medicine, and measurement systems, and we aim to innovate in the biomedical field.

Summary



Mechanobioengineering

Professor

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[**Subjects of Research**]

- Human Body Simulation using Supercomputers
- Blood Flow Simurations
- Medical Applications of Ultrasound and Microbubbles
- Multiscale Modeling of Biomembrane

[**Field of Study**]
Fluid Mechanics, Medical Ultrasound, Biomechanics, Computational Science

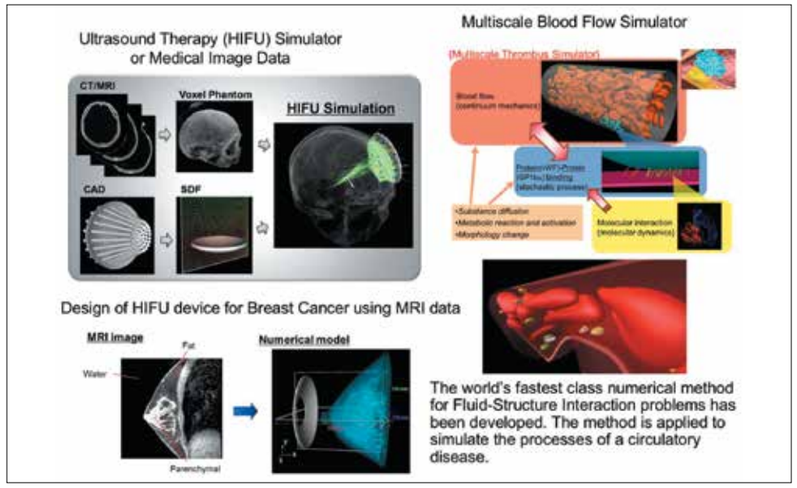
Multiscale biomechanics for medical applications

Toward the next generation medical treatment using the patient-specific image data

Research Objective

Our objective is to contribute the medical treatment through the development of simulation tools for a new type of ultrasound diagnosis and therapy systems and also for the prediction of a circulatory disease using our own codes for the supercomputers. Both numerical and experi-mental studies have been conducted to achieve the actual feedback to medical applications.

Summary



Mechanobioengineering

Associate Professor

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[**Subjects of Research**]

- Surgical robots for pediatric, eye and neurosurgery
- Automation of surgical robots
- Surgical skill assessment

[**Field of Study**]
Medical Robotics, Computer Aided Surgery

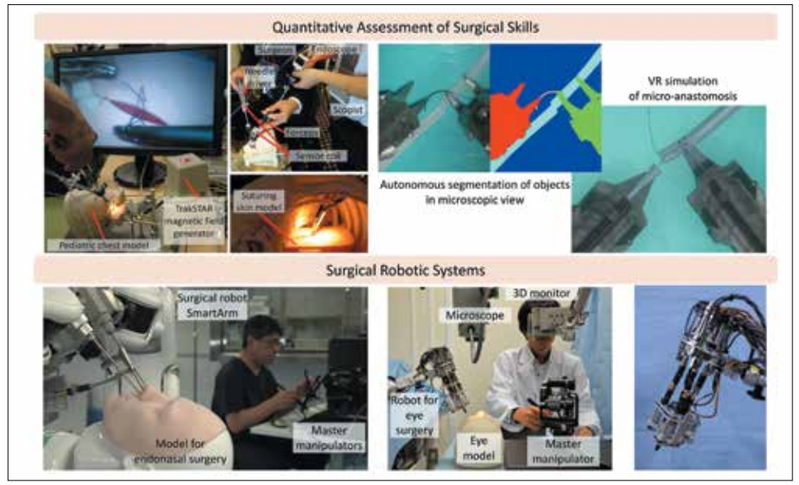
Smart surgical robotic systems

Toward skilled surgical robots

Research Objective

We have been developing surgical robots for microsurgery, in particular, for pediatric, eye and neurosurgery using bioengineering technologies. We are also trying to automate the surgical robots considering surgical skills quantitatively assessed using high-fidelity patient/organ models equipped with sensors (named Bionic Humanoids) and virtual-reality simulators. Medicine-engineering collaboration is essential in this research domain, and basic knowledge of regulatory science is necessary.

Summary



Mechanobioengineering

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[**Subjects of Research**]

- Regenerative engineering of vascular blood vessel and cartilage tissue under mechanical stress
- 3D organ design with/without scaffolds
- Rapid prototyping technology for 3D scaffold design
- Real-time imaging of blood vessels under physiolosical stimulations

[**Field of Study**]
Mechanobioengineering, Regenerative Medicine, Biomaterials

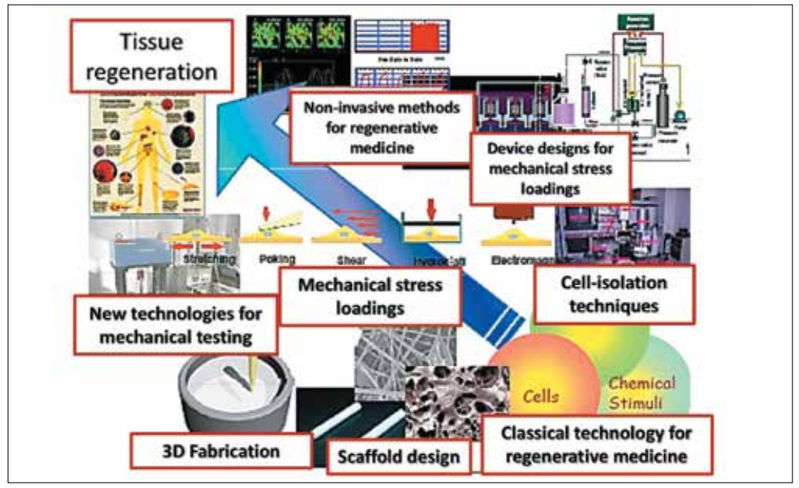
Tissue engineering based on Mechanoengineering ~From tissue regeneration towards to organ regeneration~

Let' s enjoy cutting-edge researches for regenerative medicine based on engineering technologies!

Research Objective

Furukawa Laboratory aims to develop fundamental technologies necessary for tissue engineering in terms of biomechanics. By designing devices for physical stimulation, we focus on enhancement of the functionality of tissue-engineered organs such as cartilage, blood vessel, and bone, with immature stem cells as cell sources. In particular, tissue-engineered cartilages produced at this lab have shown very promising results. Like such, we are actively developing new technologies for tissue-engineering with clinical feedbacks.

Summary



Bioelectronics

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[**Subjects of Research**]
- Research on devices that mimic brain functions (neurons, synapses) using spin fluctuation learned from bioinformatics
- Electric Nose -the electronic nose that keeps us safe and secure-
- Medical engineering application of THz-wave plasmonics by Dirac electron system
- Studies on hydration state by broadband (microwave to terahertz to mid-near infrared) dielectric spectroscopy
- Stochastic Resonance Devices and Sensors Learning from Biological Fluctuation
- Ultra-sensitive magnetoencephalography and magnetocardiography using spin-wave (magnon) quantum interference devices (quantum measurement)

[**Field of Study**]
Nano Bio-Electronics and Photonics

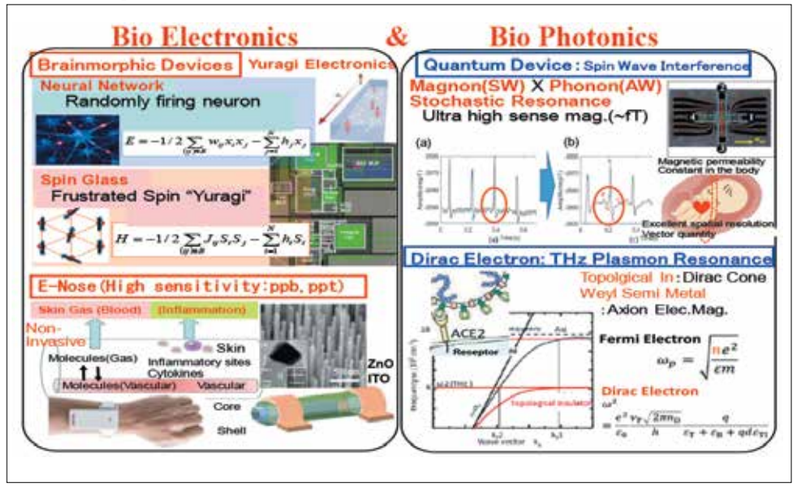
Challenging Medical Engineering with Quantum and Nanoelectronics

Electronics learning "from" bio-system and learning "about" bio-system

Research Objective

We are researching electronics that learn" from bio-system and learn "about" bio-system. In the former theme, we focus on the fact that the physical description of neuron signal processing can be described by a Hamiltonian, the same as the spin glass, a spin fluctuation physical property, and we are developing and studying brain-like devices utilizing spin fluctuation. In the latter theme, we have created an ultra-sensitive skin gas sensor using semiconducting nanotechnology and are developing a wearable healthcare sensor (sniffing device) for smartwatches to realize an undiseased and ultra-early diagnosis. In addition, we are developing non-fluorescent labeling, non-invasive inspection, and diagnostic technologies for selective coherent excitation, hydration state by plasmon, and intermolecular bonding using infrared region light represented by THz waves based on Dirac electron system.

Summary



Bioelectronics

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[**Subjects of Research**]
- Brain-like signal processing
- Adaptive wireless communications and imaging
- Intelligent ubiquitous electronics

[**Field of Study**]
Neural Networks, Adaptive Signal Processing

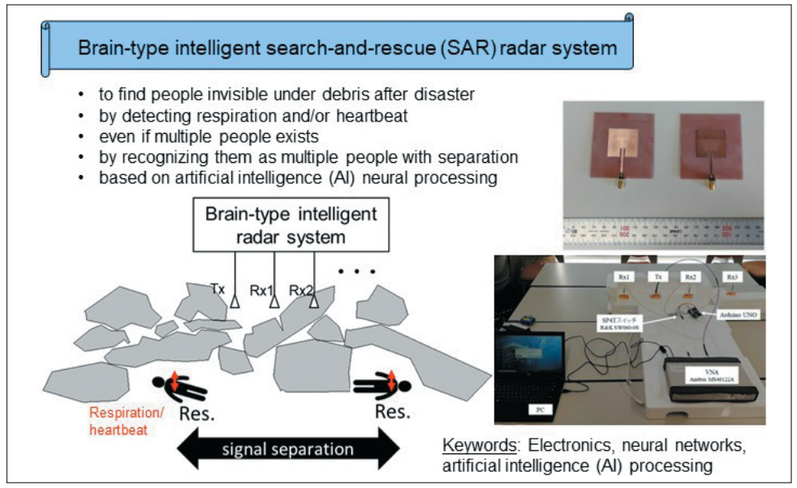
Adaptive sensing and imaging based on brain dynamics and functions

Bioinstrumentation and Medical Front Applications of Brain-Inspired Wireless Electronics

Research Objective

We construct a new field as the fusion of wireless electronics and brain-inspired adaptive information processing to realize novel bioinstrumentation to visualize invisibles and to develop systems useful and comfortable in the medical front.
(1) Active image acquisition systems based on coherent neural networks,
(2) Adaptive wireless communications workable under medical rigid restrictions, etc.

Summary



Bioelectronics

Project Professor
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[**Subjects of Research**]
- Development of voice biomarkers (stress, depression, dementia, Parkinson's disease, etc.)
- Application of voice biomarkers (athlete mental care, etc.)

[**Field of Study**]
Medical engineering, Disaster medicine, Occupational health

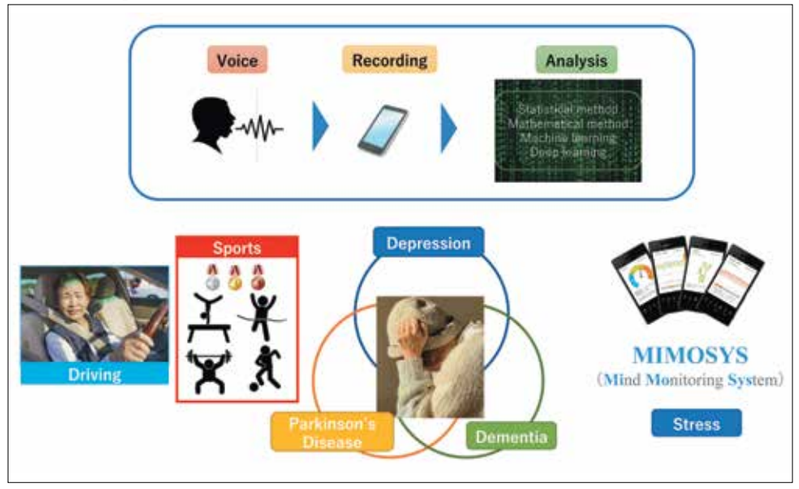
Voice Analysis and Measurement of Pathophysiology : Technology to visualize disease by voice

Hear a silent voice New medical engineering to analyze pathological condition from voice

Research Objective

We are researching technology to detect minute changes in voice associated with disease and visualize the disease in a non-invasive manner. Voice stress assessment technology has already been developed and has been commercialized by several companies. It was also adopted as one of the ME-BYO Index promoted by Kanagawa Prefecture. Currently, we are conducting research on depression, dementia, and Parkinson's disease with a view to the aging society. Furthermore, we are looking for ways to utilize this technology in fields other than healthcare.

Summary



Bioelectronics

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[**Subjects of Research**]
- High-sensitive biomolecular sensing for IoT/AI applications
- Optical detetions for biomechanical functions based on smart biomaterials
- Development of flexible bio-masure systems and stress sensing
- Engineering for biological defense
- Spectroscopic sensing for biological-related gases

[**Field of Study**]
Biological molecular (gas) sensing, Nanophotonics, Plasmonics and biomaterials

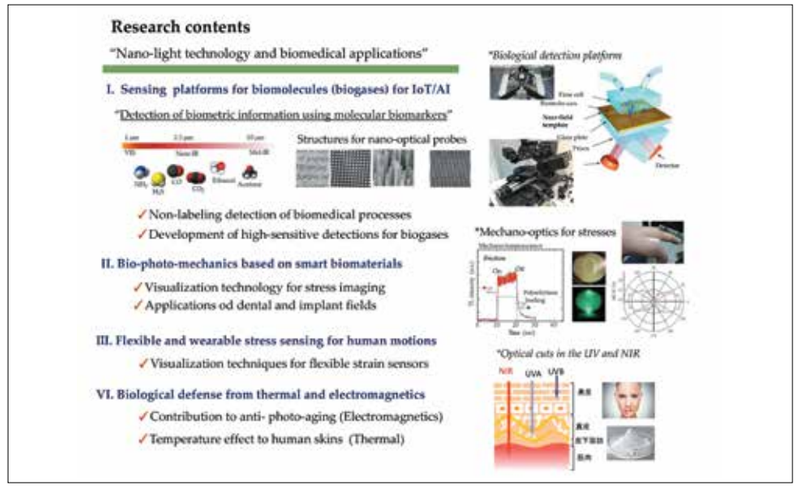
Nano-optical techniques for biomedical applications

Development of biomedical applications based on nano-optical techniques

Research Objective

Our research group focuses on biomedical applications for biometric information sensing and biological defense technology. As typical studies, Development of surface detection techniques of biochemical information using nano-photonics based on nano-plasmonic materials and near-field lights. Visualization technology and stress detection in biological samples using stress-induced luminescent phenomena. In addition, Applications of biological defense, and beauty and health based on optical control in biomaterials.

Summary



Bioelectronics

Project Associate Professor
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[Subjects of Research]
- Artificial ego and morality-based behavioral control of robot using *the new operator*
- Fundamentals for development of Neumann and non Neumann computers using *the new operator*

[Field of Study]
Computer science, Voice emotion recognition, Pathophysiological Voice Analysis, Artificial intelligence

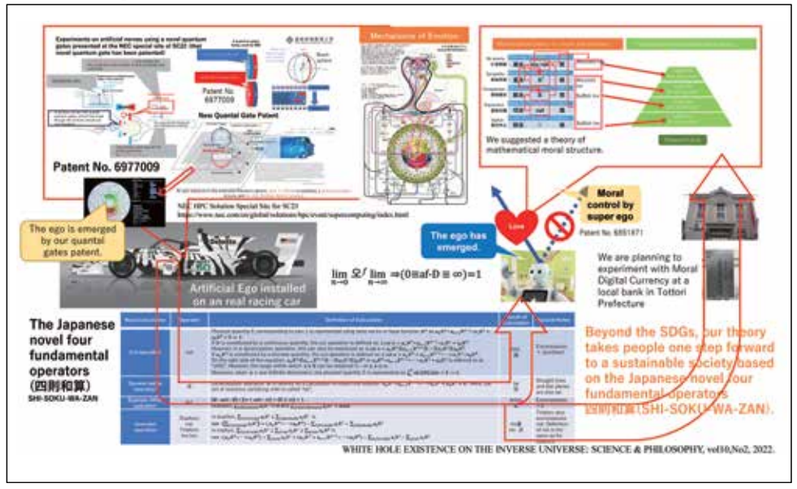
"Artificial ego", quantification of human empathy, and control of morality-based behaviors of robots

We devote ourselves to advancing mathematical models for numerically evaluating width of human empathy and the way how we control robots based on morality

Research Objective

Mathematical Engineering of Morality Emotions aims to create both Neumann and non Neumann computers using *the new operator*, which enables phase transitions, computational emergence and autonomy.
We develop emulators to demonstrate Artificial ego (AE) equipped with *the motivation* using conventional computer systems.
Our final goal is to establish the way how we control robots using autonomy and morality derived from AE.

Summary



Biodevices

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[Subjects of Research]
- Development of biocompatible biointerfaces based on bioinspired materials for applications in biodevices
- Development of highly sensitive immunoassay and cell separation device by use of polymeric microfiber
- Development of block copolymers and hydrogels to investigate the cell-material interactions

[Field of Study]
Biointerface, Biomaterials, Biosensing

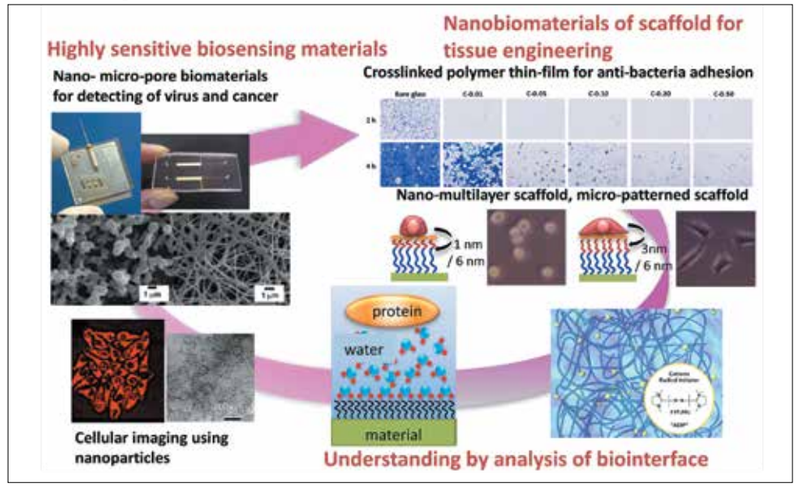
Development of Highly Functional Medical Devices by Design of Biointerface

Biointerface Science Pioneers the Future Medicine

Research Objective

The biointerface is created when biomolecules, proteins, and viruses, or cells touches solid surfaces such as inorganic, synthetic polymer, or bio-inspired materials. The aim of our study on biointerface science is to understand and control the behavior of such biological objects on the surfaces. We are developing the highly functional medical devices for artificial organ, for medical diagnosis, for regeneration medicine by design of the biointerface.

Summary



Biodevices

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[Subjects of Research]
- Development of innovative nano/microfabrication technologies
- Microplasma technology
- High-speed molecular evolution systems

[Field of Study]
Nano and Micro Manufacturing, Biodevices, Plasma Process

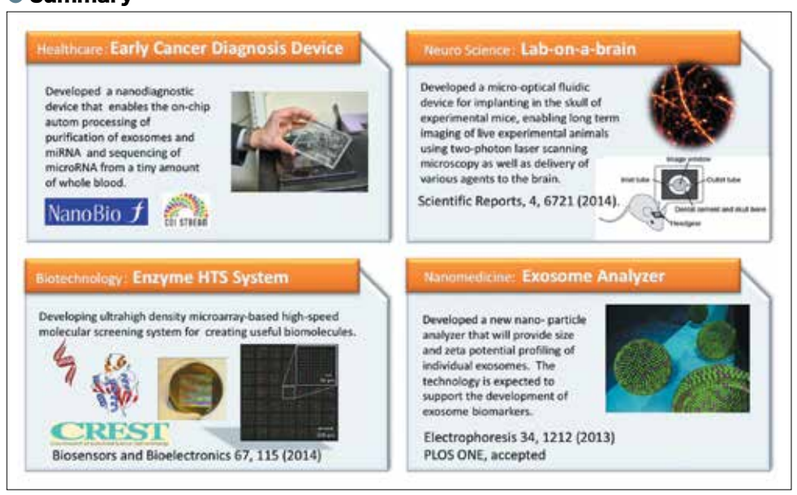
Development of evolutional bio-sensing platforms based on nano-biodevice technology

From nano/microprocess development to system integration

Research Objective

To realize innovative systems for bioanalysis and biosynthesis, we are developing higher-order functional integrated bio-devices based on the advanced nano/microfabrication technologies and hetero-integration technologies of inorganic and organic materials.

Summary



Biodevices

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[Subjects of Research]
- Single-molecule biophysics of rotary molecular motors
- Single-molecule digital bioassay with femtoliter reactor array
- High-throughput Enzyme screening with artificial reactor array
- Synthesis of autonomously self-replicating cell reactor

[Field of Study]
Single-molecule biophysics, Micro/Nano bioscience

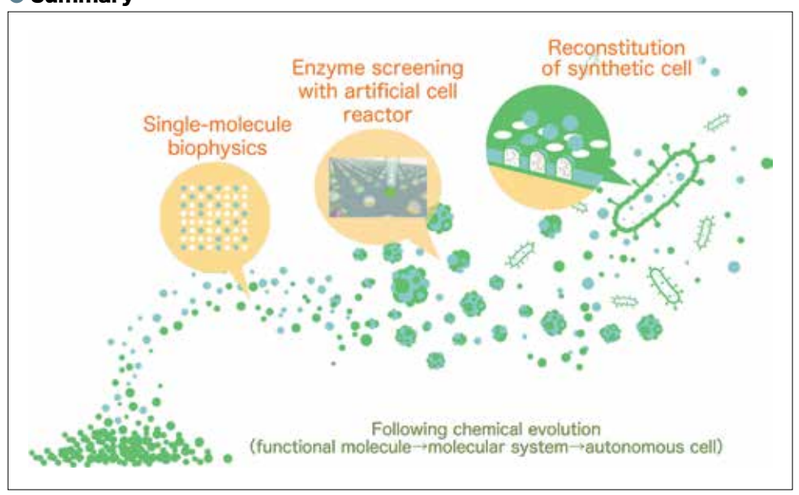
New Science and technology innovation by single-molecule and artificial cell reactor technologies

Enjoy Science and create new technology

Research Objective

For over two decades, we have been studying the molecular mechanism of ATP synthase by single molecule technology. Through our research, we have been creating novel and innovative technologies such as femtoliter reactor array, that is currently utilized in digital bioassays such as ELISA, and ratiometric fluorescent ATP sensor proteins. Development of these new technologies is motivated more by our own curiosity rather than the need of the society. These technologies are widely used now and have been further developed by other researchers or companies.

Summary



Biodevices

Professor
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[**Subjects of Research**]
- 3D tissue engineering using microfluidic technology
- Material synthesis and processing for biomedical micro devices

[**Field of Study**]
Micro tissue engineering, Biomaterials, Regenerative medicine, BioMEMS

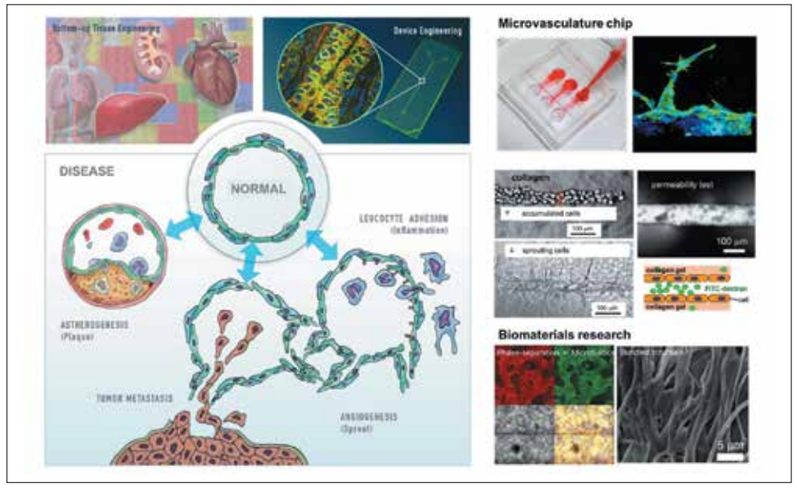
Visualization of Microenvironment of the Body

Fabrication of 3D Living Tissues to Understand Disease Mechanisms

● Research Objective

We have been focusing on disease tissue engineering by combining biomaterial synthesis, microfabrication and cell biology. Our goal is to develop controllable in vitro models to “visualize” the microenvironment of tissues from normal to disease state at the cellular level. This approach is a powerful tool for mechanistic understanding of disease and drug discovery.

● Summary



Biodevices

Project Associate Professor
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[**Subjects of Research**]
- Development of a next-generation automated analytical system for clinical samples based on specific biomolecular interactions in micro-space
- Research on wearable biochemical lab systems
- Development of a rapid, minimally invasive, low-cost automated analysis system for low volume clinical samples
- Realization of next-generation medical technologies such as detection of presymptomatic state, ultra-early diagnosis, on-site diagnosis, precision medicine of cancers, and remote medicine.

[**Field of Study**]
Quantitative analytical chemistry of biomolecules, creation of new analytical instruments

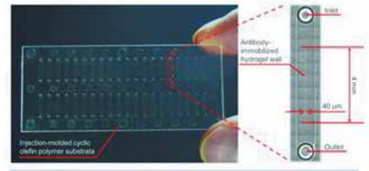
Creation of novel testing equipment for realizing the next-generation medical systems and healthy aging society.

Integration of processing technology from nano to centimeter and software development technology for meeting the needs of society.

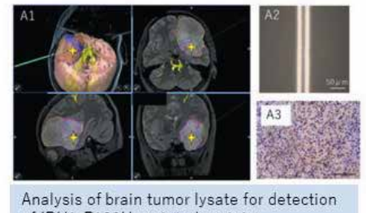
● Research Objective

I am conducting research on automated testing equipment with the aim of social implementation of technology that enables anyone, anywhere, at any time to do what could only be done in hospital laboratories. I am also developing wearable lab systems that can constantly monitor biomarkers for the purpose of examining the state of the body and mind.

● Summary



Micro-channel immunoassay device.



Analysis of brain tumor lysate for detection of IDH1-R132H mutated protein.

Automated immunoassay systems.

Biodevices

Project Professor
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[**Subjects of Research**]
- Modelling of micro-fluid elements for biochemical operations
- Design tools for micro-fluid circuit
- Micro-analysis systems for biomedical diagnostics
- Compact water-quality monitors

[**Field of Study**]
Micro fluidics

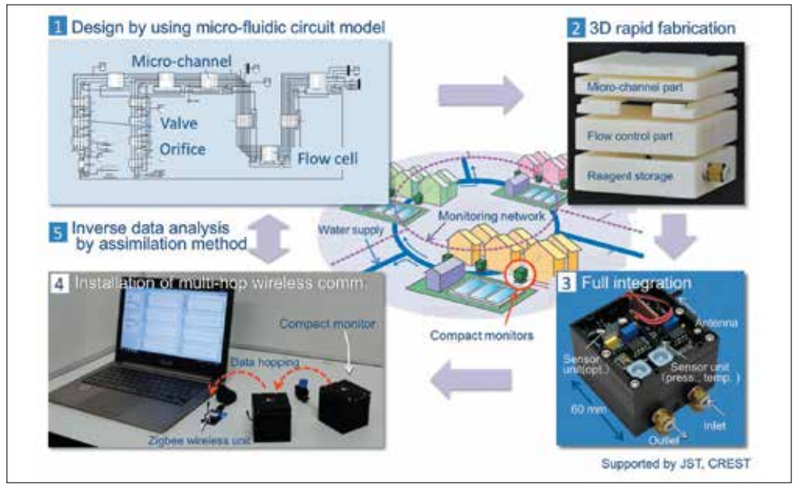
Development of design tool for micro-fluidic circuit

Integration and installation technologies for monitoring network system of water-quality

● Research Objective

Modelling of micro-fluid elements, and development of design tools and manufacturing processes of micro-fluid systems for biomedical diagnostics, enviromental analysis and micro-chemical plants. Development of micro-fluid elements and modelling of the fluid behavior inside the elements, and a design tools of micro-fluid circuit by connecting those elements in series and by arraying them in parallel.

● Summary



Chemical bioengineering

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[**Subjects of Research**]
- Hydrogels
- Membranes
- Particles
- Minimally invasive surgical treatment
- Regenerative medicine and drug delivery

[**Field of Study**]
Chemical Bioengneering

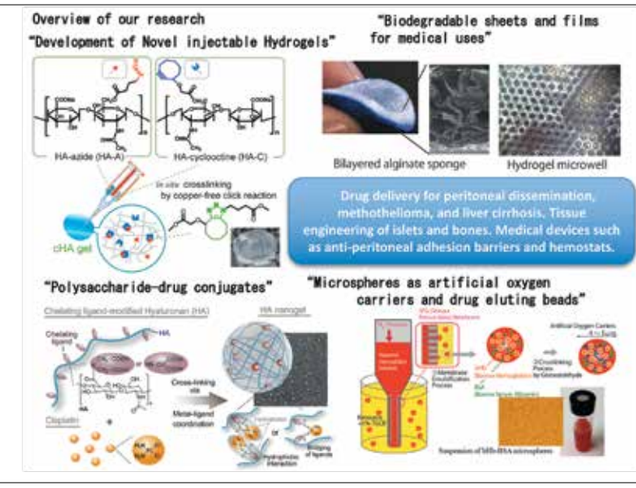
Polymeric Biomaterials and Therapeutic Device

Bio-inspired and biomimetic biomaterials

● Research Objective

Based on chemical engineering and polymer chemistry, we are developing new biomaterials (hydrogels, separation membranes, and microparticles) and new therapeutic devices that can be administered into the body. As materials, we combine polysaccharides such as hyaluronic acid and alginic acid with proteins such as gelatin and albumin to develop anti-adhesive materials, anti-stenosis materials, hemostatic materials, tissue adhesive materials, wound dressing materials, and artificial oxygen carriers, which are necessary for safe and minimally invasive surgery. We are developing topical drug delivery using injectable biomaterials and achieving local tissue regeneration using scaffolds and cell delivery materials.

● Summary



Chemical bioengineering

Professor

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[**Subjects of Research**]

- Progagation and differentiation of stem/progenitor cells in various scales
- Organization of vascularized tissues/organs for regenerative medicine
- Development of physiological tissue/organ models for efficacy/hazard evaluations and disease analyses
- Multi-scale numerical sumulations of human metabolisms

[**Field of Study**]
Organs and Biosystems Engineering

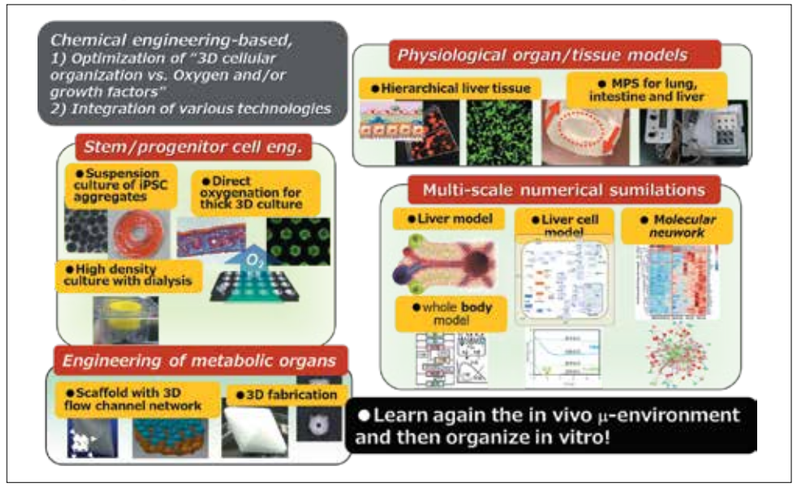
Organs and Biosystems Engineering for regenerative medicine and cell-based assays

Chemical system engineering-based applications of latest knowledge of biology and medicine

● Research Objective

The general goal of our lab is to culture and/or organization of stem and organ-derived cells in various scales for regenerative medicine and cell-based assays. Chemical system engineering methodologies and its point of view serve as the basis in achieving these goals, because it optimize mass transfers in 3D cell-based tissues or best integrate basic biology, medicine and engineering.

● Summary



Chemical bioengineering

Professor

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[**Subjects of Research**]

- Molecular Technologies for the analysis of biomolecules in vivo
- Synthetic molecules for regulation of cellular functions
- Rational design and high-throughput screening of synthetic molecules for drug discovery

[**Field of Study**]
Chemical Biology

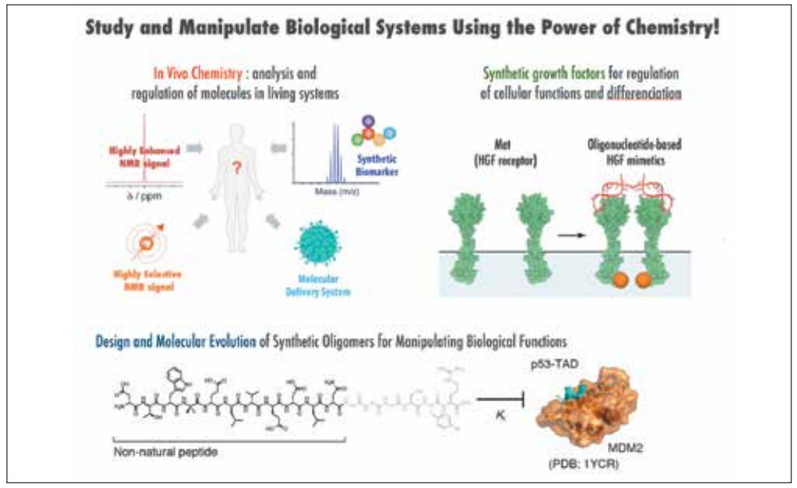
Molecular Technology for Understanding of Living Systems and for Early Diagnosis and Therapy

Study and Manipulate Biological Systems Using the Power of Chemistry

● Research Objective

Our body is composed of a variety of biomolecules. An unsolved principle of life must lay in the activities of such biomolecules and the abnormal molecular activities could cause various diseases such as metabolic disorder. Our group is conducting chemistry-based research for "understanding of living systems at the molecular level" and "developing new molecular technology contributing to early diagnosis and therapy". The research area ranges from leading edge sensing technology for non-invasive molecular diagnosis/analysis/sensing and functional molecule development for molecular therapy and regenerative therapy.

● Summary



Chemical bioengineering

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[**Subjects of Research**]

- RNA modifications associated with various biological functions
- Decoding of genetic information and protein synthesis
- Epitranscriptome and biological functions
- Molecular pathogenesis of RNA modopathy

[**Field of Study**]
Molecular biology, Biochamistry

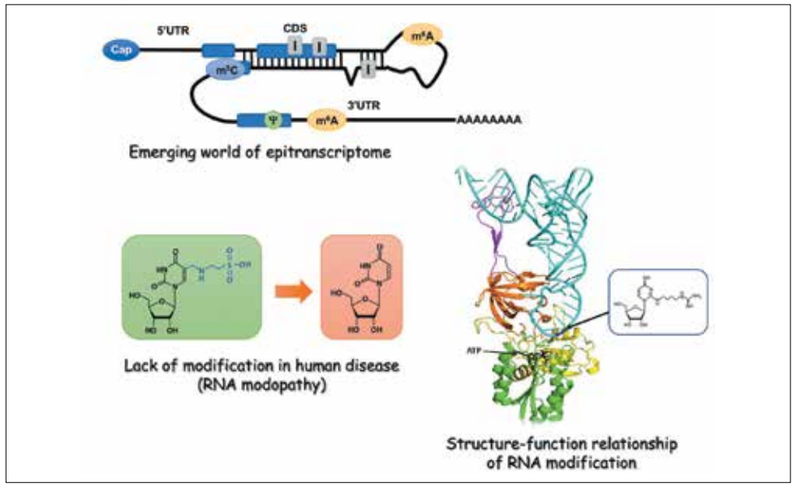
RNA biology and molecular pathogenesis

Epitranscriptome regulation of gene expression and higher-order biological process associated with RNA

● Research Objective

Higher-order biological processes, including development, differentiation and complex mental activity, are the result of sophisticated regulation of gene expression. Dysregulation of gene expression often causes a variety of human diseases. RNA molecules are deeply involved in regulation of gene expression at various steps of central dogma. We are tackling to elucidate various biological phenomena associated with RNA functions based on multidisciplinary approaches including molecular biology, biochemistry, genetics, analytical chemistry and cell biology.

● Summary



Chemical bioengineering

Professor

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[**Subjects of Research**]

- Antibody Engineering in the Era of Bio-Better
- Artificial Regulation of Biomolecular Interactions
- Focus on Disease-related Molecular Systems
- Protein Engineering in Bio-Material Design

[**Field of Study**]
Protein Engineering,
Physical Biochemistry

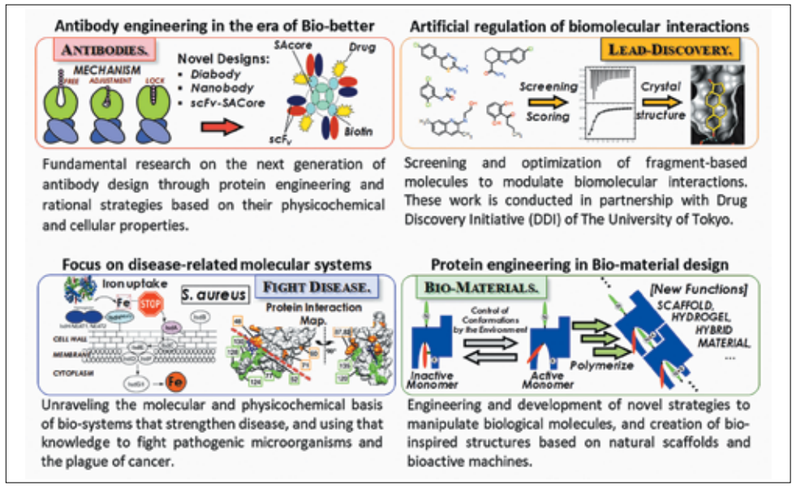
Biophysical analyses, design, and manipulation of biomolecular Interactions

Analyses, design, and manipulation of protein interactions

● Research Objective

Biological phenomena are based on highly organized and specific molecular interactions. We aim to dissect these biomolecular interactions using state-of-the-art methodologies, and to design ligands to control them. We also advance bio-medicine in the era of bio-better and bio-superior using multiple engineering approaches. Our methodologies are applied to the study of disease-related biological machineries and will stimulate the creation of safer and more efficient medications.

● Summary



Chemical bioengineering

Associate Professor

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[**Subjects of Research**]

- Fascile and sensitive detection of biomarkers using photofunctional nanoparticles
- One-pod detection of multiple biomarkers using photofunctional nanoparticles
- Constraction of a diagnostic model based on the expression profile of multiple biomarkers

[**Field of Study**]
Chemical Engineering,
Photofunctional nanoparticles

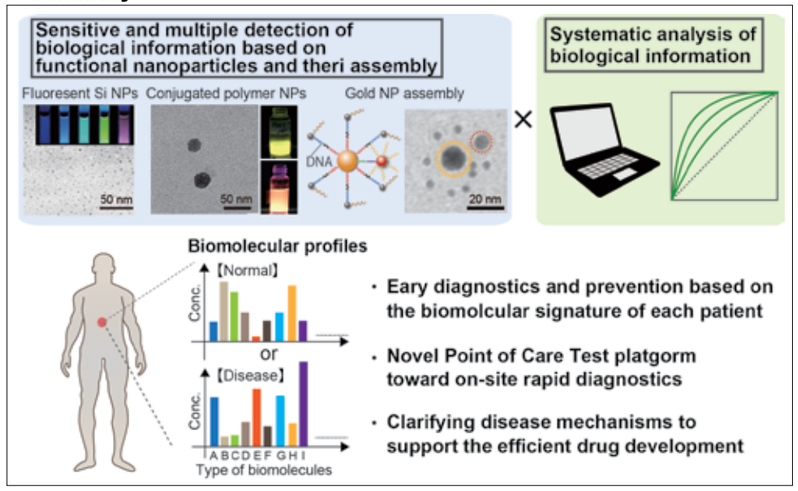
Exploring systems diagnostics using functional nanoparticles

Integrating sensitive and multiplle detection of biological information with systematic data analysis toward early diagnostics platform

Research Objective

In our body, dynamic and complicated interactions of numerous biomolecules determine biological phenomena. Using functional nanoparticles as a tool, we develop a detection/visualizing method of these interactions. Integrating with the data analysis that considers living body as a system, we aim to develop a novel diagnostic platform enabling early diagnostics, precision medicines, and efficient drug development. Chemical Engineering is a basic principle of our group, to which various medical or biological knowledge are integrated systematically.

Summary



Chemical bioengineering

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[**Subjects of Research**]

- Roles of organelle interactions
- Investigation of neuronal ultrastructures
- Adult neurogenesis

[**Field of Study**]
Molecular Biology and Cell Biology

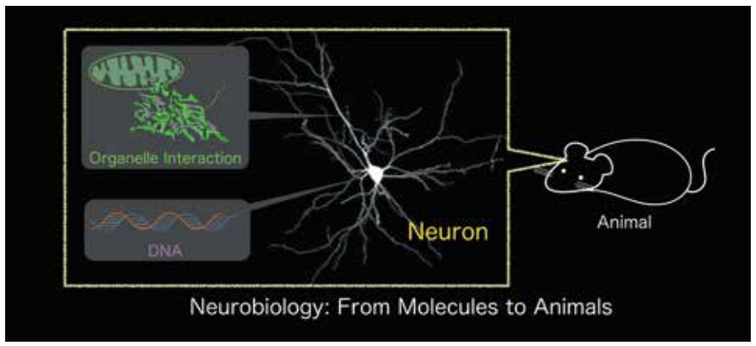
Neurobiology

From Molecules to Animals

Research Objective

The nervous system regulates our mind and behavior. Precise regulation of each neuron and connections between neurons are required for proper functioning of the brain. Therefore, elucidating the mechanisms regulating brain function facilitates developing therapies for neurodevelopmental and neurodegenerative diseases such as Parkinson' s and Alzheimer' s disease. We study how neurons, the connections between neurons, and adult neurogenesis contribute to the functions of the nervous system, from the perspective of cell biology.

Summary



Chemical bioengineering

Associate Professor

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[**Subjects of Research**]

- Understanding of epigenetic and gene expression dynamics in development and tissue repair
- Development of human organ modeling using human pluripotent stem cells
- Identification of drug candidates for skeletal formation and its application for skeletal regeneration
- Development of novel biomaterials for tissue engineering

[**Field of Study**]
Skeletal development and regeneration

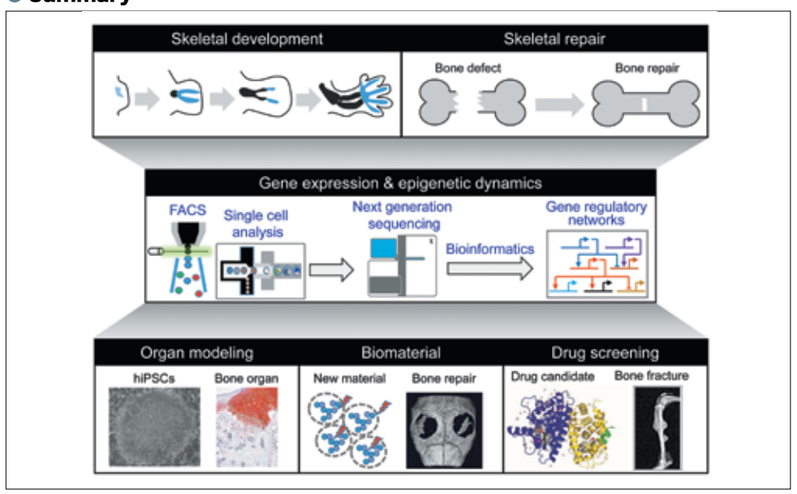
Integrative studies of developmental biology, regenerative medicine and biomaterial

Establishment of strategies for tissue engineering and disease therapy based on understanding of molecular mechanisms underlying skeletal development and repair

Research Objective

We aim at identifying gene regulatory networks underlying skeletal development and repair by understanding those complex biological contexts from aspects of the cell lineage and epigenetic dynamics.
By utilizing the identified knowledge to integrate with modeling of human development and disease, novel biomaterials and drug screening system, we aim to establish strategies for skeletal tissue engineering and disease therapy.

Summary



Chemical bioengineering

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[**Subjects of Research**]

- Development of biophysical technology for antibody and small molecule drugs
- Design of high-potential biopharmaceuticals using in silico methodology

[**Field of Study**]
Medicinal Physicochemistry,
Protein Engineering,
Biochemistry

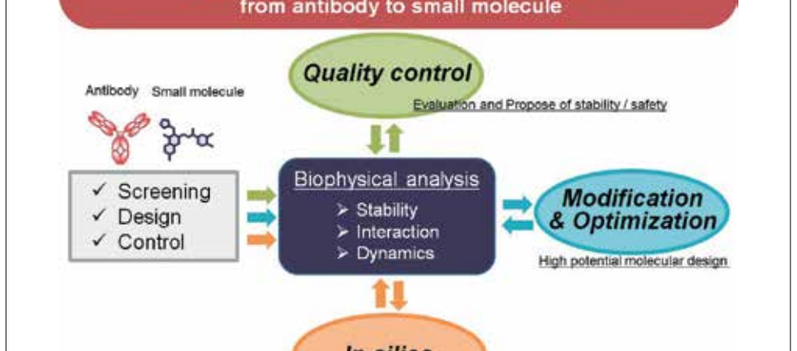
Advanced Biopharmaceutical Science using Biophysical Technologies

We propose and design the innovative biopharmaceuticals.

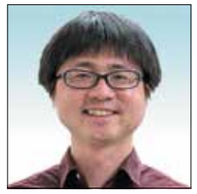
Research Objective

Developments and improvements of technology for the discovery and optimization of high-potency antibodies have greatly increased to find the specific and stable antibody with desired biological properties. Biophysical analyses of therapeutic antibody, particularly those of protein interaction and stability, are recognized as one of the critical procedures in the development of biopharmaceuticals, which would be assessed as an essential step to develop next generation antibodies. We study biophysical analyses of various antibody to propose new strategy for development of the next generation antibody.

Summary



Chemical bioengineering



Lecturer

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[**Subjects of Research**]

- Construction of a strategy to develop humanized single domain antibodies relying on in vitro selection
- Development of anti-bacterial therapeutics utilizing a variety of modality-based molecules
- Elucidation of the molecular mechanism by which extracellular tumor supressor proteins regulate signal transduction
- Elucidation and regulation of molecular transport system in brain relying on antibody engineering

[**Field of Study**]
Protein science,
Molecular medical engineering,
Molecular biological chemistry

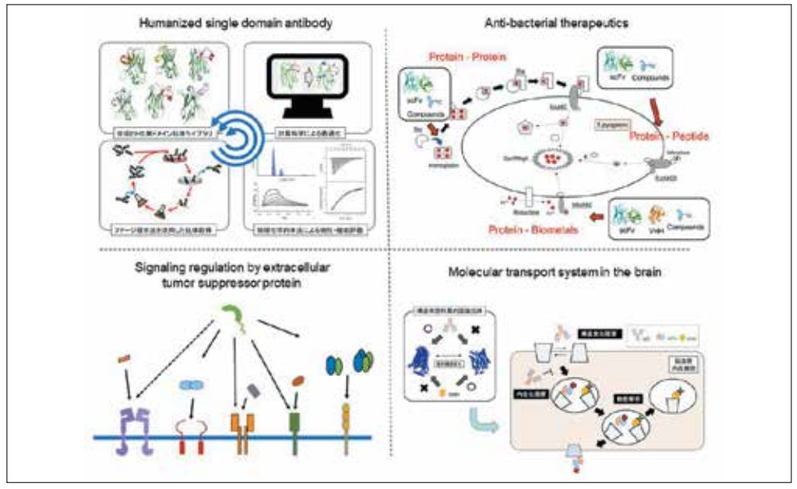
Elucidation and regulation of biological system using a variety of modality-based molecules

To elucidate and regulate biological systems and pathologies related to brain science using a variety of modality-based molecules

● Research Objective

Recently, modality-based drug discovery, which is based on appropriate selection of molecular species depending on molecular mechanisms of target diseases, have attracted increasing attention. Our research interests include development of novel stragtegy for modality-based drug discovery and elucidation of novel biology through understanding of molecular properties of target proteins. Our research is mainly relying on physicochemical approaches collaborating with other biological disciplines such as bacteriology, and aim to solve a variety of challenges in medicinal and / or biological research field.

● Summary



Biomaterials

Professor

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[**Subjects of Research**]

- Understanding of structure-property relationship of polymer gels
- Design of structural biomaterials using hydrogels
- Hydrogel scaffold for regenerative medicine

[**Field of Study**]
Biomaterials

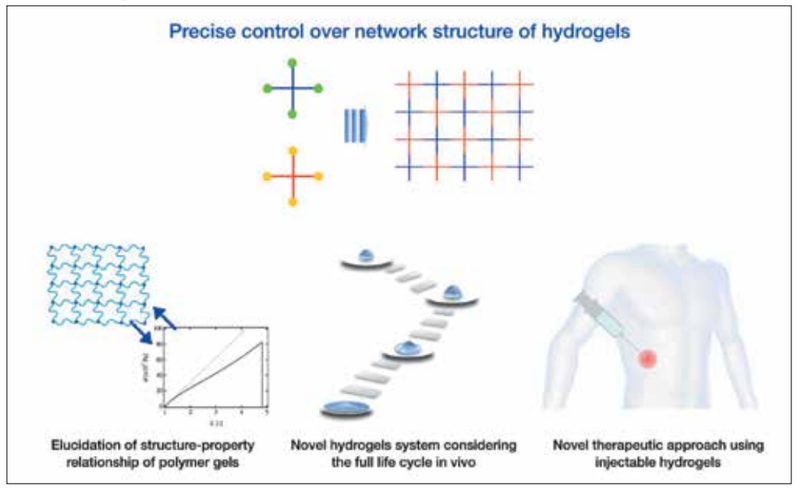
Design and Fabrication of Hydrogels for Biomedical Application

Next-generation hydrogels based on fundamental understanding

● Research Objective

Hydrogels are water-filled materials which have similar composition with that of living body. Owing to the similarity, hydrogels are promising candidates for biomaterials. We design and fabricate hydrogels with precisely controlled network structures, and attempt to develop novel hydrogels for biomedical application.

● Summary



Biomaterials

Professor

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[**Subjects of Research**]

- Development of methods precisely controlling 3D shape of biomaterials
- Optimization of regenerative signals with novel monitoring systems and screening of signaling factors
- Integration of biomaterials with signaling factors for high performance

[**Field of Study**]
Biomaterials, Regenerative Medicine/
Tissue Engineering, Skeletal Biology

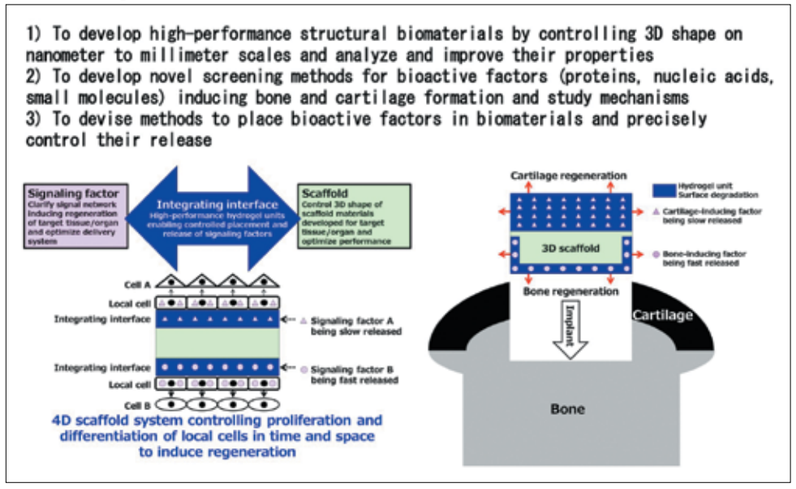
Creation of innovative regenerative device integrating scaffolds and signaling factors

Integration of life science and materials science

● Research Objective

Among the three pillars of tissue engineering/regenerative medicine, we focus on signals and scaffolds and try to integrate the two to create innovative implant devices, which locally act on host cells to induce regeneration.

● Summary



Biomaterials

Professor

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[**Subjects of Research**]

- Development of nanomedicines for oligonucleotide and mRNA delivery
- Development of nanomedicines that can target difficult-to-reach diseased tissues
- Design of polymeric nanorulers for optimal tissue permeability in diseased tissues
- Design and evaluation of novel biocompatible and functional polymeric materials alternative to PEG
- Design and evaluation of organic/inorganic hybrid biomaterials

[**Field of Study**]
Biomaterials, Nanobiomedicines

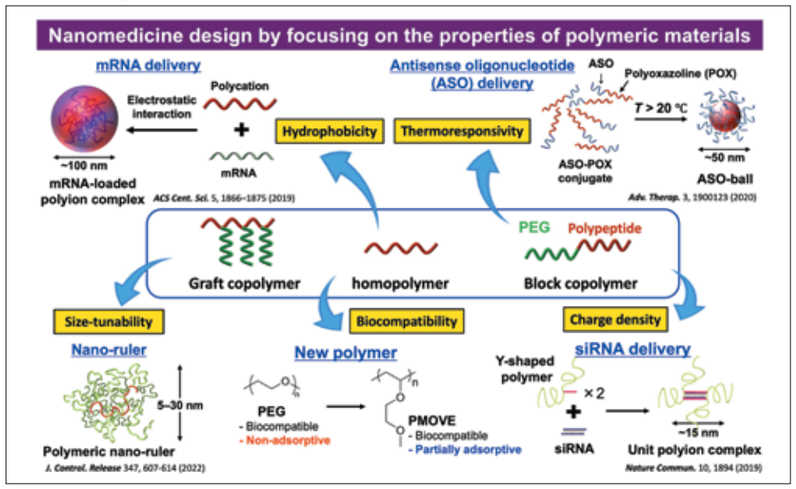
Biofunctional materials

Nanobiomedical innovation originating from material design

● Research Objective

Our vision is to elucidate the in vivo functions of biomaterials for human health. The mission is to i) controll the biodistribution of biomaterials, ii) control the functions (ON/OFF) of biomacromolecules, and iii) realize the spatiotemporal detection of biological information. Specifically, we are designing novel nanomedicines that can efficiently target the diseased sites for realizing the treatment of intractable diseases.

● Summary



Biomaterials

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[**Subjects of Research**]
- Polymeric micelles as drug delivery systems of anticancer drugs
- Tumor imaging and diagnosis
- Effect of cancer biology on nanomedicine

[**Field of Study**]
Nanomedicine

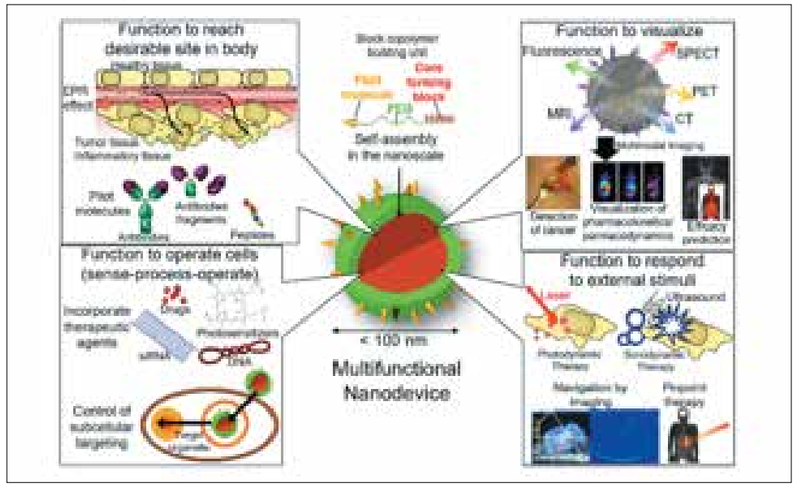
Development of the multifunctional nano-device for efficient diagnosis and reatment

Realize a safe and efficient therapy using self-assembly nano structures

● Research Objective

Nano delivery system which delivers the drug and/or genes to the desired site in the body, and that diagnose and/or trea the diseases at the disirable site when it is needed is necessary. We develop a multifunctional nano-device with high biocompatibility, based on the self assembly of the well-designed synthetic polymer for cell-scaled nano therapy.

● Summary



Biomaterials

Lecturer

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[**Subjects of Research**]
- Elucidation of rheological properties of slime with precisely structures
- Elucidation of relationship between rheology and molecular dynamics of slime
- Development of novel rheological materials for medical applications using slime

[**Field of Study**]
Rheology, Polymer dynamics, Biomaterial

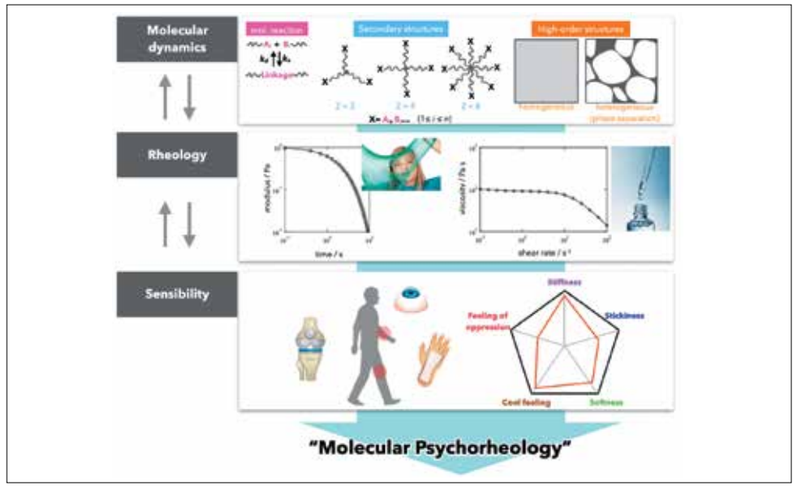
Design of novel biomaterials based on "molecular psycorheology"

Design of biomaterials from the molecular level by quantitatively evaluating human sensibility needs for materials, using the rheology of soft matter as a core technology

● Research Objective

The major objective of our laboratory is to construct and develop a discipline that precisely designs materials to match human sensibility from the molecular level via rheology (Molecular psychorheology). To this purpose, we are establishing quantitative evaluation methods for sensibility, and developing techniques to elucidate and control the correlation between rheology and molecular dynamics, with the aim of freely controlling rheology.

● Summary



Bioimaging

Professor

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[**Subjects of Research**]
- Research on robots and devices for minimally invasive surgery
- Research on intraoperative bioinstrumentation and information processing
- Research on Surgical technique evaluation
- Research on robotics for life support

[**Field of Study**]
Computer Aided Surgery,
Biomedical Precision Engineering

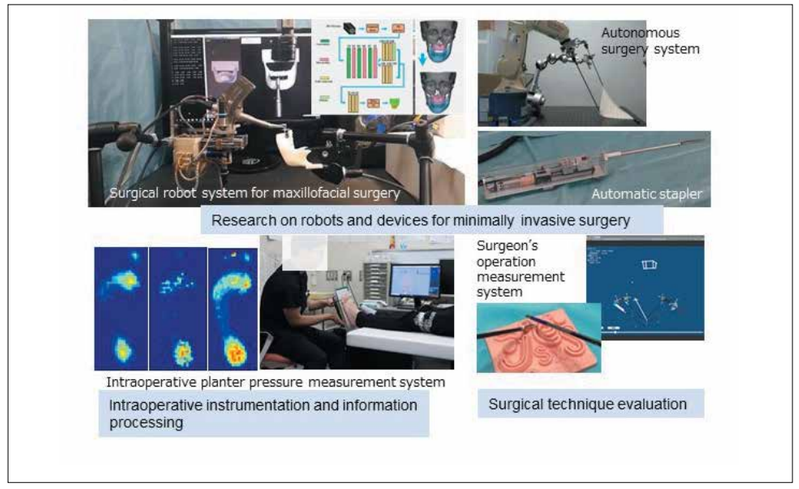
Mechatronics technology for life and medicine

Realize environments and systems that improve people's quality of life (QOL) through strong medical-engineering collaboration

● Research Objective

We study about mechatornics and image processing systems to support minimally invasive surgery and realize presicion surgery such as medical robotics and devices, intraoperative measurement devices, evaluation of organ physical properties. All researches are practical application and evaluation of life support robots Research. Our research scope ranges from basic research to system development research with a view to practical application.

● Summary



Bioimaging

Professor

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[**Subjects of Research**]
- Surgical Robotics
- Minimally Invasive Precision Guided Therapy
- Optical Mapping of Cardiac Excitation
- Cardiac Electrophysiology

[**Field of Study**]
Computer Aided Surgery,
Bio-Instrumentation,
Electrophysiology

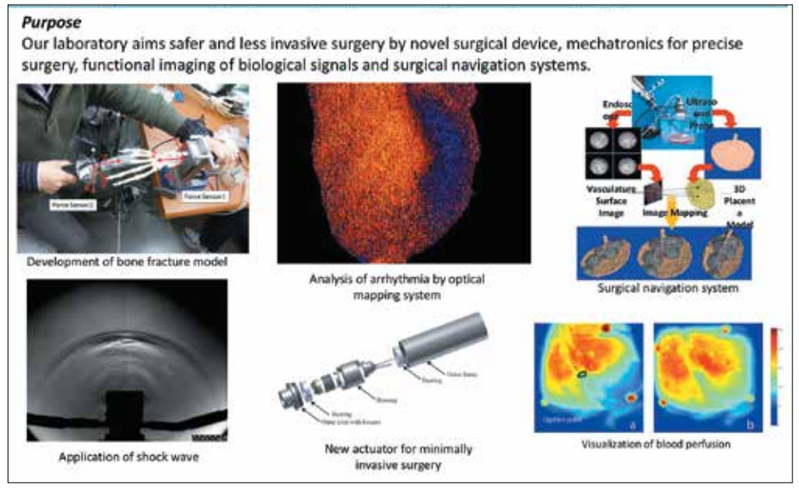
Integration of therapeutic and diagnostic system for safer and less invasive surgery

Realize minimally invasive therapies by integration of treatment and diagnosis based on advanced engineering technologies

● Research Objective

Our laboratory focuses on the biomedical applications, especially biomedical devices and systems based on mechatronics (a multidisciplinary field of electrical engineering and mechanical engineering). We are developing novel technologies such as a computer assisted surgical system for precision treatment, diagnostic method to visualize lesion, and navigation system for conducting advanced surgery. We are also doing basic research for investigating the response of biological cells, tissues and body by using precision measurements and manipulation techniques.

● Summary



Bioimaging

Professor

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[**Subjects of Research**]
- Quantum Radiation Imaging

[**Field of Study**]
Radiation Measurements and Imaging

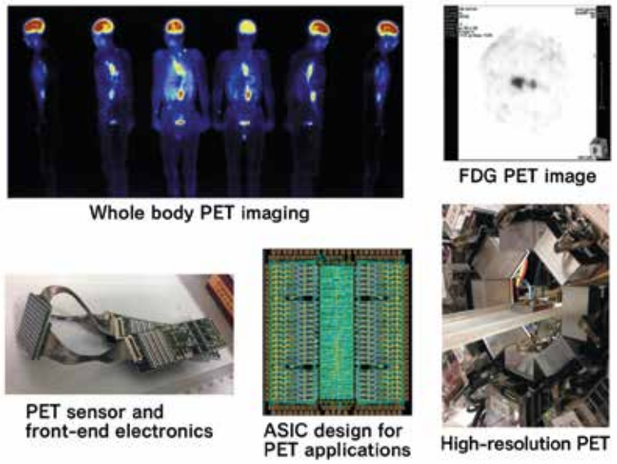
Quantum Radiation Imaging for Biomedical Applications

Function imaging with nuclear medicine and radiation imaging

● Research Objective

Positron emission tomography and other radiation imaging techniques provide biological functions and molecular information.
We are developing new sensor technologies and studying new imaging methods, which can be used for new cancer diagnostics and high resolution tracer imaging.

● Summary



Bioimaging

Professor

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[**Subjects of Research**]
- MRI measurement techniques for electrical properties and phenomena
- Magnetic stimulation of the brain
- Flexible thin-film devices for biosensing
- Magnetic prove for identifying sentinel lymph nodes

[**Field of Study**]
MRI, Magnetic Stimulation of the Brain, Biomagnetics, Applied Superconductivity

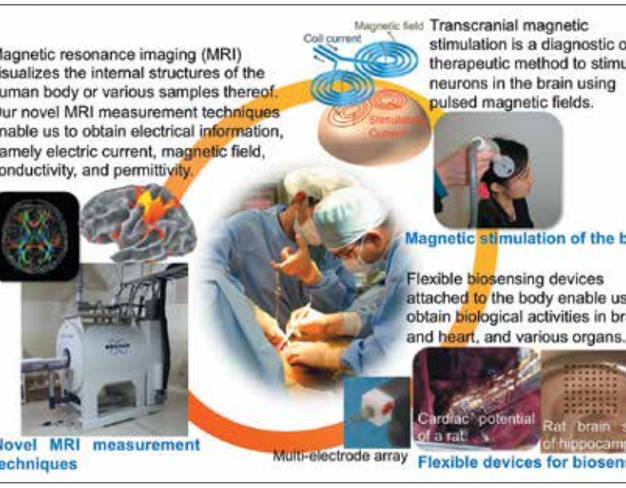
Electromagnetic Imaging of Biological Bodies and Brain Stimulation

Development of novel electromagnetic devices for medical applications

● Research Objective

Electromagnetic fields enable diagnosis of diseases at an early stage and non-invasive treatment of the diseases. Our group is developing compact and user-friendly medical equipment for use in patients' home, and flexible thin film devices which fit even the curved geometry of the brain surface.

● Summary



Bioimaging

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[**Subjects of Research**]
- Biomedical functional molecular imaging in individuals
- Nuclear Medicine
- Medical Quantum Radiation imaging
- Detection technology and sensors for quantum radiation
- Research on integration of magnetic, RI and quantum technology

[**Field of Study**]
Quantum Imaging, Biomedical Imaging, Radiation Imaging

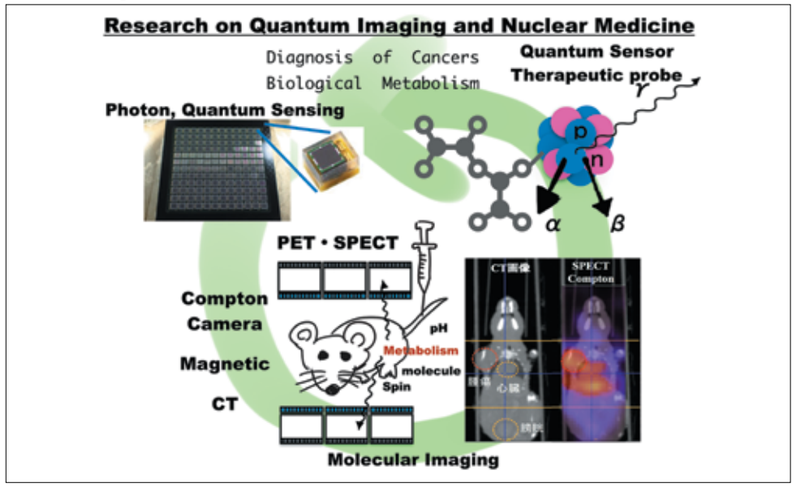
Medical Quantum Radiation imaging to visualize molecular functions at individual level

From quantum sensors to medical functional imaging

● Research Objective

CT (Computed Tomography), PET (Positron Emission Tomography) and SPECT (Single Photon Emission CT) are powerful medical quantum radiation imaging method providing precise morphological information and high-sensitive molecular functional information. Novel molecular/functional imaging technology at individual level are being developed for future accurate cancer diagnosis or prediction of diseases. New quantum sensors and combination with other modalities are also under development.

● Summary



Bioimaging

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[**Subjects of Research**]
- Dynamics of impulse propagation and rotational activity (rotor)
- Atrial Fibrillation and 3-Dimensional Scroll Wave
- Mechanisms of Ventricular Fibrillation (VF) and VF storm

[**Field of Study**]
Cardiac Electrophysiology, Cardiology

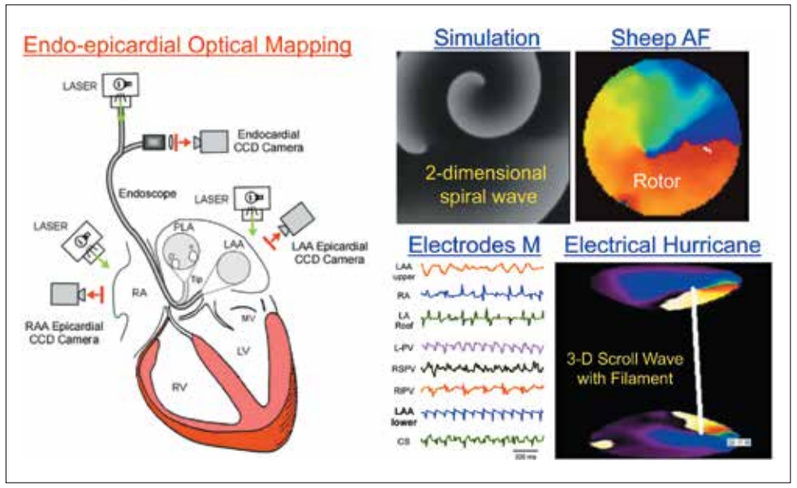
Optical Mapping of Rotor as a Mechanism of Cardiac Fibrillation

Establishment of a Novel Therapeutic Strategy for Cardiac Fibrillation

● Research Objective

Since about 100 years ago, many theoretical and experimental studies have suggested that rotor (a.k.a. 2-dimensional spiral wave reentry/3-d scroll wave) rotating around a functional obstacle, like hurricane and tornado, is the major mechanisms of cardiac fibirillation. Our objectives are first to explore spiral wave dynamics specifically in remodeled atria of chronic atrial fibrillation using high resolution optical mapping system and computer simulation; and second to examine how radio-frequency ablation of spiral wave effectively terminates and prevents cardiac fibrillation.

● Summary



Bioimaging

Lecturer

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[Subjects of Research]

- Development of photoacoustic techniques for treatment and diagnosis
- Visualization of acoustic interactions with cells and tissues
- Study on cellular response to fast mechanical stimulation
- Development of the world's fastest camera

[Field of Study]
Bioimaging,
Optical and Acoustical Engineering,
High-speed imaging

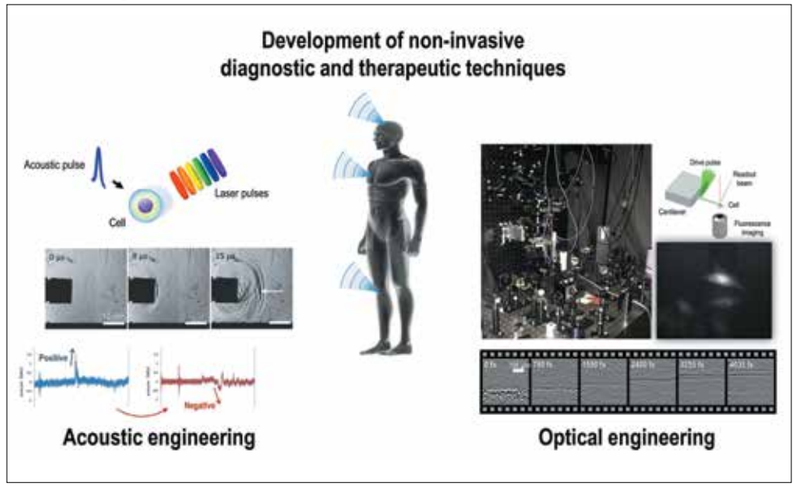
Research on acoustic interactions within living bodies

Open new avenues with innovative imaging technologies

● Research Objective

The main research interest in the Nakagawa group is to use acoustic wave as a tool to modulate the living body and cells. Based on acoustic engineering and optical engineering, we have proposed and demonstrated unique acoustic wave generators and wave modulators. We are also developing novel ultrafast imaging methods to reveal acoustic interactions with cells and tissues.

● Summary



bioengineering
THE UNIVERSITY OF TOKYO

To all the students

This Q & A describes frequently asked questions and answers.

About admission

Q Do I have to possess the knowledge of basic subjects in biology such as molecular and cellular biology before taking the entrance examination?

A No, you don't. You can choose the subjects in the examination. Details are available in the guidelines of the entrance examination. You can learn research-related knowledge in the laboratory or from lectures after you enroll in the Department of Bioengineering.

A Since you can select the subjects to be tested, you can choose the questions which are related to your own research area. There will be more opportunities for you to learn the basic knowledge of biology after you enroll in the department. It won't be too late if you start then.

Q Is there any limitation or disadvantage if I am an examinee from another university or another department?

A No, your previous affiliation has no influence on admission.

Q Where can I find detailed information about each laboratory?

A You can find an introduction of professors online.
If you have any questions you can directly contact your prospective professor.

About department and reseach

Q I've heard that one of the advantages of the Department of Bioengineering is the fusion of medicine and engineering. Is this accurate?

A Nowadays, it is necessary to solve problems considering both medical and engineering aspects in state-of-the-art medicine. Bioengineering is a discipline which integrates both subjects. See page 2.