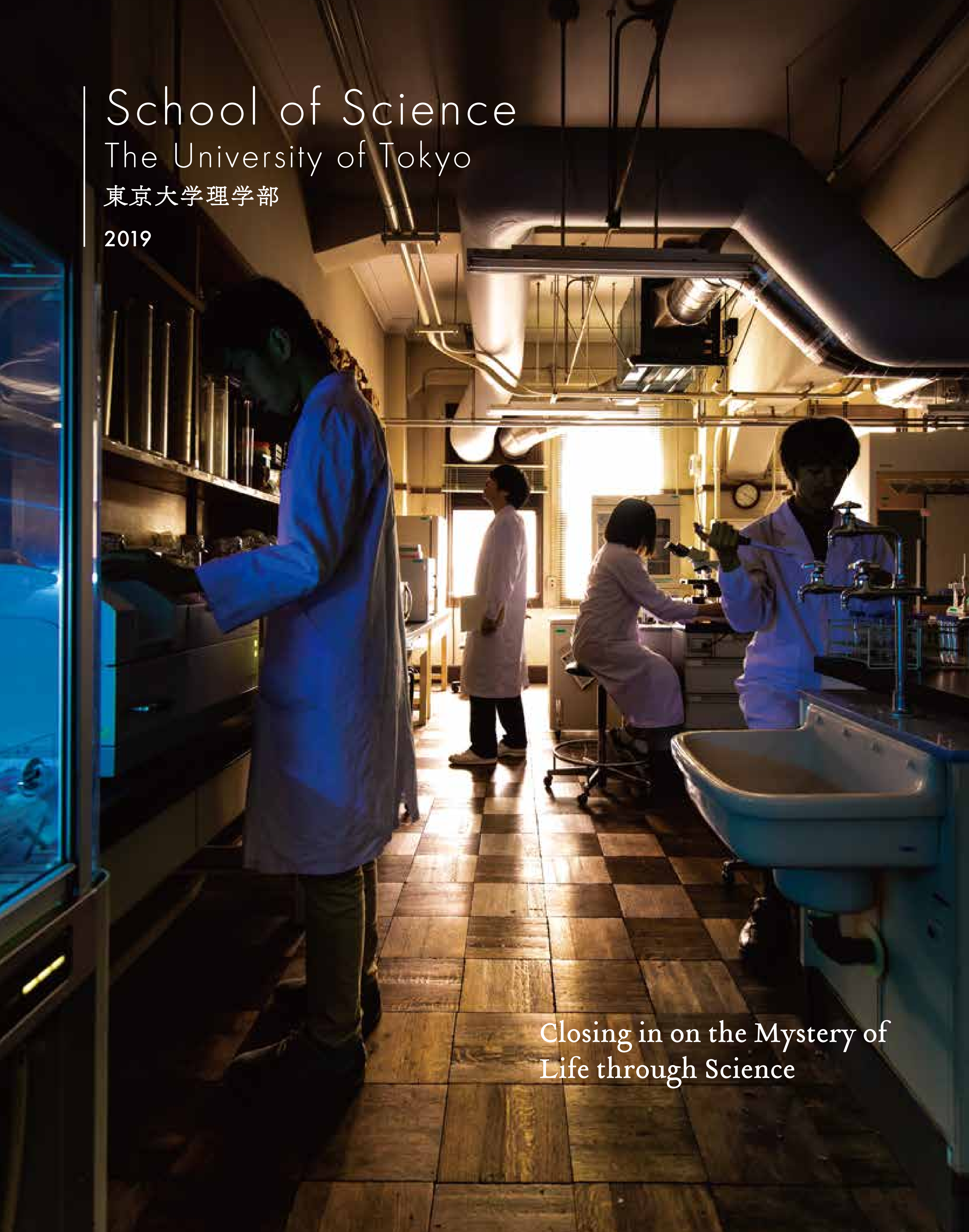
School of Science
The University of Tokyo
東京大学理学部

2019



Closing in on the Mystery of Life through Science

Message

Open New Paths, Equipped with the Power of Science

Science is driven by the simple quest to understand the world around us. It is fueled by the joy of finding out, as a result of that quest, something we did not understand before, and the many new mysteries that emerge as individual discoveries are made. The never-ending desire to unravel these mysteries moves science forward a step at a time, opening up horizons on new knowledge.

The objects of science are many and varied. They extend from the broad spectrum of natural phenomena to the abstract concepts behind them, including mathematics and information. The University of Tokyo School of Science brings together scientists active at the forefront of a diverse range of academic fields.

Science requires the ability to employ the force of logic, and the creativity and adventurous spirit to take on new challenges, going where no one has gone before. These are abilities needed not only in science but for a variety of situations in society. The School of Science is thoroughly focused on polishing these abilities, so that students can go on to play active roles in society, in a broad range of fields. Whatever path you take after graduation, the science skills you acquire will serve as powerful tools.

Dean of the School of Science,
The University of Tokyo

Hiroyuki Takeda

1985, Doctor of Science (Faculty of Science, University of Tokyo)
Appointed Professor of Department of Biological Sciences, Graduate School of Science in 2001 after serving as an Assistant at the School of Science, The University of Tokyo Science, The University of Tokyo; Researcher at RIKEN; Assistant Professor at the School of Science, Nagoya University; and Professor at the National Institute of Genetics. Has also served as Dean of the School of Science since April 2017.

What is Science?

Science is a study that unravels the mysteries of the universe.
It strives to create new knowledge by understanding nature.
This begins by approaching nature with a simple question in mind: "Why?"
This pamphlet will present some of the activities carried out by the School of Science at the University of Tokyo, which aim to cultivate skilled and knowledgeable members of society through exploring nature.

Faculty of Science

10 undergraduate departments dedicated to studying science

Mathematics / Information Science
Physics / Astronomy
Earth and Planetary Physics
Earth and Planetary Environmental Science
Chemistry / Biophysics and Biochemistry
Biological Sciences
Bioinformatics and Systems Biology

Graduate School of Science

5 graduate departments dedicated to gaining a deeper understanding of science

Physics / Astronomy
Earth and Planetary Science
Chemistry / Biological Sciences

Contents

Editing, interviews, and writing: Masatsugu Kayahara
Photography: Junichi Kaizuka; KOJI OKUMURA (Forward Stroke)
Design: Mitsunobu Hosoyamada and Azusa Suzuki (Hosoyamada Design Office)
Writing and editorial supervision: Office of Communication, School of Science, The University of Tokyo

Crossing Borders in the Pursuit of Science

The School of Science draws a variety of students from different countries around the world.
What motivated them to make the journey to Japan to study at the University of Tokyo's School of Science?

Studying chemistry in English at the historical University of Tokyo

——Could you tell us about your academic life at the School of Science?

I study chemistry systematically and in its entirety, such as organic chemistry, inorganic chemistry and physical chemistry, by going to lectures in the morning and attending student laboratories and discussions on academic articles in the afternoon. The curriculum in the Department of Chemistry is entirely in English, even for Japanese students, which is a huge strength as I want to be able to work anywhere in the world.

There are also many professors in the department who are doing interdisciplinary research and my interests are now expanding beyond the world of elements to that of chemistry related to biology, such as molecular biology and natural product synthesis.

——Why did you decide to study abroad?

I've liked Japanese food and culture ever since I was in elementary school, and in junior high school I chose to study Japanese as my third language. This is why when it came time to choose a university, I knew immediately that I wanted to study abroad. Singapore has developed greatly; however, it is a small and young country, and I wanted to broaden my horizons by seeing the world.

——Why did you choose the University of Tokyo?

I chose this university because the School of Science's Department of Chemistry provides an educational environment where I can study chemistry in English in a country I have always wanted to go to. The Department's emphasis on basic research and the University of Tokyo's history and tradition were also very appealing to me.

I came to Japan as a Japanese Government (MEXT) Scholarship student and spent one year taking preparatory courses in Japanese language and basic academic skills at the Japanese Language Center for International Students, Tokyo University of Foreign Studies, before entering UTokyo.

——How are you finding life in Japan?

I have no trouble in my daily life when it comes to using Japanese since I continued studying the language through classes offered by the College of Arts and Sciences after I became a student here. The staff at UTokyo also provide us with a lot of support, so I can easily speak with them about anything.

In my spare time, I work part-time teaching business English after school. Overall, my university and personal life in Japan are very fulfilling.

Singapore

Raffles Institution

Department of Chemistry, School of Science

Third year student, Department of Chemistry, School of Science

Goh Jin Lin Sarah

Born in Singapore. Graduated from Raffles Institution in 2014. Came to Japan in 2015 as a Japanese Government (MEXT) scholarship student and studied Japanese language at the Japanese Language Center for International Students, Tokyo University of Foreign Studies, before entering the University of Tokyo's College of Arts and Sciences in 2016. Enrolled in the School of Science in 2018.

Shanghai, China

Kongjiang High School

Department of Biological Sciences, School of Science

Senior, Department of Biological Sciences, School of Science Ohashi Laboratory

Qintong Zhang

Originally from Shanghai, China. After graduating from high school in China, studied for two years at a Japanese language school in Tokyo before entering the College of Arts and Sciences at the University of Tokyo in 2015. Became a student at the School of Science in 2017 and participated in SVAP in 2018. Will attend medical school in Japan from Spring 2019.

Making scientific and self-discoveries at the School of Science

——Why did you choose the School of Science at the University of Tokyo?

Ever since I was in high school, I wanted to attend the University of Tokyo because of its unique education system. Undergraduate students study at the University of Tokyo's College of Arts and Sciences for two years where they explore various academic disciplines and then choose a specialization for their third and fourth years. I also liked biology from a very young age and the University of Tokyo has many faculties where you can study biological sciences. I entered the College of Arts and Sciences and when it came time to choose my specialization in my second year, I found that the School of Science suited me best as it focuses on pure science and understanding the mechanisms of nature rather than immediate application.

What's more is that the Department of Biological Sciences has a special course called the Anthropology Course, which I found very interesting as it is one of the few anthropology courses in Japan where you can study anthropology from a scientific perspective. As this course includes basic biology, basic medicine, histology, history, culture, genome science and also archeology fieldwork and primate observations, it allows us to gain a comprehensive understanding of human beings and ourselves.

——What research opportunities have you had at the School of Science?

At the moment, I am doing research on genomic variations in different human populations in the Ohashi Laboratory. Assoc. Prof. Ohashi has collected many human DNA samples from Southeast Asia. Analyzing these genomic data with the help of other public human genome resources could reveal many mysteries of human evolution.

I also went to the Karolinska Institute in Stockholm, Sweden, under the Study and Visit Abroad Program (SVAP) where I did research on RNA-seq data and protein-protein interaction. The group leader and other members were very interested in my work and wanted me to help them with several other projects even after I returned to Japan.

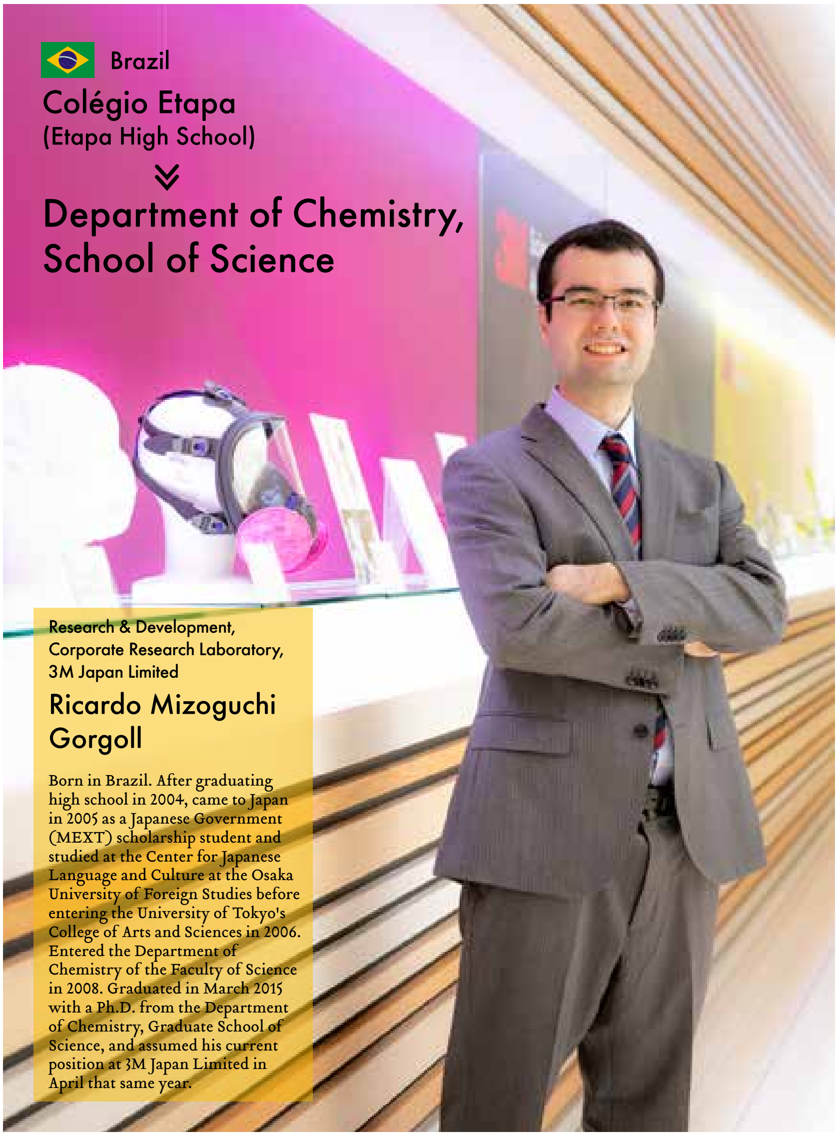
——What are your plans following graduation?

After graduating, I will go to another national university in Japan for medical school. I believe that my experiences in the School of Science helped me to reach this decision, especially the anthropology course and study abroad opportunities like SVAP. Each decision is a turning point filled with dreams and conflicts, which sometimes can be annoying and confusing, but these various experiences helped me to know more about myself and realize that it's most important to be true to yourself. UTokyo provides many opportunities, so there are limitless possibilities as to what you can accomplish.

Brazil

Colégio Etapa (Etapa High School)

Department of Chemistry, School of Science



Research & Development, Corporate Research Laboratory, 3M Japan Limited

Ricardo Mizoguchi Gorgoll

Born in Brazil. After graduating high school in 2004, came to Japan in 2005 as a Japanese Government (MEXT) scholarship student and studied at the Center for Japanese Language and Culture at the Osaka University of Foreign Studies before entering the University of Tokyo's College of Arts and Sciences in 2006. Entered the Department of Chemistry of the Faculty of Science in 2008. Graduated in March 2015 with a Ph.D. from the Department of Chemistry, Graduate School of Science, and assumed his current position at 3M Japan Limited in April that same year.

Connecting academia and industry

——What kind of work are you doing?

I am developing next generation adhesives for automobiles in the corporate research laboratory division of 3M Japan Limited, which is a subsidiary of 3M, a global chemical company that was founded in America. By using adhesives instead of screws and bolts, the body of a car can be made lighter and more fuel-efficient. As we are now transitioning from gasoline cars to electric cars, the demand for adhesives is expected to increase.

I am usually at 3M Japan Limited's Sagamihara office in Kanagawa Prefecture, where the research and development division is based, but at times go on customer visits and overseas business trips. In the three and a half years that I've been at this company, I've spent several months at the 3M headquarters in Saint Paul, Minnesota, United States, as well as the 3M branch in Germany.

—— What research did you do in undergraduate and graduate school?

I conducted research on nanocarbons in Professor Eiichi Nakamura's* laboratory in the Department of Chemistry and had two main projects.

The first involved investigating individual organic molecules by using carbon nanotubes. I examined the movements of molecules and chemical reactions through an electron microscope and discovered that the molecules changed into more stable structures.

My other research project focused on fullerene, a spherical carbon molecule. Professor Nakamura was developing technology to create bilayer structures by joining many fullerenes together. Lipid bilayers are also found in cell membranes but a fullerene bilayer is 10,000 times less permeable to water than the lipid bilayer of a cell. By utilizing this property, I conducted research on the development of new materials and their applications to drug delivery.

——Why did you decide to enter industry, specifically 3M, after completing your Ph.D.?

I decided to work in industry as I was looking for a change in my life. I wanted a job with a chemical company where I could be active globally while based in Japan. There were several reasons for this. I like chemistry so I wanted to remain involved in the field. Professor Nakamura's laboratory also had people from various countries and it was very enjoyable to work with them, so I wanted to continue doing research in that kind of international environment. On the other hand, having lived in Japan for 10 years, I grew to love Japanese culture and enjoyed living in Japan.

3M had everything I was looking for. The company was also developing a wide range of businesses, which was a huge strength. Research in academia is difficult to apply directly to industry, but I felt that I could find opportunities at 3M.

Now that I am working on the research and development of next-generation technology, I can see the importance of basic research. It is essential to accumulate basic research in order to produce something new; however, companies are limited in terms of what they can do. Provided this, I want to eventually become a bridge to connect academia and industry.

——What influenced your decision to study in Japan and at the University of Tokyo?

I wanted to study in Japan as it is a leading country in the field of chemistry. I have been interested in chemistry since I was a child and often played with chemistry sets. My grandparents are also Japanese so I had a strong interest in Japanese culture.

At the time, I could not speak any Japanese; however, under the Japanese Government (MEXT) Scholarship Program, students could receive preparatory education in the Japanese language and other subjects before entering a university in Japan. Therefore, I decided to study abroad in Japan after I received the scholarship.

I chose the University of Tokyo because another scholarship student from Brazil strongly recommended UTokyo, a top university in Japan, to study science. UTokyo also has an outstanding reputation and is recognized worldwide.

——Could you please give a message to students who are thinking of studying abroad in Japan?

There is no reason to worry about living in Japan. Japanese people are kind and will look after you when it comes to your daily life. I've lived in Japan for 13 years and found that Japanese people always try to understand my situation whenever I'm in trouble. Their warmth has left a strong impression on me, especially in comparison to my short-term study abroad experiences in university and long-term international business trips after I started working.

When I was a student, I received thorough guidance from professors and senior students, and I was able to ask for advice from my laboratory members when I had trouble with my research or daily life. I also learned business etiquette, which was very useful when it came time to search for a job.

If there is any kind of research you want to do in Japan, you should come without hesitation.

*Molecular Technology Innovation Presidential Endowed Chair

International Programs at the School of Science

The School of Science offers both short-term and long-term options for students abroad who are interested in broadening their scientific knowledge in an international environment.

01

Global Science Course (GSC)

GSC is an all-English undergraduate transfer program. It was established to enhance cross-cultural interactions among young minds from around the world and to help develop their potential for scientific research. Selected students from abroad are accepted into the third year of undergraduate studies at the Faculty of Science and provided a monthly scholarship as well as accommodation with fully supported monthly rent. Upon completing two years in GSC, they will be awarded with a Bachelor of Science degree from the University of Tokyo.
https://www.s.u-tokyo.ac.jp/GSC/

02

Global Science Graduate Course (GSGC)

GSGC is an international graduate program that welcomes excellent graduates from universities all over the world to study at the Graduate School of Science. It aims to foster world-class science professionals and standardizes a five-year integrated education scheme in which students attend both the Master's program and the Doctoral program in sequence. Students on GSGC are also provided with a monthly scholarship during their time on the program.
https://www.s.u-tokyo.ac.jp/GSGC/

03

The University of Tokyo Research Internship Program (UTRIP)

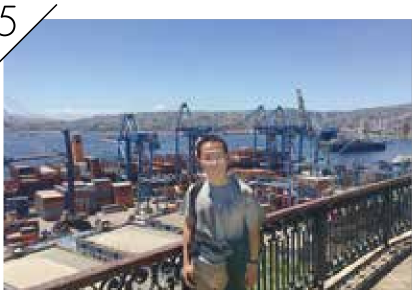
UTRIP is an intensive summer research program targeted at undergraduates who are interested in pursuing an M.S. or Ph.D. degree in the future. During the program, participants receive intensive instruction and guidance on conducting research from renowned faculty members. UTRIP is open to students who are enrolled in a Bachelor's degree program anywhere outside of Japan, and are majoring in a natural science or related field. Participants will be granted financial support and can take part in cultural activities and excursions to learn more about Japan.
https://www.s.u-tokyo.ac.jp/en/utrip/

04

Study and Visit Abroad Program (SVAP)

SVAP is a program that provides funding for undergraduate students enrolled in the School of Science to build their own study abroad experience by pursuing either a research internship or attending a short-term course of their own choosing at a university or research institute outside of Japan.
www.facebook.com/UTokyo.SVAP/ [Activity Reports]

05

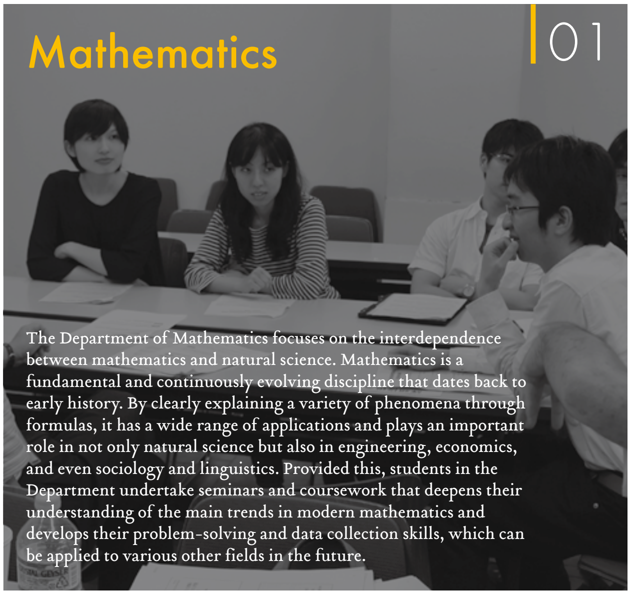


Undergraduate Research Abroad in Science Program (UGRASP) & Graduate Research Abroad in Science Program (GRASP)

UGRASP is a short-term research program for fourth-year undergraduate students in the School of Science and GRASP is for graduate students. These programs provide support for students to engage in collaborative scientific research at a university or research institute outside of Japan.
UGRASP: https://www.s.u-tokyo.ac.jp/ja/offices/ilo/ugrasp/application.html [in Japanese]
GRASP: https://www.s.u-tokyo.ac.jp/ja/offices/ilo/grasp/application.html [in Japanese]

Departments in the Faculty of Science

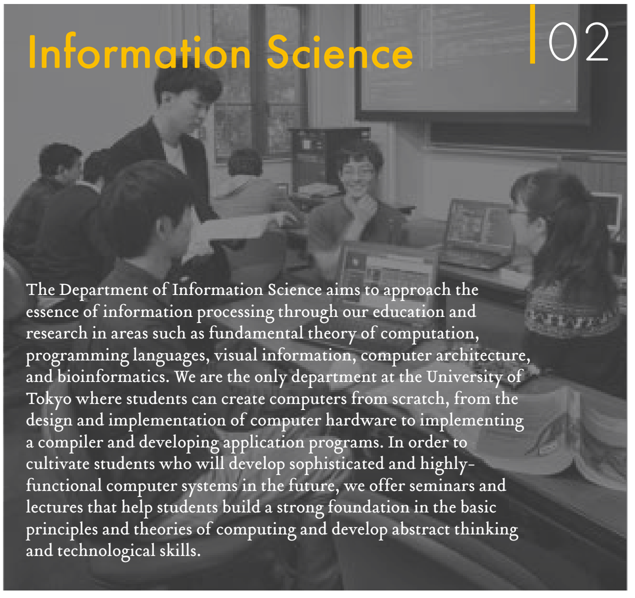
Explore our world-class education and research at the undergraduate-level



Mathematics

01

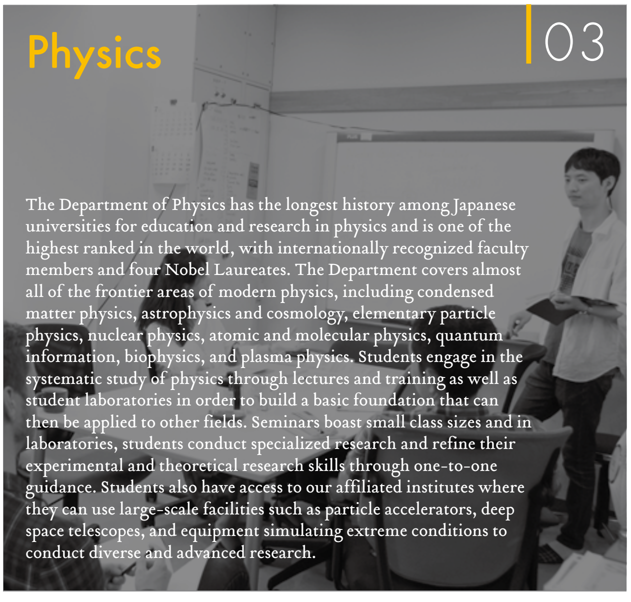
The Department of Mathematics focuses on the interdependence between mathematics and natural science. Mathematics is a fundamental and continuously evolving discipline that dates back to early history. By clearly explaining a variety of phenomena through formulas, it has a wide range of applications and plays an important role in not only natural science but also in engineering, economics, and even sociology and linguistics. Provided this, students in the Department undertake seminars and coursework that deepens their understanding of the main trends in modern mathematics and develops their problem-solving and data collection skills, which can be applied to various other fields in the future.



Information Science

02

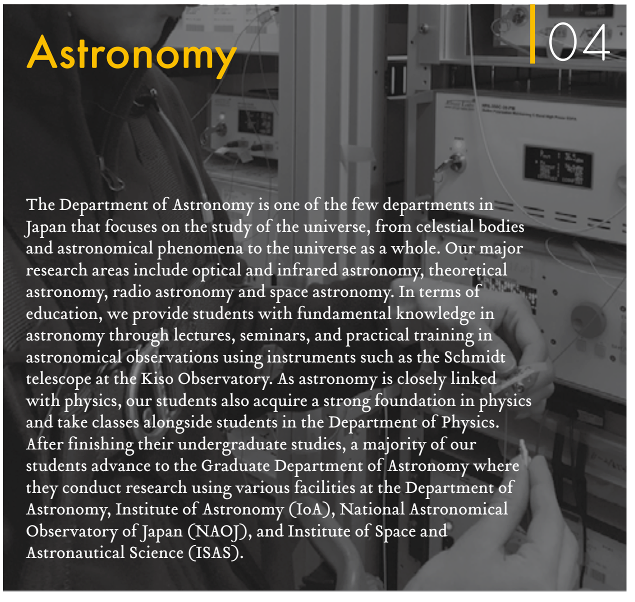
The Department of Information Science aims to approach the essence of information processing through our education and research in areas such as fundamental theory of computation, programming languages, visual information, computer architecture, and bioinformatics. We are the only department at the University of Tokyo where students can create computers from scratch, from the design and implementation of computer hardware to implementing a compiler and developing application programs. In order to cultivate students who will develop sophisticated and highly-functional computer systems in the future, we offer seminars and lectures that help students build a strong foundation in the basic principles and theories of computing and develop abstract thinking and technological skills.



Physics

03

The Department of Physics has the longest history among Japanese universities for education and research in physics and is one of the highest ranked in the world, with internationally recognized faculty members and four Nobel Laureates. The Department covers almost all of the frontier areas of modern physics, including condensed matter physics, astrophysics and cosmology, elementary particle physics, nuclear physics, atomic and molecular physics, quantum information, biophysics, and plasma physics. Students engage in the systematic study of physics through lectures and training as well as student laboratories in order to build a basic foundation that can then be applied to other fields. Seminars boast small class sizes and in laboratories, students conduct specialized research and refine their experimental and theoretical research skills through one-to-one guidance. Students also have access to our affiliated institutes where they can use large-scale facilities such as particle accelerators, deep space telescopes, and equipment simulating extreme conditions to conduct diverse and advanced research.



Astronomy

04

The Department of Astronomy is one of the few departments in Japan that focuses on the study of the universe, from celestial bodies and astronomical phenomena to the universe as a whole. Our major research areas include optical and infrared astronomy, theoretical astronomy, radio astronomy and space astronomy. In terms of education, we provide students with fundamental knowledge in astronomy through lectures, seminars, and practical training in astronomical observations using instruments such as the Schmidt telescope at the Kiso Observatory. As astronomy is closely linked with physics, our students also acquire a strong foundation in physics and take classes alongside students in the Department of Physics. After finishing their undergraduate studies, a majority of our students advance to the Graduate Department of Astronomy where they conduct research using various facilities at the Department of Astronomy, Institute of Astronomy (IoA), National Astronomical Observatory of Japan (NAOJ), and Institute of Space and Astronautical Science (ISAS).

05 Earth and Planetary Physics

The Department of Earth and Planetary Physics examines various phenomena occurring on Earth and other planets in the solar system and even beyond from a physics standpoint. Our research areas include the interior of solid Earth, earthquake occurrence and propagation of seismic waves, atmospheric and oceanic circulations, climate change prediction, the evolution of the solar system and planets, and space plasmas. Many different approaches have been utilized to tackle the broad range of topics covered by the Department. Therefore, our curriculum includes physics and mathematics for theoretical backgrounds, field observations, laboratory experiments, as well as computer programming for data analysis and numerical simulations. Students are also split into small groups and engage in scientific discussion on selected topics in specific fields and then conduct independent research in their final year.

06 Earth and Planetary Environmental Science

The Department of Earth and Planetary Environmental Science specializes in the study of phenomena on the surface of the Earth and other planets from an environmental perspective. Our research includes clarifying the origins of nature from surveying geology and topography, and deepening our understanding of the solar system through planetary exploration and meteorite analysis in order to elucidate the mystery of evolution and the origins of life. We also tackle environmental problems that have affected us in the past and will have an influence on us in the future, such as climate change and resource management. Students build a foundation in this field through lectures and practical training in chemical analysis, gene analysis and numerical simulation, as well as through fieldwork in both Japan and abroad to study rocks, minerals, geological formations and fossils. Students also learn how to examine atmospheric, oceanic and planetary systems from various perspectives by conducting independent research.

07 Chemistry

The Department of Chemistry investigates atoms and molecules that constitute nature in order to elucidate fundamental questions about their underlying mechanisms, create new substances and technologies, and discover novel phenomena. For more than 150 years, we have helped students who possess an intellectual curiosity to elucidate nature cultivate their academic and experimental skills through systematic lectures as well as student laboratories. Education in the Department focuses on developing leaders who have an international perspective, which is why all lectures for undergraduate students are delivered in English, creating a unique environment where Japanese students and students from abroad can learn alongside one another. Following graduation, our students pursue graduate studies or find employment in a broad range of fields in the public or private sector.

08 Biophysics and Biochemistry

The Department of Biophysics and Biochemistry uses an interdisciplinary approach to elucidate the fundamental principles of biological phenomena and understand the underlying mechanisms at a molecular level. In living organisms, molecules mutually interact in accordance with the principles of physics and chemistry while creating various kinds of life, from simple organisms to complex ones. The field of biophysics and biochemistry examines this breadth of biological phenomena, from the shape and behavior of a single molecule to brain function and animal behavior. Our students conduct experiments and attend lectures that merge theory from mathematics, information science, and physical chemistry with biochemistry and molecular biology experimentation in order to understand the relationship between molecules and understand biological phenomena.

09 Biological Sciences

The Department of Biological Sciences studies the biological mechanisms and phenomena of the myriad of organisms that have appeared and evolved on Earth over the past four billion years. Students in the Department specialize in flora, fauna, or anthropology, and take special lectures such as taxonomy workshops at the University's affiliated botanical gardens and Yakushima Island (flora), experiments and workshops related to marine organisms at the University's Misaki Marine Biological Station (fauna), archaeological excavations in Hokkaido (anthropology), and the observation of primate behavior in Nagano's Jigokudani Monkey Park (anthropology). Through this, students gain knowledge through first-hand experiences with animals and plants in their natural environment.

10 Bioinformatics and Systems Biology

The Department of Bioinformatics and Systems Biology aims at exploring a new, cutting-edge academic field that merges approaches in biological and computational sciences. Unlike traditional biological sciences that attempt to study each gene or protein separately, bioinformatics and systems biology use a dual-faceted approach that clarifies life principles as systems by developing new ideas and utilizing advanced technologies. Our students are expected to master both biology and informatics in order to conduct experiments and handle enormous quantities of data. As only a few universities around the world offer specialized undergraduate programs in bioinformatics and systems biology, our graduates are expected to successfully develop their careers in various areas such as government, industry, and academia.

Explorers of the Field of Science

— Closing in on the mystery of life —

What is life?
This question was asked by Schrödinger,
a physicist who looked at life from the perspective
of physics in the mid-20th century.
Now researchers from various fields are tackling
the great mystery of life.

Clues for solving the mystery of evolution

Why is life so diverse?

Great discoveries in the life sciences, such as Darwin's theory of evolution and Mendel's law of inheritance, were made by closely observing various living things. From the diverse organisms in the forests and seas, we can explore the origins of evolution.

Toru Miura

Challenging the mysteries of biological evolution by opening a treasure trove of intriguing marine creatures

On some mornings, the first thing Professor Miura does after arriving at his laboratory is put on his wet suit and dive into the sea. His laboratory is based in the Misaki Marine Biological Station (MMBS), The University of Tokyo, which is located at the tip of the Miura Peninsula (in Kanagawa Prefecture), which divides Tokyo Bay from Sagami Bay.

His research theme is "phenotypic plasticity" in animals. Phenotype is the observable characteristics or traits of an organism. While the phenotype is largely determined by the genome, genetic information is not the only determinant of the phenotype, which in many cases is influenced by environmental factors as well. Phenotypic plasticity refers to the ability of an organism to plastically change its phenotype depending on the environment.

"Many insects change their phenotype according to the season they undergo ecdysis or metamorphosis. A typical example is how some butterflies can change the shape and color of their wings depending on the season. Another example is social insects such as ants, bees and termites. They have different castes within their colony, and the queen, king, soldiers and workers each show distinct traits even though their genomes are nearly identical. I study the mechanism of this phenotypic plasticity and its significance in evolution."

Professor Miura dives into the sea to catch and study marine organisms with phenotypic plasticity. The sea area around MMBS is at the border of Tokyo Bay and Sagami Bay, blessed with rich marine biodiversity. "I often catch weird creatures that are hardly studied by anybody," he said, smiling like a boy who has found a treasure chest.

Different traits expressed from the same genome

One of the marine animals that Professor Miura is focusing on right now is the Syllidae, a family of worms closely related to sandworms (see bottom left and right photos below). This worm attaches itself to rocks or the sea bottom where it matures. As it matures, it gradually develops an ovary or testis at the posterior end of its body. When the worm is fully mature, the posterior end breaks off and starts swimming on its own to spawn eggs or sperm. This spawning individual is called a stolon, which also has its own head and eyes. The stolon is a clone that has the same genome as its parent. The stolon dies when it completes its mission of spawning eggs or sperm, but the parent worm remains on the seabed and grows a new posterior end (another stolon), which will be released again for another round of spawning.

"Although the stolon is a clone of the parent worm, it expresses a different set of traits from its parent. We are now working to find out the secrets of what environmental factors induce the formation of a stolon and how the posterior end turns into a stolon."

Professor Miura started to study marine organisms in earnest when he was assigned to MMBS in 2017. Until then, his research focused on mainly social insects, namely termites and aphids (see top left and top right photos below).

Termites have several castes (i.e., classes with different morphology and roles) in their colony: the reproductive caste (queens and kings), soldiers, and workers. In *Hodotermopsis sjostedti* (a termite species), which Professor Miura has been studying for a long time, some workers differentiate into reproductive individuals and soldiers through a series of molts, while other workers remain as workers throughout their lives.

"Termites live in colonies born from the same parents. Although all the individuals in a colony have nearly identical genomes, they express different traits depending on their caste. Caste differentiation is determined by hormone concentrations in the individual's bloodstream, but we do not know yet what regulates that hormone concentration. When certain castes such as the reproductive caste or soldiers are removed from a colony, other individuals differentiate into those castes to fill in the gap. This implies that the reproductive caste and soldiers are emitting some sort of pheromones that regulates hormone concentration in other individuals."

Science can accommodate the interests and persistence of a lifetime

"I wanted to become an adventurer when I was a student," answered Professor Miura when I asked him how he came to be a biologist. "I used to love unicorn beetles and stag beetles as a kid so I decided to major in biology. However, biology was a popular subject at the School of Science and I needed good grades in order to advance to the biology course in my junior year. So, I voluntarily repeated my sophomore year and studied harder than when I was preparing for the university entrance exam."

He took many language classes to raise his overall grades in foreign language, including Indonesian.

"I was also a Boy Scout as a child. I was fascinated when I visited Iriomote Island in Okinawa and felt like I was on an adventure. Eager to see real tropical rainforests, I also traveled to Borneo Island in Indonesia. I thought that if I studied insects that inhabit tropical rainforests, I would be able to enjoy adventure and learn about insects at the same time, which is why I decided to advance to graduate school. I joined a lab doing field work in the tropics; however, it's not that easy to find unicorn beetles and stag beetles. I started studying termites because they could be found everywhere in the rainforests and they were easy to handle."

Since then, his research focused primarily on social insects, so why has he started studying marine animals in addition to insects?

"Insects are taxonomically classified as *Insecta*, a very large group within the arthropod phylum. We have learned a lot about insects, but there are even more diverse creatures in the sea, many of which are positioned nearer to the root of the phylogenetic tree or the tree of evolution. These creatures exhibit various phenomena that cannot be explained by our common understanding of insects or arthropods. If we can clearly understand their biology and the mechanism of their development and differentiation, we will be able to come closer to the origins of evolution."

Professor Miura is also studying acoels, which are considered to have been the first animals that came to have a symmetrical morphology in the process of biological evolution. He says that research on acoels will "provide important clues for understanding the evolution of symmetric animals, including humans."

He consistently had a joyful smile on his face as he talked about his research.

"I enjoy research so much that even now I feel like I'm on summer vacation. I hope students will stick to what they find interesting until they get to the very bottom of it as I believe that science is broad and deep enough to accommodate the interests and persistence of a lifetime."

(Top left) *Hodotermopsis sjostedti* kept in the lab. Those with large brown jaws are the soldiers. The white ones are the workers. (Top right) Aphids gathered on the back of a leaf that was found on the premise of MMBS. (Bottom left and right) Images of a Syllidae worm seen through a microscope. In the bottom right image, the longer body on the right is the parent worm and the shorter body on the left is the stolon.

Professor, Misaki Marine Biological Station, Graduate School of Science, The University of Tokyo

Toru Miura

Graduated from the Department of Biological Sciences, Faculty of Science, The University of Tokyo in 1994. Completed his PhD at the Department of Biological Sciences, Graduate School of Science, The University of Tokyo in 1999. Became a postdoctoral fellow of JSPS that same year. Held positions such as an assistant professor at the Graduate School of Arts and Sciences, The University of Tokyo and at the Graduate School of Environmental Earth Science, Hokkaido University, before assuming his current position as a professor at the Misaki Marine Biological Station, Graduate School of Science, The University of Tokyo in 2017.

What are the universal principles of life?

Searching for the essence of life through physics

The ultimate goal of physics is to explain everything in nature by applying universal laws, even when it comes to explaining life.

Biology has been advancing at a remarkable pace since the late 20th century. This has been propelled by new techniques developed in the fields of molecular biology and biophysics, the most notable ones being genome analysis and measurement of cell function, respectively.

A number of complex biological phenomena are being elucidated at the molecular level. Nevertheless, humanity has yet to find a definitive answer to the fundamental question of "What is life?" because individual research findings exist separately from each other. Given this, Professor Higuchi is searching for the universality underlying a rich diversity of life phenomena, the key to which is physics.

"Biophysics is a discipline aimed at finding fundamental laws and principles in complex living systems," he explained. "Advances in physics and chemistry have led to an enormous volume of quantitative data being accumulated in the life sciences. In order to gain a better understanding, this wealth of knowledge needs to be integrated into one theory by utilizing physics and mathematics. This is becoming feasible now that a mountain of data has been amassed."

Professor Higuchi is working to identify a universal mechanism of molecular motors that power movements within cells. Muscle cells, immune cells, and cancer cells all move frequently. Cell division and intracellular vesicle transportation are also powered by molecular motors.

As such, molecules within cells are controlled by a motor mechanism that differs from the one that enables our daily lives.

"In the macro world, an object in motion stays in motion for a while even after the force that had set it in motion is removed because of the law of inertia," said Professor Higuchi. "In contrast, nanoscale molecular motors move when energy is input, but stop immediately when energy ceases to be applied due to the viscosity of water providing massive resistance. I examined in detail the ways in which various kinds of molecular motors move forward by repeating this stop-and-restart cycle, resulting in the discovery of a universal principle of how they move."

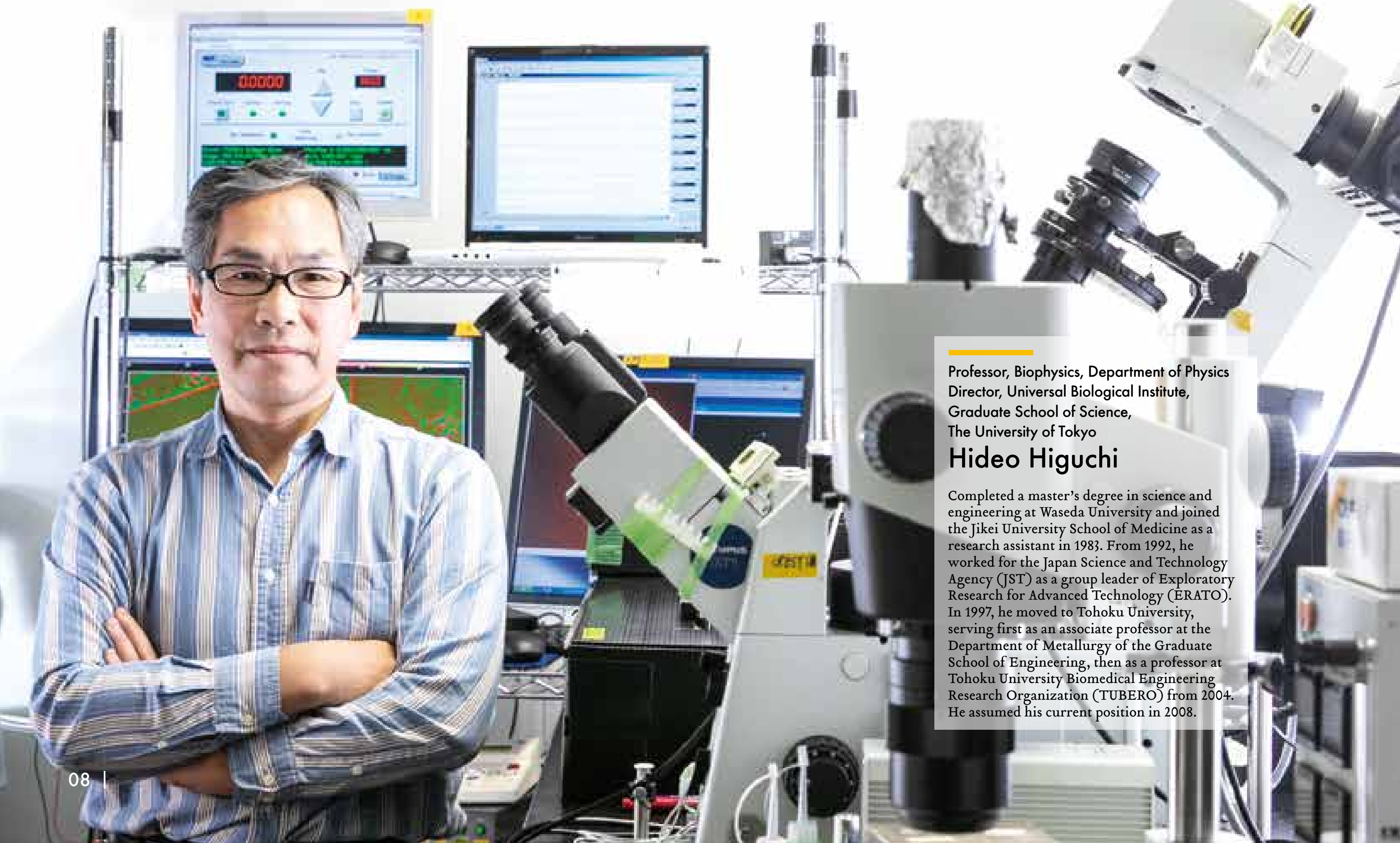
The Higuchi Laboratory utilizes a single-molecule technique, a tool that allows a single molecule's movement to be visually monitored and its function to be quantified. While a group of molecules move intricately, a single molecule moves straightforwardly.

"*Single* is a notion we physicists prefer. A good example of this is our exploration of the nature of a single particle or electron," he pointed out. "The single-molecule technique is the result of applying this notion to life phenomena."

Elucidating a universal mechanism of intracellular molecular movement is expected to help uncover the essence of life or pave the way for new treatment for diseases.

Fascinated by muscle movement and structure, Professor Higuchi has long researched molecular motors, affiliated with a range of faculties over the years. After studying the fundamentals of physics and biophysics at a faculty of physics, he obtained a research position at a school of medicine, followed by working for a school of engineering and a medical research organization with the aim of applying findings from his single-molecule research to biomaterials and medicine.

"Knowledge has no boundaries," he declared with a gentle smile. "All that matters is what you do, not which faculty or department you study at. Having said that, I strongly encourage those who wish to choose academia as a career to study at a school of science first. I have been able to continue my research beyond the boundaries of faculties and schools thanks to the principles of natural science that I learned. A correct understanding of these principles enables you to comprehend a variety of phenomena, providing the basis for application as well."



Professor, Biophysics, Department of Physics
Director, Universal Biological Institute,
Graduate School of Science,
The University of Tokyo

Hideo Higuchi

Completed a master's degree in science and engineering at Waseda University and joined the Jikei University School of Medicine as a research assistant in 1983. From 1992, he worked for the Japan Science and Technology Agency (JST) as a group leader of Exploratory Research for Advanced Technology (ERATO). In 1997, he moved to Tohoku University, serving first as an associate professor at the Department of Metallurgy of the Graduate School of Engineering, then as a professor at Tohoku University Biomedical Engineering Research Organization (TUBERO) from 2004. He assumed his current position in 2008.

To what extent can life be described in molecular words?

The truths of life as described by analytical chemistry

Advances in analytical chemistry have pushed forward the frontiers of life sciences.
Now that the actors within the cell are becoming revealed, analytical chemistry will step into a new realm.

Analytical chemistry is the analysis of certain materials to gain an understanding of their chemical components and their quantities. Advances in analytical chemistry, such as gene analysis using a DNA sequencer and protein analysis by mass spectrometry, have brought significant breakthroughs to life sciences.

Professor Ozawa of the Analytical Chemistry Lab has devoted more than twenty years of research to in vivo molecular imaging to directly visualize the dynamics of biomolecules within the living cell. His first encounter with this research was in 1997 when he was a doctoral student.

"I was fascinated by the GFP imaging technique, a technique to label calcium ions with green fluorescent protein (GFP) to observe how the ions work spatiotemporally within the cell. I will never forget the excitement I felt when I first saw those cells glowing in green under the microscope. They looked like stars shining in the sky, and I could also clearly see the motions of the molecules."

Ever since, fluorescent imaging using GFP has become an important part of his research. In addition, he has been working on developing a new visualization technique in recent years. When light is radiated on a material, it interacts with the molecules and scatters as light with a different wavelength from the original incident light. This is called Raman scattering. Since each molecule has a unique vibrational frequency, analysis of the spectral information in the scattering light will allow us to identify what kinds of molecules are present in what amounts in a given space. Professor Ozawa is committed to the development of this Raman imaging technique.

"We have gained quite a lot of information about who the 'actors' are; that is, what molecules are active within the cell. Our next step is to learn more about how these actors interact with each other to be able to quantitatively describe the molecular network and reactions. The movements of proteins and calcium ions can be captured with fluorescent imaging, while lipids, hormones, and metabolic products within the cell can be identified with Raman imaging. I believe we will be able to elucidate the interactions between various molecules by using both techniques at the same time."

Professor Ozawa is also working to develop new technologies by applying these intracellular visualization techniques. One such technology is a protein identification by library screening. Receptors on the cell membrane called G-protein coupled receptors (GPCR) are associated with various diseases and researchers are searching for chemicals that will inhibit their function as potential candidates for drug development. Building on intracellular visualization techniques, he has developed a unique technology to efficiently identify GPCR inhibitors.

Another example is a technology born from an innovative concept going far beyond the boundaries of conventional analytical chemistry. The basic idea is to control the activity of enzymes (proteins) in the cell by using light. By connecting the target enzyme with a plant-originated protein that responds to light, enzyme activity can be switched on or off in response to light stimulus. Using this technology, it will be possible to closely observe the reactions an enzyme induces in the cell.

"The technologies we have today will sooner or later be replaced with new technologies in the future," Professor Ozawa said when looking back on his past work. "What really counts is to develop a new concept. A fundamental concept will be passed down, leaving a mark in history. This is the best part about science. The desire to understand the origins of natural phenomena is what led me to a career in science and what continues to fascinate me even now."

Professor, Department of Chemistry
Professor, Department of Biological Sciences
(joint appointment)

Takeaki Ozawa

Graduated from the Department of Chemistry, Faculty of Science, The University of Tokyo in 1993. After completing his PhD at the Department of Chemistry, Graduate School of Science, The University of Tokyo in 1998, he served as a research associate (1998-2002) and lecturer (2002-2005) at the Department of Chemistry, School of Science, The University of Tokyo. In 2005, he was appointed as an associate professor at the Department of Molecular Structure, Institute of Molecular Science. He has held his current position as a professor at the Department of Chemistry, School of Science since 2007. In 2014, he was jointly appointed as a professor of the Department of Biological Sciences, Graduate School of Science.

History of the School of Science

In 2017, the School of Science at the University of Tokyo celebrated its 140th anniversary.
In commemoration, we look back over its history.

Science in Japan and its Origins

The School of Science was founded alongside the University of Tokyo in 1877, but its origins can be traced back to the 17th century.

In 1684, the Tokugawa government formed the Astronomy Agency (Tenmonkata) to compile calendars. The technology used for astronomical observation, as well as the Agency's accumulated knowledge, were inherited by what would later become the School of Science. That same year, the Tokugawa government also established the Koishikawa Medicinal Herb Garden (presently known as Koishikawa Botanical Garden), which became part of the School of Science in 1877. In 1860, the Seirenkata (Department of Refining), which was the predecessor of the Department of Chemistry, was formed by the Tokugawa government as part of the Bansho Shirabesho (Institute for the Study of Barbarian Books).

The School of Science consisted of five departments when it was first established: Mathematical Physics and Astrology, Geology and Mining, Chemistry, Biology, and Engineering. The Department of Mathematical Physics and Astrology separated into what are now the Departments of Mathematics, Physics, and Astronomy. The Department of Geology and Mining would later become the Department of Earth Science, and eventually the current Department of Earth and Planetary Environmental Science. (The Department of Engineering would later separate from the School of Science and become the predecessor of the School of Engineering.)

Faculty at the time included Dr. Kenjiro Yamakawa (1854-1931), who is known as "the founder of Japanese physics," and Dr. Joji Sakurai (1858-1939), who is referred to as the "father of modern chemistry in Japan." Among Dr. Yamakawa's students was Dr. Hantaro Nagaoka (1865-1950), who created the "Saturnian model of the atom" in 1903. In addition, one of Dr. Sakurai's students was Dr. Kikunae Ikeda (1864-1936), who in 1907 discovered Umami.

The School of Science in a Global Context

The School of Science has pioneered new fields of study in various eras. The Great Kanto Earthquake in 1923 led to the establishment of the Department of Seismology that same year. The department was renamed to the Department of Geophysics in 1941, and then became the present Department of Earth and Planetary Physics. In the 1940s, the field of molecular biology underwent rapid advances, particularly in the United States. In response, the Department of Biophysics and Biochemistry was established in 1958, which was the first university department in Japan to specialize in molecular biology.

In 1975, around when computers started to become more prevalent in society, the Department of Information Science was established with the aim to both teach and conduct research in the field of Information Science. Developments in information science significantly transformed approaches to science, especially in life science. This resulted in the formation of a bioinformatics research program in 2001 that focused on examining life as information. The program was then expanded to become the Department of Bioinformatics and Systems Biology in 2007.

Over the past 140 years, many students have graduated from the School of Science, and among these graduates are recipients of globally prestigious awards. The first alum to enjoy international success was Dr. Kunihiko Kodaira (1915-1997), who in 1954 became the first Japanese person to be awarded a Fields Medal for his achievements in the theory of complex manifolds. In 1973, Dr. Leo Esaki became the first alum to win the Nobel Prize in Physics for his discovery of tunneling phenomena in semiconductors. Three other graduates have gone on to make significant achievements in the field of elementary particle physics and win a Nobel Prize in Physics: Dr. Masatoshi Koshiba in 2002 for the detection of cosmic neutrinos, Dr. Yoichiro Nambu (1921-2015) in 2008 for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics, and Professor Takaaki Kajita in 2015 for the discovery of neutrino oscillations.

In 2016, another graduate from the School of Science, Dr. Yoshinori Ohsumi, won the Nobel Prize in Physiology or Medicine for his discoveries of mechanisms for autophagy. Throughout its history, the School of Science has played an integral role in the global field.

Kunihiko Kodaira
Graduated from the Department of Mathematics in 1938
Former Dean of the School of Science
©Graduate School of Mathematical Sciences, The University of Tokyo

Takaaki Kajita
Special University Professor, The University of Tokyo
©Institute for Cosmic Ray Research, The University of Tokyo

The 140-year History of the School of Science

- **1684** — Tokugawa government established Tenmonkata
- **1684** — Tokugawa government established Koishikawa Medicinal Herb Garden
- **1860** — Tokugawa government established Seirenkata as part of Bansho Shirabesho
- **1877** — The University of Tokyo was founded
- **1877** — The College of Science was established
  - The Department of Mathematical Physics and Astrology
  - The Department of Geology and Mining
  - The Department of Chemistry
  - The Department of Biology
- **1877** — Koishikawa Medicinal Herb Garden became part of the University of Tokyo (commonly known as Koishikawa Botanical Garden)
- **1880** — The Department of Geology and Mining was divided into the Department of Geology and the Department of Mining (The Department of Mining later became part of the Department of Engineering)
- **1881** — The Department of Mathematical Physics and Astrology was divided into the Department of Mathematics, the Department of Physics, and the Department of Astrology
- **1886** — The University of Tokyo became Imperial University
- **1886** — The Department of Biology branched into the Department of Zoology and the Department of Botany
- **1886** — The Marine Laboratory was established
- **1893** — The Seismology Course was set up as part of the Department of Physics
- **'97** — Imperial University was renamed to Tokyo Imperial University
- **1901** — The Department of Physics was divided into the Department of Theoretical Physics and the Department of Experimental Physics
- **'02** — Nikko Branch Botanical Garden was established
- **'07** — The Department of Geology was divided into the Department of Geology and the Department of Mineralogy
- **'19** — The Department of Theoretical Physics and the Department of Experimental Physics reintegrated into the Department of Physics
- **'19** — The Department of Astrology was renamed to the Department of Astronomy
- **'19** — The Department of Geography was established
- **'19** — The College of Science renamed to the School of Science due to a legal amendment
- **'23** — The Seismology course became the Department of Seismology in response to the Great Kanto Earthquake
- **'39** — The Department of Anthropology was established

Column

Marine life and terrestrial plants

Two affiliated facilities in the Graduate School of Science dedicated to the study of diverse living things

Misaki Marine Biological Station

A historic facility founded in part through the efforts of Edward S. Morse

The Misaki Marine Biological Station (MMBS) is situated on the southwestern tip of the Miura Peninsula in Kanagawa Prefecture. The word "Misaki" is derived from its location in Misaki Town of Miura City. On the Miura Peninsula, which faces Tokyo Bay to the east and Sagami Bay to the west, MMBS is placed at the point where the two bays intersect. This location affords opportunities to observe some of the world's most diverse fauna in the surrounding waters.

MMBS is engaged in cutting-edge life science research on rich and diverse marine life and covers a wide range of research fields including developmental biology, cell biology, molecular biology, animal taxonomy and evolutionary biology.

Dating back to 1886, this world-renowned marine biological station with a proud history was made possible by Edward S. Morse, who laid the foundation for the study of anthropology and archaeology in Japan. Dr. Morse came to Japan in 1877, the year in which the University of Tokyo was founded, and became the first professor of the Department of Zoology in the university's School of Science. Immediately thereafter, he established a temporary marine biological station in Kanagawa Prefecture, recommending to the Japanese government that a permanent station be built.

Misaki is also known as a place that revolutionized the global jewelry industry through the founding of Mikimoto, an internationally acclaimed brand for pearls. MMBS was deeply involved in the process, as its proprietary pearl farming technology was adopted by the company's founder, Kokichi Mikimoto, to lay the groundwork for today's pearl industry.

In the early 20th century, MMBS shut down its research on pearl farming. However, after around 100 years, it resumed interacting with Mikimoto in 2008, inspired by the symposium jointly held by the company and the University of Tokyo to commemorate the 150th anniversary of the birth of Kokichi Mikimoto.

Since then, in cooperation with Mikimoto, Keikyu Corporation and local high schools, the university has been running the Miura Pearl Project to revive the pearl farming industry that existed briefly in the city after World War II. Joint efforts are now underway to make the Miura Peninsula sparkle with pearls again.

The cultured pearls donated to the university by Kokichi Mikimoto in 1925, along with a handwritten memo from Seitaro Goto, a professor at the School of Science.

Botanical Gardens (Koishikawa and Nikko)

The birthplace of modern botany in Japan

The main botanical garden of the Graduate School of Science is situated in Koishikawa, a district neighboring the university's Hongo Campus. This place, commonly known as Koishikawa Botanical Garden and designated as a Historic Site and Place of Scenic Beauty in Japan, is in essence a facility to promote botanical research and education.

Koishikawa Botanical Garden is Japan's, and one of the world's, oldest botanical gardens. Its history dates back to 1684 when its earliest predecessor, the Koishikawa Medicinal Herb Garden, was established by the Tokugawa shogunate. Upon the founding of the University of Tokyo in 1877, the garden became part of the university, and has been open to the public ever since.

The garden is topographically diverse, consisting of plateaus, slopes, and ponds, and has approximately 4,000 species of plants. Furthermore, the facility is visited by numerous botanists both in and outside the university who access its collection of more than 600,000 plant specimens and around 20,000 botany-related books.

Its satellite garden, called Nikko Botanical Garden, is located in Nikko, Tochigi Prefecture. It was created in 1902 for the purpose of research and education on mountain plants that are difficult to grow in Tokyo.

The Koishikawa Botanical Garden is also known as the birthplace of modern botany in Japan because the nation's first epoch-making discovery in the history of global botany was made there, which was the 1896 discovery of sperm of a ginkgo tree by Sakugoro Hirase, an assistant professor of the Department of Botany at the School of Science.

As ginkgoes are gymnosperms, Hirase's discovery has served as an important key to elucidating the evolutionary process of plants by linking mosses and ferns that produce sperm to angiosperms that do not.

This ginkgo tree still stands, alive and majestic, near the center of the garden. It is estimated to be 300 years old with a trunk circumference of 4.9 meters.

The majestic ginkgo standing near the center of the Koishikawa Botanical Garden. By studying this tree, Sakugoro Hirase discovered that the ginkgo produces sperm.

- 1941 — The Department of Seismology became the Department of Geophysics
- '47 — Tokyo Imperial University was renamed to the University of Tokyo
- '49 — The University of Tokyo was reorganized under the new education system
- '49 — The Departments of Physics, Astronomy and Geophysics integrated into the Department of Physics
- '49 — The Departments of Zoology, Botany, and Anthropology were integrated into the Department of Biology
- 1958 — The Geophysical Observatory was established
- 1958 — The Department of Biophysics and Biochemistry was established
- 1964 — The Geophysical Observatory became the Geophysical Research Facility
- '67 — The Department of Physics was divided into the Department of Physics, Department of Astronomy, and the Department of Geophysics
- 1970 — The Information Science Research Laboratory was established
- '74 — The High Energy Physics Laboratory was established (Exists today as the International Center for Elementary Particle Physics)
- '75 — The Information Science Research Laboratory became the Department of Information Science
- '76 — The Center for Spectrochemistry was established (Exists today as the Research Center for Spectrochemistry)
- '78 — The Meson Science Laboratory was established (Exists today as the Center for Nuclear Study)
- 1983 — The Molecular Genetics Research Laboratory was established
- '84 — The Institute of Astronomy was established
- 1990 — The Department of Geophysics and its affiliated Geophysics Research Laboratory were combined to form the Department of Earth and Planetary Physics
- '99 — The Research Center for the Early Universe was established
- 2001 — Undergraduate Program for Bioinformatics and System Biology was established
- '05 — The Actuary and Statistics Program was established
- '06 — The Department of Earth Science was renamed to the Department of Earth and Planetary Environmental Science
- '06 — The Bioinformatics and Systems Biology Program for Undergraduate Education was established
- '07 — The Bioinformatics and Systems Biology Program for Undergraduate Education became the Department of Bioinformatics and Systems Biology

Training the Next Generation of Scientists

Department Chairs in the Faculty of Science

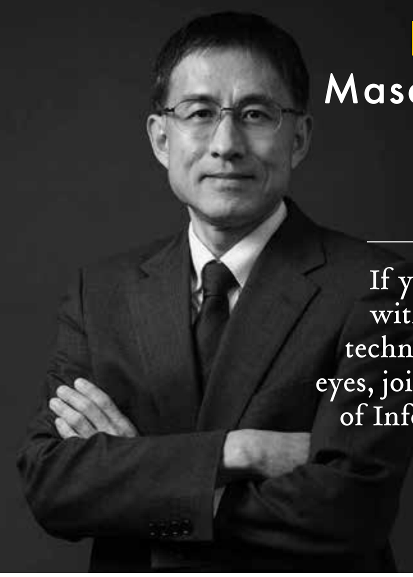
Members of our society have been responsible for science throughout the ages.
The passion to unravel the mysteries of nature motivates us to conduct in-depth research.
This passion then becomes a driving force that is passed down to others, strengthening and further developing research.

These ceaseless efforts to transmit knowledge to the next generation aim to both advance science and lay the foundation for a better society.
Each generation of scientists will continue to devote themselves to achieving this goal.

Mathematical Sciences

Mikio Furuta

Return to the fundamental principles of phenomena, and you will see a scene nobody knows.



Information Science

Masami Hagiya

If you are dissatisfied with the information technology before your eyes, join the Department of Information Science.

Physics

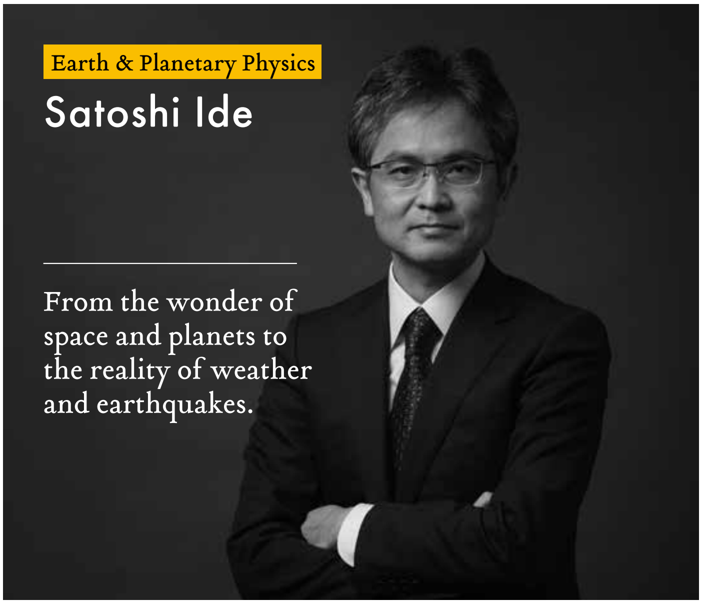
Satoshi Yamamoto

Have a big dream and the power to do science with a little courage!

Astronomy

Tomonori Totani

Approach, and then feel the mystery of the great universe by the power of science.



Earth & Planetary Physics

Satoshi Ide

From the wonder of space and planets to the reality of weather and earthquakes.

Earth & Planetary Environmental Science

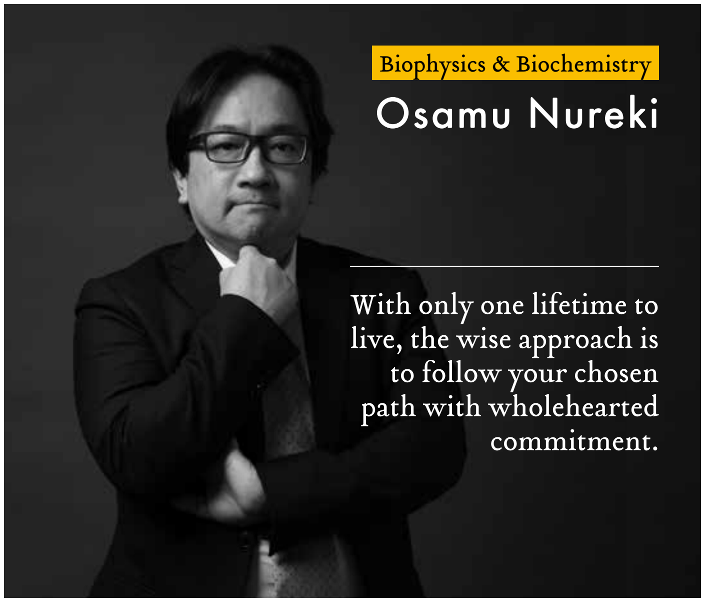
Yoshio Takahashi

Foster future-oriented human resources by learning about the past and present of the Earth, the environment, and other planets.

Chemistry

Kaoru Yamanouchi

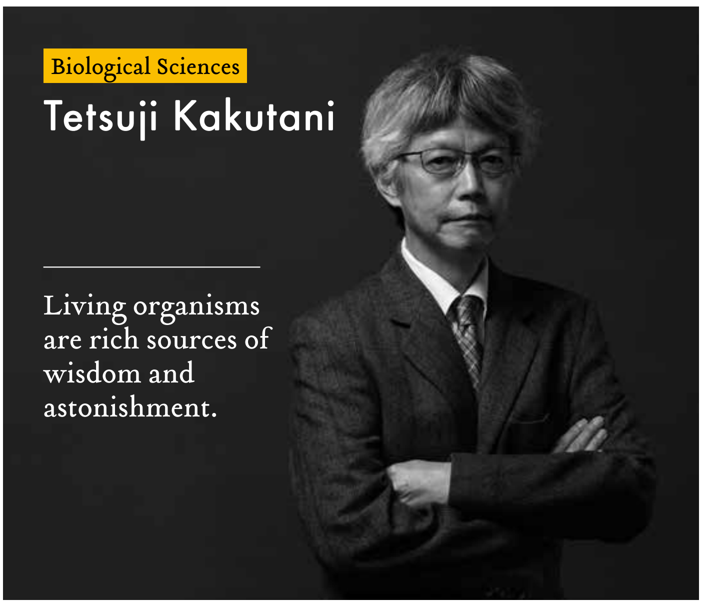
Explore together the frontiers of chemistry.



Biophysics & Biochemistry

Osamu Nureki

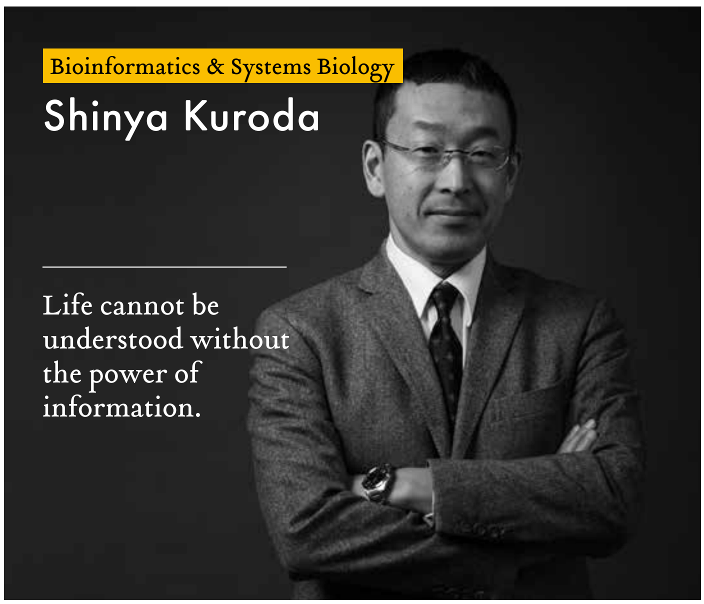
With only one lifetime to live, the wise approach is to follow your chosen path with wholehearted commitment.



Biological Sciences

Tetsuji Kakutani

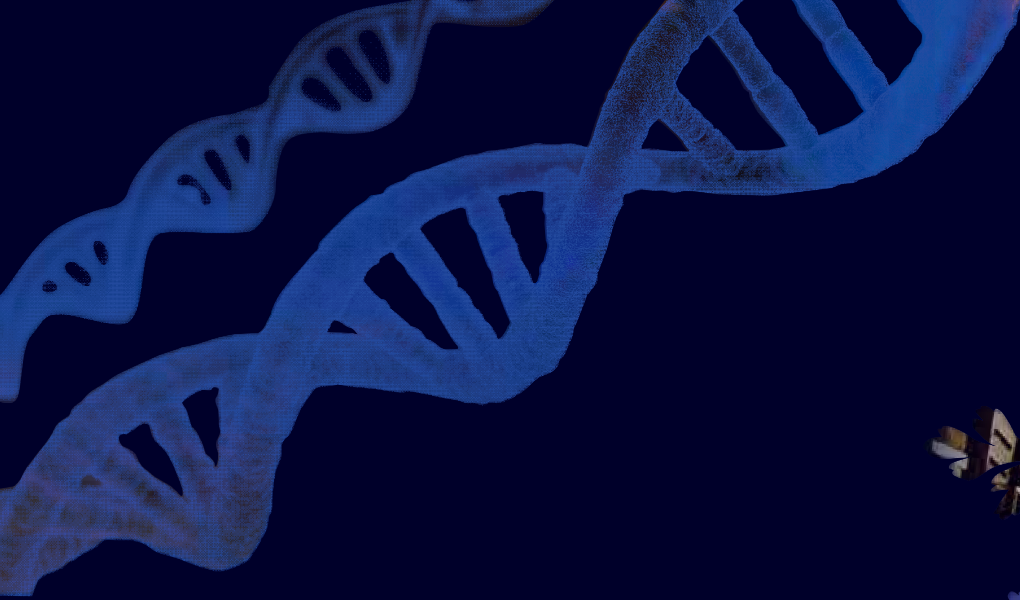
Living organisms are rich sources of wisdom and astonishment.

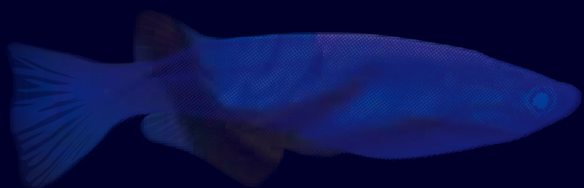


Bioinformatics & Systems Biology

Shinya Kuroda

Life cannot be understood without the power of information.





School of Science, The University of Tokyo
7-3-1 Hongo, Bunkyo-ku,
Tokyo 113-0033, JAPAN

kouhou.s@gs.mail.u-tokyo.ac.jp

東京大学
THE UNIVERSITY OF TOKYO

東京大学 大学院
理学系研究科・理学部
SCHOOL OF SCIENCE, THE UNIVERSITY OF TOKYO