

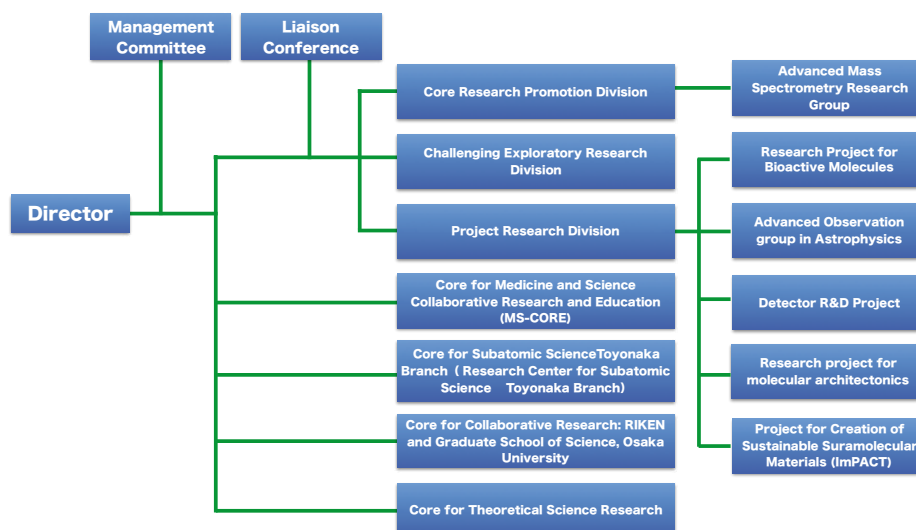
Project Research Center for Fundamental Sciences

Overview

The Graduate School of Science at Osaka University is responsible for carrying out fundamental scientific research. In the spirit of the first president of Osaka University, Dr. Hantaro Nagaoka, whose motto was “Souhaku wo Namuru Nakare (Lack not in originality)” it is dedicated to the discovery of new insights and the development of new perspectives on matter. Our research programs also aim to foster young researchers, who will serve as the next generation of researchers in fundamental science and as internationally active leaders across many fields. The primary research style of the Graduate School of Science is thus to advance fundamental research with a long-term vision through the free thought and creativity of the individual. Research projects demonstrating major findings and showing great promise for future breakthroughs are awarded large-scale competitive funding. However, such large-scale research projects require short-term investments in people, facilities, and time as well as rapid implementation. Although this mode of research can certainly open a path to continuing the development of fundamental science, it does not fit the traditional research style of the Graduate School of Science. Therefore, The Project Research Center for Fundamental Sciences was established on October 1, 2011 to serve as a facility for large-scale research projects and other efforts, with open laboratories and specialized environments for working with radiation. Large-scale projects

and interdisciplinary research in progress at this center have brought about remarkable advances in collaboration with ERATO, ImPACT, and medical research under projected budgetary allocations, as well as the establishment of an international therapeutic base for the treatment of advanced cancer.

The Project Research Center for Fundamental Sciences was reorganized on July 1, 2015 to strengthen its engagement in highly challenging and creative research, education leading to germinal research, the creation of new research and development sectors through new collaborations, and strengthening of industrial-academic co-creation, as well as the advancement of large-scale research projects. With this re-organization, mid- and long-term projects will be carried out by the Graduate School of Science led “Core Research Promotion Division”, while “Challenging Exploratory Research Division” was constructed and established as a new framework for engaging in challenging exploratory research. New centers of excellence were also established to facilitate the freedom of growth for research that extends across organizations and institutions. In this way, the Project Research Center is enhancing its platform for advancing cutting-edge research and providing an environment for carrying out original and creative fundamental research at a level worthy of consideration for future Nobel prizes.



Faculty Members:

Director[Professor]Michisato TOYODA
Vice Director[Professor]Masahiro UEDA (Fbs)

Core Research Promotion Division

[Division head]Michisato TOYODA

Advanced Mass Spectrometry Research Group

[Professor]Michisato TOYODA, Masaaki ASHIDA (Es), Kunio AWAZU (Eng), Masahiro UEDA (Fbs), Yasuo KANEMATSU (e-square), Toshifumi TAKAO (Protein), Hitoshi TANAKA (Law), Kentaro TERADA (Grad), Koichi FUKASE (Grad), Shinya MURAKAMI (Dent), Taku YAMANAKA (Grad)
[Associate Professor]Morio ISHIHARA (Grad), Osamu HISATOMI (Grad), Tetsuro HIRANO (Grad), Hiroshi FURUTANI (Reno)
[Assistant Professor]Jun AOKI, Yosuke KAWAI (Grad), Yukihiro MIYANAGA (Fbs)

Project Research Division

[Division head]Michio MURATA (Grad)

Research Project for Bioactive Molecules

[Professor]Michio MURATA (Grad), Yasuhiro KAJIHARA (Grad)
[Associate Professor]Kazuya KABAYAMA (Grad)
[Guest Associate Professor]Shigeru MATSUOKA (Grad)
[Assistant Professor]Yoshiyuki MANABE (Grad), Yuichi UMEGAWA (Grad)
[Visiting Researcher]Toshiaki HARA

Advanced observation group in Astrophysics

[Professor]Hiroshi SHIBAI (Grad), Hironori MATSUMOTO (Grad)
[Associate Professor]Takahiro SUMI (Grad), Kiyoshi HAYASHIDA (Grad)
[Assistant Professor]Hiroshi NAKAJIMA (Grad), Taro MATSUO (Grad)

Detector R&D Project

[Professor]Taku YAMANAKA (Grad), Hiroshi SHIBAI (Grad), Michisato TOYODA, Hironori MATSUMOTO (Grad)
[Associate Professor]Hajime NANJO (Grad)
[Assistant Professor]Jun AOKI, Hiroshi NAKAJIMA (Grad)

Research Project for Molecular Architectonics

[Professor]Takumi OGAWA (Grad)
[Lecturer]Ken-ichi YAMASHITA (Grad)
[Assistant Professor]Yosuke TANI (Grad)

Project for Creation of Sustainable Suramolecular Materials (ImPACT)

[Professor]Tadashi INOUE (Grad), Sadahito AOSHIMA (Grad), Katsumi IMADA (Grad), Kiyotaka ONITSUKA (Grad), Takahiro SATO (Grad), Hiroyasu YAMAGUCHI (Grad), Akihito HASHIDZUME (Grad)
[Specially Appointed Professor]Akira HARADA
[Lecturer]Yoshinori TAKASHIMA (Grad)
[Assistant Professor]Takuya KATASHIMA (Grad)
[Specially Appointed Assistant Professor]Yuichiro KOBAYASHI, Yongtai ZHENG, Tomoko SEKINE, Motofumi OSAKI

Mass Spectrometry Open Innovation Joint Research Chairs

[Professor]Michisato TOYODA, Masahiro UEDA (Fbs), Toshifumi TAKAO (Protein)
[Specially Appointed Researcher]Junichi OSUGA
[Visiting Associate Professor]Yoshihisa UEDA (JEOL)
[Visiting Academic Staff]Takaya SATOH (JEOL)

Core for Medicine and Science Collaborative Research and Education (MS-CORE)

[Division head]Atsushi SHINOHARA (Grad)
[Professor]Atsushi SHINOHARA (Grad), Masahiro UEDA (Fbs), Yasuhiro KAJIHARA (Grad), Michisato TOYODA, Koichi FUKASE (Grad), Michio MURATA (Grad), Hiroyasu YAMAGUCHI (Grad), Hidenori INOHARA (Med), Yasufumi KANEDA (Med), Eku SHIMOSEGAWA (Med), Jun HATAZAWA (Med),

Takashi NAKANO (RCNP), Masaharu NOMACHI (RCNP), Mitsuhiro FUKUDA (RCNP), Takashi YOSHIMURA (RI)

[Guest Professor]Tsuneo YANO (Grad)
[Associate Professor]Kazuya KABAYAMA (Grad), Koichi FUJIMOTO (Grad)

[Specially Appointed Associate Professor]Atsushi TOYOSHIMA
[Lecturer]Yoshitaka KASAMATSU (Grad), Hiroki KATO (Med), Toru TAKANO (Med), Mitsuaki TATSUMI (Med)

[Assistant Professor]Atsushi SHIMOYAMA (Grad), Yoshiyuki MANABE (Grad), Yukiko NAKATA (Med), Tadashi WATABE (Med), Tomokazu SUZUKI (RCNP)

[Specially Appointed Assistant Professor]
Kayako ISOHASHI (Med), Yasukazu KANAI (Med), Shinichiro WATANABE (Med), Kazuko KANEDA

Core for Subatomic Science Toyonaka Branch (Research Center for Subatomic Science Toyonaka Branch)

[Division head]Masaharu NOMACHI (RCNP)
[Professor]Masaharu NOMACHI (RCNP), Tadafumi KISHIMOTO (Grad), Yoshitaka KUNO (Grad)
[Associate Professor]Masaharu AOKI (Grad), Shuhei AJIMURA (RCNP), Atsushi SAKAGUCHI (Grad), Sei YOSHIDA (Grad), Tatsushi SHIMA (RCNP)
[Assistant Professor]Akira SATO (Grad), Yorihito SUGAYA (RCNP), Keiji TAKAHISA (RCNP)
[Specially Appointed Assistant Professor]
Saori UMEHARA (RCNP)

Core for Collaborative Research: RIKEN and Graduate School of Science, Osaka University

[Division head]Yasuhiro KAJIHARA (Grad)
[Professor]Yasuhiro KAJIHARA (Grad), Takuji OGAWA (Grad), Takashi KUBO (Grad), Koichi FUKASE (Grad), Michio MURATA (Grad), Hiroyasu YAMAGUCHI (Grad)
[Guest Professor]Fumiaki HAYASHI (RIKEN)
[Lecturer]Ryo OKAMOTO (Grad)
[Assistant Professor]Yuta MAKI (Grad)

Core for Theoretical Science Research

[Division head]Koji HASHIMOTO (Grad)
[Professor]Koji HASHIMOTO (Grad), Tetsuo OGAWA (Grad), Hikaru KAWAMURA (Grad), Kentaro NAGAMINE (Grad), Atsushi HOSAKA (RCNP)
[Associate Professor]Koichi FUJIMOTO (Grad)

(Grad) Concurrent post belonging to Graduate School of Science (RCNP) Concurrent post belonging to Research Center for Nuclear Physics
(Es) Concurrent post belonging to Graduate School of Engineering Science
(Eng) Concurrent post belonging to Graduate School of Engineering
(Med) Concurrent post belonging to Graduate School of Medicine
(Law) Concurrent post belonging to Graduate School of Law and Politics
(Dent) Concurrent post belonging to Graduate School of Dentistry
(Fbs) Concurrent post belonging to Graduate School of Frontier Biosciences
(RI) Concurrent post belonging to Radioisotope Research Center
(Reno) Concurrent post belonging to Center for Scientific Instrument Renovation and Manufacturing Support
(e-square) Concurrent post belonging to Office for University-Industry Collaboration e-square
(Protein) Concurrent post belonging to Institute for Protein Research (RIKEN) .. Concurrent post belonging to The Institute of Physical and Chemical Research (RIKEN)
(JEOL) JEOL Ltd.

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Advanced Mass Spectrometry Research Group

[Research Themes]

- 1) Development of the most advanced mass spectrometers
- 2) Interdisciplinary research using the developed mass spectrometers

The division aims at new interdisciplinary research beyond the framework of major disciplines, departments, or universities. The Graduate School of Science created Japan's first mass spectrometer apparatus in the latter half of the 1930s, and has continued since that time in developing a number of globally leading and original spectrometers. In particular, the multi-turn time-of-flight mass spectrometer (MULTUM) developed recently represents a compact apparatus that nonetheless is capable of an extremely high mass resolution. The MULTUM signifies an opportunity for on-site high-resolution mass spectrometry, previously an impossibility. Scientists across the globe look forward to tremendous advancements in this undeveloped domain.

The Division of Interdisciplinary Science develops compact, lightweight, original mass spectrometers and associated

technologies for purposes of greenhouse gas monitoring, detection of hazardous or illegal substances, medical diagnostics, deployment to planetary probes, etc.; leads interdisciplinary research across different fields of research through collaborative efforts among division members, faculty members belonging to the Graduate School of Science, researchers at other departments or other universities, and industry; and aims to promote new scientific inquiry.



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Research Project for Bioactive Molecules

[Research Area]

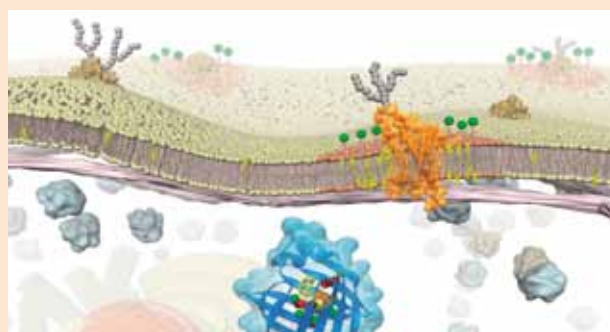
- 1) Elucidation on membrane lipid structure which affects the structure and function of membrane proteins
- 2) Analysis of structure and dynamics on biomolecular complexes in a lipid bilayer
- 3) Construction for molecular basis of mutual interaction of lipid ligands and soluble proteins

[Research Activities]

Lipids are a main component of the biomembranes. The membrane lipids have been recently shown to play key roles in cell physiology through interactions with membrane proteins. On the other hand, structural biology, which has greatly accelerated the advance of biosciences, mainly focuses on proteins but little on lipids and lipid ligands. Because, lipids are highly flexible molecules, therefore the elucidation of the 3D structures binding to membrane proteins receptor is extremely difficult even with X-ray crystallography.

In this project, we will elucidate the active structure of lipids in

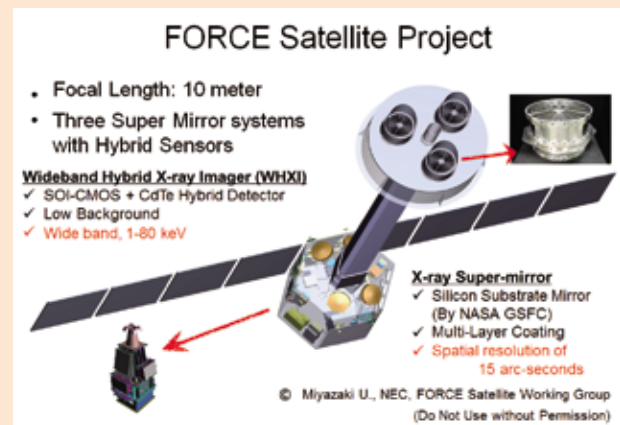
and around proteins by means of solid-state NMR techniques combined with X-ray crystallography, organic synthesis and protein engineering. Function of lipids will be more profoundly understood in terms of their 3D structures. This breakthrough will advance our knowledge in biological and biomedical sciences over the next decade, thus eventually stimulating research and development in medical and pharmaceutical areas.



Advanced Observation Group in Astrophysics

We are aiming to develop observational instruments by using state-of-the-art technologies and to operate them for actual observations by ourselves. For cosmic X-ray observation, we are developing a new X-ray CCD camera for the next X-ray satellite following to the Hitomi Satellite. In parallel of this, together with domestic institutions as well as with NASA Goddard Space Flight Center, we are advancing the FORCE project, which will be able to observe high-energy X-rays with high spatial resolution. One of the main subjects is to elucidate the origin of the cosmic X-ray background radiation to understand the growth mechanism of massive black holes. In the field of infrared astronomy, we are leading the SPICA project, a Japan-Europe collaborative infrared space telescope with many countries/regions. We also lead the Japanese contribution to the WFIRST project of NASA. These projects are pursuing to investigate the formation histories of galaxies, stars, and planets after the Big-Bang of the universe. In addition to them, we are studying on small-scale satellites as well as balloon-borne telescopes that can be executed by ourselves only. These smaller projects enhance the frequency of research projects.

Actually, we will launch FITE (Far-infrared Interferometric Telescope Experiment) that has the highest spatial resolution in the far-infrared region. It is a unique project, and is expected to image the distribution of materials around stars.

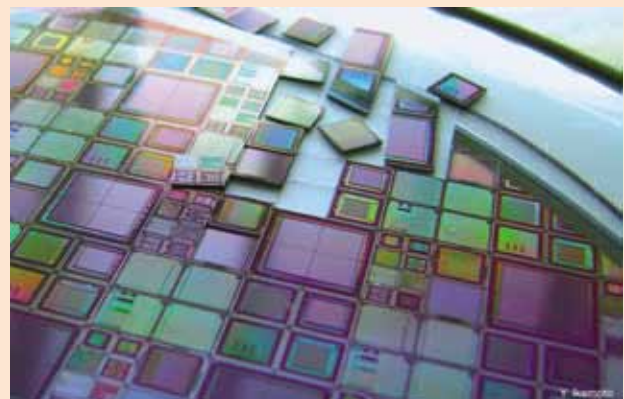


Detector R&D Project

The importance of detector technologies have been increasing dramatically in modern physics experiments. In particle physics, radiation-hard semi-conductor detectors with very fine position resolution, and photon detectors with extremely low inefficiency are often required. In astrophysics, detectors and electronics on satellites are required to have light weight, low energy consumption, and radiation hardness. The detector used in infrared astronomy needs an ASIC that can be operated in ultra low temperature. In mass spectroscopy, semi-conductor detectors are being considered.

The development of these instruments nowadays is highly specialized and subdivided. To be competitive with researchers world-wide, it is more efficient to study and develop common basic technologies, and then apply them to cutting-edge detectors for each application. The detector technologies developed here can be utilized in various fields, such as experimental particle physics, astrophysics, mass spectroscopy, and imaging in chemistry and biology.

This project aims to build a foundation to develop new detector technologies that can be utilized in many fields in the School of Science.

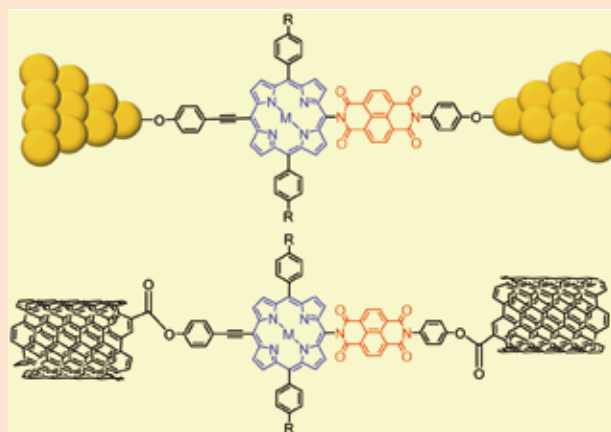


Research Project for Molecular Architectonics

This project aims to establish rational design principles of single molecule electronics functionalities and to emerge higher functionalities by integration of each molecular unit, which will be the most efficient method to exert the potential of organic molecules for electronic applications.

- 1) Design, synthesis and measurement of single molecular electronic properties of molecules which will show non-linear and non-symmetric properties such as rectification, signal amplification, negative differential resistance, integrated threshold, hysteresis, magnetic resistance will be performed to elucidate structure – single molecule electronic property relationship.
- 2) Control of self-assembling of the molecules on solid surfaces.
- 3) Fundamental science and application to electronic materials of combined materials of organic molecules with single-walled carbon nanotubes of pure (m, n) indexes and graphene nano ribbons will be performed.
- 4) By integration of single molecules with non-linear and non-symmetric electronic properties, higher electronic

functionalities such as small signal detection by stochastic resonance, neuron-like noise / pulse generator, and electric ameba will be realized.



Project for Creation of Sustainable Supramolecular Materials (ImPACT)

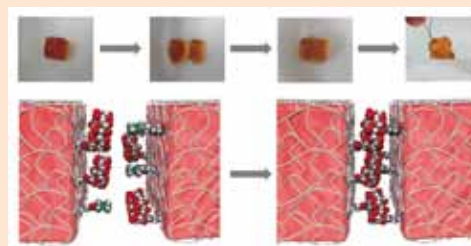
Realizing High Toughness and Self-Healing of Polymers by Supramolecular Assembly

Creation of New Joining Technology Based on Chemical Bonding

Soft materials such as synthetic polymers, biopolymers, liquid crystals, and molecular assemblies have been widely used in our daily life, and modification of these soft materials and development of new functional soft materials are still desired. New types of gels have been developed, for example, stimulation-responsive gels, self-healing gels and so on.

In this project, we develop a new type of tough polymer by introducing “*molecular recognition junction*” or “*molecular mechanical junction*” in polymer networks. These junctions can work as a well-controlled self-healing point and a pulley effective for avoiding the stress concentration, respectively. Tough polymers are the prerequisite and promised material for light-weight, reliable, safe, and sustainable industrial products including next-generation vehicles.

Adhesives have been widely used to glueing components of product. However, the adhesives have some weak points in toughness and durability for organic solvents. We develop a new material joining technique by introducing covalent bonds between dissimilar materials without using adhesives. We are also studying new adhesive techniques based on molecular recognition, which make it possible to adhere the components with distinguishing their materials.



Self-healing gel using molecular recognition junctions

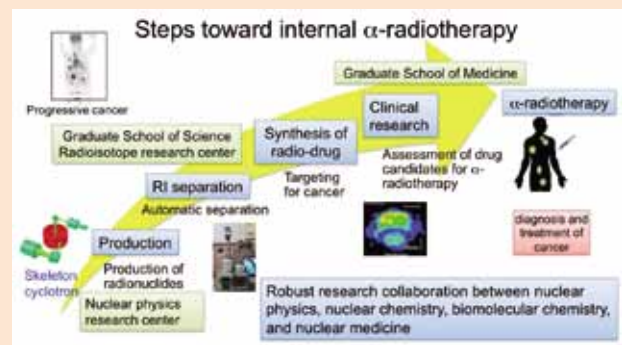
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Core for Medicine and Science Collaborative Research and Education (MS-CORE)

[Project Overview]

Joint research on production and medical applications of radionuclides using the accelerator is conducted with the cooperation of Graduate School of Science, Research Center for Nuclear Physics, and Graduate School of Medicine. The aim of this project is to promote the interdisciplinary researches and educations between nuclear physics, nuclear chemistry, biomolecular chemistry, nuclear medicine, and radiology. The development of new cancer treatments has been desired, since one-third of cancer patients are diagnosed as progressive cancers such as adjacent organ invasion and distant metastasis at the time of initial diagnosis, and therefore the 5-year relative survival rate are less than 15%. In this project, we will develop a new internal radiotherapy for advanced cancer, i.e., “targeted α -particle radiotherapy” where cancer patients are treated by irradiating the α ray to cancer by administrating cancer-targeting agents tagged with α -emitting radionuclides. This therapy will achieve the high cancer cell-killing ability as well as the less invasiveness to peripheral organs and the reduction of side effects at the same time, owing to the high-energy and the short flight of α ray and the short-lives of α -emitting radionuclides. In order to develop this therapy, we are working on the development of skeleton cyclotron that can

produce the high beam intensity with power-saving property as well as the development of the large quantity production α -emitting radionuclides and the automatic separation of the radionuclides. Further, we are studying the synthesis of the radionuclide-carrying targeting agents as the radiation drug candidates, verifying the therapeutic effects and side effects of the agents, and investigating the clinical trials of the therapy. In the future, we are aiming for the establishment of Medicine and Science Collaborative Research Center.



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Core for Subatomic Science Toyonaka Branch (Research Center for Subatomic Science)

Subatomic Science is subject to study the early Universe before it became transparent to radiation. In Project Research Center for Fundamental Sciences, Lepton physics in Subatomic Science is studied.

MUSIC

Why there are three kinds of quarks and lepton existing in nature and why are they transformed from one to another? It is one of the mysteries, which should be answered by elementary particle physics. In order to answer this question, physics phenomena which cannot be explained by the Standard Model of particle physics are seemed for with using muons. To do these searches, many muons are needed. At the MuSIC facility, we are expecting a number of muons of 10^8 - 9 /second with 400 Watts proton beam power from the RCNP cyclotron. It is one of the highest intensity muon beam in the world.



CANDLES

Our universe is made of matter and no anti-matter exists. In order to explain why, we need to show that particle number violation and CP violation. The CP violation indicates that matter world and anti-matter world is different a little bit. By the observation of neutrino-less double beta decay of ^{48}Ca , we wish to demonstrate the violation of particle number is violated and our universe was inclined to matter world.



Project Research Center for Fundamental Sciences

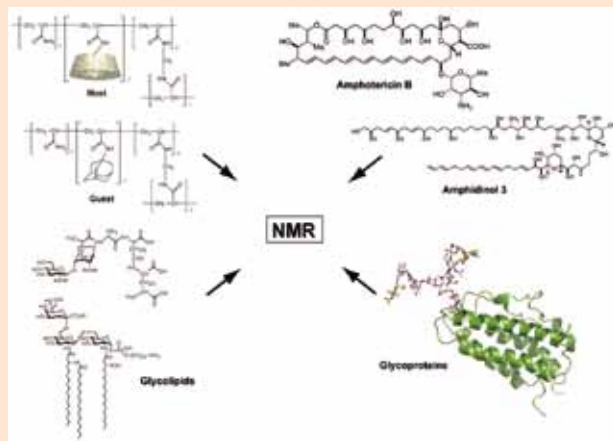
Core for Collaboration Research : Riken and Graduate School of Science, Osaka University

[Research Topics]

- 1) Studies of host-guest interaction by means of nuclear magnetic resonance (NMR)
- 2) Studies of structural analyses as well as molecular dynamics of lipids, glycolipids, and glycoproteins by means of NMR

This project examines frontier scientific researches by combining both techniques accumulated in Riken and graduate school of science, Osaka University. Riken has developed a huge frontier NMR facility in Yokohama and elucidated many protein structures. These results have been applied not only to the elucidation of protein functions but also to basic researches and the development of pharmaceutical drugs. Researchers in graduate school of science, Osaka University have demonstrated isolation, chemical syntheses and structural analyses of valuable natural molecules and novel functional derivatives, e.g. specific binding experiments between novel macromolecular gels modified with unique host and guest molecules, syntheses of glycolipids concerned with our immune system, antibiotics interacting with

cell lipid bilayer and glycoproteins. The collaboration of Riken's NMR techniques and chemical approaches by graduate school of science, Osaka University will open up a new avenue to elucidate the functions and molecular dynamics of natural and new functional compounds in detail.



Project Research Center for Fundamental Sciences

Core for Theoretical Science Research

Any theoretical science is based on equations and mathematical structure, which are universal and are a basis of any scientific research. On the other hand, because of the intense subdivision of scientific research subjects of recent years, unfortunately communication among different research area is missing.

The project members try to overcome this serious problem which resides in any department in Osaka university, and in particular using theoretical common background may help resolving the issue, we expect. This simple project in fact should create a seed of new sciences, and will promote the total atmosphere of science research in Osaka university to an upper level.

We first start a theoretical colloquia with which we put a basis of opportunities for researchers to come and see each other, to start with. The colloquium is named "Nambu colloquium" where we obtained the renowned name of a distinguished professor in Osaka unvieristy, Yoichiro Nambu, a Nobel loreate. A successful

organization of the colloquia should be the first ground for the promotion of research in Osaka unvieristy.

