TOKYO TECH RESEARCH 2019-2020
Research at Tokyo Tech

Since its founding in 1881, Tokyo Tech has stood at the front line of research as one of the world’s leading universities in science and engineering. Building upon the Institute’s long-standing philosophy of monotsukuri, or technical ingenuity and innovation, Tokyo Tech consistently produces high-impact research across numerous science and technology fields, including physics, chemistry, mechanical engineering, materials science, environmental engineering, and life sciences.

Three Crucial Engagements in Research

Creation of Innovative Science and Technology for Sustainable Development of Humanity

Search for Truth and Acquisition of New Wisdom

Contribution to Society Through Deployment of Wisdom

From President Masu

As a national designated university corporation where the world’s highest pedigree of education and research is expected, Tokyo Tech seeks new potential among science and technology and aspires to pioneer a new era in discourse with society. This pamphlet presents the essence of our institution’s research from three perspectives: creation of innovative science and technology; search for truth and acquisition of new wisdom; and deployment of wisdom in society. I would be pleased if the reader gains a sense of the future from the many research efforts at Tokyo Tech, a lens from which new alliances between industry and academia could emerge. The diversity groomed in a university setting provides opportunities to conduct exciting and intriguing research under fast-paced decision-making and execution. As we challenge ourselves to pursue research that will contribute to society, I ask you to look forward to the research prowess at Tokyo Tech.

Patent Income

Tokyo Tech Ventures

280

million yen (2017)

92 companies (as of December 2018)

46.02 billion yen

Wisdom

Deployment of

Society Through

Contribution to

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Three Crucial Engagements in Research

- Creation of Innovative Science and Technology for Sustainable Development of Society
- Contribution to Society Through Deployment of Wisdom
Development of a solar power-focused next-generation electrical energy system

Junichiro Imura
School of Engineering

We are conducting joint research and development for a power system control method which utilizes photovoltaic power predictions to achieve harmonized and stable supply of electricity power even when a large amount of photovoltaic power generation has been implemented. The joint research is being conducted by researchers at 17 domestic universities and research centers (16 researchers) and 8 foreign universities. It is extremely difficult to predict photovoltaic power output. Furthermore, in the case of photovoltaic power, its generation is only possible during limited time periods. Therefore, we are working to comprehensively develop an energy management method which assumes that major discrepancies with predictions will occur, and which utilizes storage battery control and electricity market mechanisms. Based on this development, we seek to construct a next-generation energy system that will serve as the foundation of a super-smart society.

Energy and environmental research from a global perspective

Mika Goto, Jeffrey S. Cross
School of Environment and Society

Goto studies energy and environment issues from a corporate management and innovation perspective. She uses a variety of data to analyze productivity improvements and the promotion of technological progress taking into account the social dimension of companies such as dealing with environmental protection and leveraging human resources, conducting research on future corporate management in a sustainable society. Cross conducts research on future energy policy and educational technology in fields such as sustainable energy, biofuels and engineering education. He is also actively engaged in the development and production of massive open online courses (MOOCs), as well as research in the field of online learning analytics.

Earthquake and Disaster Mitigation

Seismic resistant technology for steel building structures

Saboshi Yamada
Institute of Innovative Research

In order to mitigate seismic damage, Yamada develops seismic isolation and passive control technology as well as seismic resistant isolation technology for steel buildings such as high-rises and gymnasiums. To evaluate the full extent seismic performance of steel building structures under extreme severe earthquakes, he investigates a broad range of research topics, including seismic response analysis of steel structures based on the realistic hysteretic behavior of structural components. Furthermore, he is involved in structural earthquake fracture experiments on structural members, and evaluation of energy input due to earthquakes. He is also conducting research on whole-scale safety improvements for buildings, including non-structural components and equipment.

Architecture and Transportation

Challenges for creating a safe low-carbon society

Tosi Takeuchi, Yoshitani Tsukamoto
School of Environment and Society

Takeuchi, Tsukamoto, and Itoh overview the architectural design of the Environmental Energy Initiative (EEI) Building, a globally unique building with an energy system that supplies nearly 100% of the power consumed, with reducing carbon dioxide emissions by over 60%. Takeuchi engages in research to create “elegant and tough” architecture with a focus on spatial steel structures such as space trusses and tension structures, as well as response control technologies, based on the concept that buildings must be resilient to natural disasters, but should also be beautiful. Tsukamoto is exploring better inter-relationships between architectural composition, the “behavior” of people and nature, and social frameworks for systems through research on and engineering of architectural design, based on the ethnographical wisdom of architecture responding to the local climate and their ecology of livelihood. Hara oversees the design of energy systems for the EEI Building, developing and evaluating the smart energy system Ene-Swallow that controls 1.4 MW of solar cells, fuel cells, gas engine of people and automobiles, and also works on future energy system and scenario research using big data.

Multidisciplinary monitoring of Kusatsu-Shirane volcano by integrating geophysics and geochemistry

Fumiy Nagami, Ayrike Terada, Wataru Kanda, Yasuo Ogaara
School of Science

Kusatsu-Shirane volcano in the northwest corner of Gunma is one of Japan’s 11 active volcanoes. Tokyo Tech has been continuing observational research at the volcano for over half a century. The Kusatsu-Shirane Volcano Observatory was established in 1986 in Kusatsu town, and continues observa- tional research and forecasting of phreatic eruptions. Phreatic eruptions have extremely faint precursors, so eruption forecasting remains a challenge. However since March 2014, researchers have tracked how Kusatsu-Shirane has become active with regards to ground deformations, seismic activity, total magnetic intensity, and compositions of crater lake water and fumarolic gas. These results have led to disaster countermeasures by the Japan Meteorological Agency and the Kusatsu-Shirane Volcano Disaster Prevention Council.

Health, Medicine, and Supporting People with Disabilities

Creating new materials that are people- and environment-friendly

Hidetoshi Hosoda
Institute of Innovative Research

Hosoda conducts research and
Mal iPad In the Future, We Will Have a Remote Control System for Intelligent Devices. We Will Be Able to Control Appliances and Electronics Remotely.
We are conducting research to achieve a deeper understanding of the brain-body interactions that allow us to live with safety and peace of mind, even when people or animals have some kind of disability. We also hope to establish new rehabilitation methods and auxiliary equipment that can be integrated with the human body.

**Development of functional materials using protein assemblies**

**Takafumi Ueno**

Institute of Life Science and Technology

All cells in multicellular organisms have the same genetic information, but genes expressed in individual cells vary, and each shows a particular morphology and integrity. To figure out the mechanisms by which genes are regulated, Ueno uses antibody-derived probes to analyze the dynamics of posttranslational modifications of histones and RNA polymerase in living cells. He also takes part in joint research with overseas institutions, such as the International Human Epigenome Consortium.

**Unlocking the evolution of photosynthetic organisms and lipid production through lipid research with plants and algae**

**Hiroyuki Ohta**

School of Life Science and Technology

Ohta has had early success in the field of lipid lipid research. He was the first to identify the gene for biosynthesis of the major glycolipid of plant chloroplasts, the most abundant biomembrane lipid on Earth, and also determined both its necessity during photosynthesis and its function during phagocytic deficiency response. In recent years, he has made notable discoveries involving algae, such as decoding the genome of charophytes considered the algae phytoplankton most closely related to terrestrial plants, and demonstrating that charophytes have lipid components like wax on the cell surface despite being algae. He continues to produce innovative results such as uncovering the oil accumulation mechanism of algae with high oil productivity, and developing basic technology for manipulation of oil synthesis.

**Mathematics for making computers think**

**Takao Nishida**

Institute of Liberal Arts

From the time of being born, human beings have had many unknowns involved in the nuclear reactions and decay properties of unstable nuclei needed to develop innovative nuclear power systems, but Chiba is performing theoretical research to elucidate them. He is using this technology to study the origin of heavy elements in the universe and the evolution of the universe.

**Mathematical science**

**Takanori Fukushima**

Institute of Liberal Arts

Research methods to make computers think. However, as symbolized by extraordinary developments in technology, they continue to produce innovative results even with thinking problems. To promote this dramatic development in technology, they research methods to make computers think from a mathematical perspective.

**Politics and Religion**

**Takahiro Nakajima**

Institute of Liberal Arts

In recent years, there has been a surge in xenophbic nationalism and a rise in religious fundamentalism across the world. Nakajima examines the social, economic, and historical backgrounds of these fundamentalisms, and highlights the role of media, politics, and international collaboration in understanding these phenomena. He engages in interdisciplinary research, exploring the interconnectedness of art, society, and religion to foster a more inclusive and open-minded future.

**For the pursuit of knowledge**

**Analyze data and extract underlying rules.**

**Yoshiyuki Kabashima, Makoto Yamashita**

School of Computing

Asa Ito

Institute for Liberal Arts

The world “seen” by the blind using hearing, taste, and language is completely different from what the world perceived with sight. People who research in the design field, integrating art, science, and technology to explore new possibilities of the blind, are creating new places and ideas connecting art and design. Based on the former two research themes, she organized a workshop called “Let’s design a country without ‘hearing’ and ‘vision’”, and works to reevaluate the world from the perspective of not being able to see, rather than from the humanistic perspective of supporting the blind.

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**Mathematical analysis of interfaces moving by surface tension**

**Yoshifumi Tonogawa**

School of Science

Tonogawa has established a fundamental existence and regularity theory for a general solution for the so-called mean curvature flow problem, in which interfaces of arbitrary dimensions and configurations such as networks with singularity move due to surface tension. In recent years he has given intensive courses on mean curvature flow at the world’s top research centers, and has attracted attention for a series of findings. The mean curvature flow of interfaces is a model problem of gran boundary motion. It is a research topic of high academic significance related to wide-ranging fields such as differential geometry, the calculus of variations, materials science, and image processing.
Super computer technology for supporting next-generation big data.
Toshiro Endo
School of Computing
We are conducting research and development for fundamental software technology used in high-performance computing (HPC). Examples include massively parallel algorithms, memory layer utilization technology for next-generation big data, and efforts to achieve high-speed and large-scale machine learning. The importance of advanced supercomputing technology for the growth of scientific technology will continue to increase in the future. Related technologies include large-scale processing of genome analysis, earth observation image analysis using satellites, and simulations of molecules and weather.

Transparent oxide semiconductor for organic EL displays
Hideto Hisamori
Institute of Innovative Research
Quantum annealing, proposed by Nishimori and his student Kadowaki, is a basic principle for solving problems known as combinatorial optimization problems. In artificial intelligence, many of the tasks for machine learning are optimization problems, and quantum annealing is attracting a great deal of attention as a next-generation information processing technology to further promote the development of machine learning and artificial intelligence. The Canadian startup company D-Wave Systems Inc. has implemented quantum annealing as hardware, and Google, NASA, and others have introduced it or begun using it for cloud services. With unique quantum annealing machine development by Google and as part of a large-scale national project in the United States, a large flow originating from the research at Tokyo Tech is driving the world.

Emotional experience design: Building desirable interaction between systems and people
Miyuki Umehira
School of Engineering
As robots, AI, and other systems grow even more intelligent, human beings increasingly treat these systems as "agents" with intentions and personality during interaction. When using tools or machines, human beings mainly engage in rational thinking and evaluation. However, as systems grow more intelligent and display greater personality, affective experiences such as trust and affection become increasingly important during interaction with systems. In western nations, it is already commonplace for engineers to collaborate with expert psychologists when researching interaction with robots and information systems. However, in Japan, the majority of engineers design interaction by using themselves as a point of reference or by imagining other human beings. As a team of experts on the psychological characteristics of human beings, our team contributes to technical design for an even better affective experience.

Realization of a quantum computer based on the theory of quantum annealing
Hidetoshi Nishimori
Institute of Innovative Research
For industry and innovation

Developing a flexible terahertz scanner
Yukiko Kawano
Institute of Innovative Research
Kawano and colleagues have developed a terahertz scanner that can detect electromagnetic waves from 0.1 to 30 THz with high sensitivity and at high resolution. By increasing the response sensitivity of carbon nanotube detectors for photovoltaic power and integrating a large number of the detectors in a curved array, they have made it possible to measure objects of any shape from any direction. They plan to demonstrate its use in non-destructive, contactless inspection of medical instruments and drug tablets of various shapes.

Electronics and Communication

Platform software and algorithms for next-generation supercomputers
Rio Yokota
School of Computing
Yokota’s research group is developing fast algorithms for the next generation of supercomputers. They are designing highly parallel computing algorithms with high arithmetic intensity that operate efficiently on GPUs installed in Tokyo Tech’s TSUBAME 3.0 supercomputer. The hierarchical low rank approximation method, used for large-scale fluid and molecular simulations, as well as advanced precision arithmetic can be applied to the recently popular deep learning computation. As such, Yokota’s group is active in both of scientific computation and deep learning.

Translucent and Communication

High-precision indoor positioning with low model dependency using "ellipsoid features"
Masamichi Shimosaka
School of Computing
Although positional information is becoming more important due to various services and its usefulness in the field of ubiquitous computing, it is difficult to achieve high-quality positioning with conventional indoor positioning technology due to hardware and other differences. To resolve this, Shimosaka’s research group focused on "ellipsoid features" using the difference in radio wave intensity obtained from multiple access points. He found that there is less dependency on the model, and the position of the terminal to be located can be narrowed down to a smaller area than with existing methods.

Quantum simulation and quantum sensors using ultra-cold atoms
Mikio Kozuma
School of Science
The world’s first ytterbium quantum gas-microscope, developed by Kozuma’s laboratory, is expected to be used as a quantum simulator for understanding the mystery of high-temperature superconductivity. The copper oxide superconductor discovered in 1986 achieves superconductivity at a high temperature that cannot be explained by the traditional BCS theory. Its microscopic mechanism is still not fully understood even 30 years after the phenomenon was discovered. They simulate high-temperature superconductivity quantitatively using ultra-cold atoms instead of electrons, and using an optical lattice with lasers instead of an sonic lattice, with the goal of understanding this mystery and revealing the conditions for room-temperature superconductivity. When entering the Mott insulator state, which is a phenomenon in the stage prior to achieving high-temperature superconductivity, electrons occupy each site in

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New Materials

Expanding the limits of semiconductors with new materials and process technologies
Kazuo Tsutui
Institute of Innovative Research

In recent years, Tsutui has been struggling to overcome the limits of Moore’s law by developing semiconductor technology and working to push the limits of existing materials and process technologies used for devices. By going back to basic physical mechanisms, he is developing device structure technologies as well as materials and fabrication processes that could be applied in future electronics. Development is mainly focused on the field of next-generation power semiconductor devices, which are essential for an energy-saving society, and on creating the foundation for the progress of future society.

Development of ultra-low power consumption SOT-MRAM using topological insulators
PHAN NAM HAI
School of Engineering

In recent years, there has been active development of nonvolatile memory with low power consumption. There are particularly high expectations for magnetoresistive random-access memory (MRAM). In addition to being nonvolatile, MRAM has extremely outstanding characteristics such as high-speed operation in the 10 ns class and superior durability (more than 10^16 writing operations). Research and development was conducted for a spin-injection magnetization reversal method as writing technology for second-generation MRAM which is currently being commercialized. This technology has been used in products since around 2012. However, the spin-injection magnetization reversal method has a significant drawback of high power consumption for writing operations. In order to achieve third-generation SOT-MRAM, we conducted research on a spin-injection method that does not require spin injection and thereby reduces energy consumption. In order to achieve this, we developed a spin-injection method using the properties of ultra-cold atoms as waves. This method does not require spin injection and reduces energy consumption. This opens new possibilities for applications as spintronic devices, but nitride semiconductors currently in use contain rare elements. The newly identified material uses only earth-abundant elements and has properties that differ from conventional nitride semiconductors, widening the range of applications. This discovery is the result of the application of materials information, which is a blend of materials science, computational science, and data science.

New molecular assemblies with functional nanospaces
Michito Yoshizawa
Institute of Innovative Research

Yoshizawa’s group is creating new molecular assemblies with functional nanosized spaces through the rational use of various chemical bonds and interactions. For example, a capsule-shaped assembly bearing a 1 nm-sized cavity can efficiently encapsulate molecules with the complementary size and shape. The captured molecules exhibit unique properties and reactivity that are not observed outside the cavity. Recently, it was revealed that the capsule binds D-sucrose, which is the main component of sugar, in water from a mixture of natural sugars with 100% selectivity. Further development of functional nanospaces will lead to industrial and bio-medical applications.

Development of an immobilized rhodium catalyst with extremely high activity
Ken Motokura
School of Materials and Chemical Technology

Precious metal catalysts are used industrially in the hydrosylation reaction, which is a silane synthesis method used for various applications such as water repellents and paints. Motokura has developed an immobilized rhodium catalyst that demonstrates extremely high activity in this reaction. The catalyst turnover number (the number of times one molecule of the catalyst propogates to the desired reaction) reached 1.9 million times, an order of magnitude higher than in the past. This will greatly reduce the amount of precious metal catalysts used and contribute to the stable production of silicone.

Comparison of activity between the catalysts developed in this study and published reports

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Turnover number</th>
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<tbody>
<tr>
<td>SOT/Rh-Nru</td>
<td>24</td>
</tr>
<tr>
<td>MOF/Rh (Paper *2)</td>
<td>72</td>
</tr>
<tr>
<td>SiO2/Rh (Paper *1)</td>
<td>10^3</td>
</tr>
</tbody>
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Developments of peptides "aligned" on the surface of 2D nanosheets
Yuhei Hayamizu
School of Materials and Chemical Technology

Hayamizu and collaborators have developed peptides, types of small proteins, that spontaneously form nanosheets on the surface of 2D nanosheets with a nanometer thickness, such as graphene and molybdenum disulfide. These peptides specifically modulate the electrical conductivity of single-layer graphene and molybdenum disulfide. Their work has opened the door to develop future biosensors with new mechanisms using peptides and nanosheets.

Design and development of fuel cell and water splitting materials and functional membranes
Takeo Yamaguchi
Institute of Innovative Research

Although traditional material development is based on trial and error, Yamaguchi is systematically designing and developing functional materials from the molecular level to the device level. Through a systematic material design approach, he successfully developed new materials, such as electrolyte membranes, electro-catalysts and systems for fuel cells and water splitting applications. He also developed functional membranes for water treatment and disease diagnosis through the same approach.

Environment and Energy Technology

Solid-state lithium batteries
Byou Kanno
Institute of Innovative Research

In conventional lithium batteries, a liquid electrolyte is used for flowing ionic current. However, Kanno demonstrated the possibility of using a solid electrolyte in defiance of conventional wisdom. Solidification reduces flammability and also improves stability. It can operate in a wide temperature range, and it is easy for the current to flow and become powerful. It also enables rapid charging and discharging, providing many advantages as a battery. In the future, Kanno and colleagues plan to tackle issues such as cost reduction for further practical application.

Measuring liquid water inside of fuel cells and seeking high efficiency
Shusshino Hiro, Takashi Saibae, Manabu Kodama
School of Engineering

Fuel cells are the power source for next-generation zero emission automobiles. These clean engines only emit water when driving. However, there are cases in which that water has an adverse effect on high efficiency and low cost. This is because the water generated by fuel cells can interfere with the supply of the oxygen required for fuel cells. This creates the need to control water and ensure smooth discharge from the fuel cell. By using X-ray technology, we succeeded in measuring the incessantly changing status of liquid water behavior inside of solid fuel cells that do not transmit light. The diagram shows how water is generated and behaves when the electrical current of a fuel cell has increased. Utilizing this measuring technology makes it possible to evaluate the effect of newly-developed materials on liquid water behavior. This contributes significantly to the advancement of fuel cell technology.
Thermal conductive film composed of viruses
Toshiki Sawada, Takeshi Serizawa
School of Materials and Chemical Technology

Because organic polymers are generally regarded as thermal insulators due to the low thermal conductivity, they have not been considered suitable for heat dissipation materials for electrical or electronic devices. However, we prepared thermal conductive films composed of liquid crystalline filamentous viruses, which are polymeric assemblies of proteins and nucleic acids. Importantly, the film can be prepared by a simple flow-induced method using a glass substrate circularly patterned with hydrophobic polymers. We expect that our development will contribute to the establishment of a preparation method for organic polymeric materials with high thermal conductivity, as well as to the clarification of novel heat conductive mechanisms on the materials.

Institute of Innovative Research
contribute to industry by replacing conventional sulfuric acid catalysts. His aim is to develop alternative catalysts such as ethanol from biomass and resins such as ethanol from biomass. He has also succeeded in producing biofuels from bioethanol. Hara has also developed functional materials that perform well in combination with medical equipment. Some systems have already progressed to clinical trials, and his research is expected to lead to innovations in medicine, society, and industry.

Earthquake and Disaster Mitigation
Vibration control and seismic isolation technology using laminated rubber and many other materials
Kazuhiko Kasai
Institute of Innovative Research

Kasai and Wada are overturning conventional building structure concepts by engaging in cutting-edge research of seismic isolation technology. One of the isolators uses laminated rubber: it can move horizontally and isolates the building from seismic ground motion, while sustaining the enormous weight of the building. They are also leading research on vibration control technology which uses dampers to absorb vibration energy from the building and dissipate it as heat. A variety of types of dampers are now available in Japan.

Solid catalyst for solving industrial and environmental problems
Michihiko Hara
Institute of Innovative Research

When the functions of liquid catalysts are transferred to a solid, it becomes easier to separate it from the product, making it possible for the catalyst to be reused. Carbon solid catalysts developed from coal have already been successfully put to practical use, and their performance surpasses that of conventional sulfuric acid catalysts. Hara has also succeeded in producing biofuels and resins such as ethanol from plants and other biomaterials using solid wide catalysts. His aim is to resolve environmental problems and contribute to industry by replacing conventional catalysts with new materials to efficiently produce target chemical compounds.

Health, Medicine, and Supporting People with Disabilities
Next-generation diagnostic and therapeutic drugs using macromolecular design
Nobuhiro Nishiyama
Institute of Innovative Research

Nishiyama is aiming to develop diagnostic and therapeutic systems for diseases that exhibit advanced functions in vivo by integrating smart functionalities such as targetability and environmental responsiveness into a platform of synthetic polymers. Specifically, his goal is to realize effective but less toxic anticancer treatment, practical application of biopharmaceuticals including nucleic acid medicines, and highly sensitive biosensing and minimally invasive treatments in combination with medical equipment. Some systems have already progressed to clinical trials, and his research is expected to lead to innovations in medicine, society, and industry.

Developing artificial hearts using micro maglev technology
Tadahiko Shinshi
Institute of Innovative Research

Shinshi is developing implantable and disposable artificial hearts using micro magnetic levitation technology. The impellers of centrifugal blood pumps are suspended and rotated by electromagnetic force. Non-contact support of the impellers can greatly reduce red blood cell destruction and blood clotting. In animal experiments, extracorporeal disposable maglev centrifugal blood pumps successfully supported blood circulation for two months without any clot formation inside the pumps or organ damage. He is working on practical application through a joint venture between Tokyo Tech and Tokyo Medical and Dental University.

Middle molecule IT-based drug discovery through collaboration with chemistry and biology researchers
Yutaka Akiyama, Masahito Ohue
School of Computing

While middle molecules can be chemically synthesized inexpensively, they possess various advantages similar to large macromolecules and are expected to take on a new leading role in drug discovery. Development time can be drastically reduced through intelligent support using IT. Examples include molecular simulation and machine learning to determine drug targeting molecules and predict cell membrane permeability, plasma stability, and toxicity among other aspects, making fast industrial development of new drugs possible. Akiyama and Ohue are working in innovative middle molecule drug discovery research in collaboration with faculty members from the School of Life Science and Technology as well as other areas.

Soft robotics
Koeichi Suzuki, Hitoyuki Nabe, Hiroto Tanaka
School of Engineering

Conventional robotics has focused on speed, power, accuracy, and reliability. Although these efforts have yielded outstanding results in industry, today’s robots still have difficulty engaging in soft movement which is so easy for living creatures. One example of such movement is using the appropriate amount of strength to hold a baby. In recent years, there is a new trend towards softness in various fields such as mechanical and electronic engineering, information processing, materials science, and biology. By fusing these fields from a broad perspective, our research seeks to create new robotics based on biological system values such as flexibility, adaptation, and appropriate force. We are advancing research on soft bodies, supple movement, and adaptable intelligence in an effort to develop robots for medical care, nursing care, and a human-robot symbiotic society.

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Human measurement through physiology: determining taste and emotion from facial blood flow response
Naoyuki Hayashi
Institute of Liberal Arts

Darwin described that changes in facial expression related to taste are universal, regardless of time, culture, and region. In 2011, it was discovered that basic taste preferences are related to changes in blood flow in the face. For example, blood flow in the eyelids increases when we taste something good. Later, Hayashi reported a similar result related to the influence of complex taste, and he is now applying it in various fields through an industry-academia partnership. In addition, he discovered that facial blood flow increases only at the site where a massage roller was used. Based on his physiological knowledge of the circulatory system, he is contributing to industrial fields such as food and cosmetics.

Construction of molecular computers, artificial cells, and molecular robots
Masahiro Takinoue
School of Computing

In living systems, DNA and RNA are involved in information retention and transmission, and proteins act as expressions of biological function. By utilizing these biomolecules, Takinoue and colleagues are striving to develop molecular robots with autonomous information processing mechanisms. They use those biomolecules not only from the viewpoint of actual biological properties in living systems; but also from a wider, physicochemical point of view as material science. In the future, molecular robots are expected to be applied to molecular computers and cell controllers in nano/micro spaces such as the inside of a cell, health condition monitors inside our bodies, and machines to deliver medicine to a disease site.
Creating true innovation at the front line of science and technology
Taking a leading role in the advancement of basic and applied research

The mission of the IIR is twofold — to promote active cooperation within and beyond the organization by providing an open research environment, and to continuously improve this environment so that researchers can focus fully on their work and make the most of their abilities. By accomplishing this mission, the IIR can create new research areas and new technologies that address existing problems in society and lay the foundations of future industry. In the long run, the IIR aims to become a leading global innovation center.

Institute of Innovative Research (IIR)

3. Institutes and Schools

Research Centers

International Research Center of Advanced Energy Systems for Sustainability (AES Center)
The AES Center and partner entities pursue development of fundamental next-generation energy technology. They aim to realize “smart communities” that fully incorporate renewable energy sources and energy conservation, practices which are central to achieving a low-carbon society.
Center Director: Institute Professor Takaki Kashiwagi

Advanced Research Center for Social Information Science and Technology (ASIST)
ASIST develops safe and secure social information distribution infrastructures that allow individuals to acquire, confirm, and utilize personal information managed by public administrations and medical institutions. They are also engaged in research and development of systems that provide one-stop service by public administrations and life-long individual health management.
Center Director: Professor Naigaki Ohyama

Cell Biology Center
This Center investigates various aspects of cells through observation, manipulation, and creation of unique cells. They seek to understand molecular mechanisms, from gene expression and editing to synthesis, modification, and the resolution of proteins, and to elucidate the dynamics of cellular functions with applications in next-generation cell engineering.
Center Director: Honorary Professor Yoshinori Ohsumi

Research Units

Research Units carry out work in prioritized areas under the leadership of prominent scientists. Each Unit has an initial 5-year term to deliver results. Tokyo Tech provides Research Units with a wide range of support, including research resources.

Quantum Computing Unit
Basic theory of quantum annealing is one main topic of research. We have been leading the world in this field since our first proposal of quantum annealing in 1998.
Unit Leader: Professor Hiroshi Nishimori

Global Hydrogen Energy Unit
Identifies issues in the development of advanced hydrogen technology and systems, and industrial and social structures; evaluates these from a subjective and scientific perspective, and conducts necessary research and development to realize a hydrogen energy society.
Unit Leader: Institute Professor Kazuaki Yonezawa

Biointerfaces Unit
Performs research to understand how the brain controls the body and develops devices that can be controlled by thought alone, also creates new methodologies and instruments to evaluate organism status for early detection of diseases.
Unit Leader: Professor Takahiro Itoke

Advanced Data Analysis and Modeling Unit
Studies a wide range of phenomena and risks in society from a scientific perspective utilizing big data that includes extremely detailed and comprehensive records of human behaviors to build a sustainable and resilient society.
Unit Leader: Professor Mutsuo Takayasu

Hybrid Materials Unit
Seeks to establish sustainable production methods for indispensable chemical resources to human society without using petroleum resources, and to establish new industries.
Unit Leader: Professor Masakazu Sekigama

Advanced Computational Drug Discovery Unit
Promotes development and application of an open-source, effective drug discovery platform through the integration of IT and biochemical experimentation.
Unit Leader: Assistant Professor Yoshikazu Yoneyama

Research Unit for All Solid-state Battery
Develops the unique solid electrolyte materials including superionic conductors as the key technologies for implementing all-solid-state batteries, which are expected to be the first choice in next-generation batteries.
Unit Leader: Professor Ryoji Kanno

Research Unit of Actinide Management Division
Performs research to understand how the brain controls the body and develops devices that can be controlled by thought alone, also creates new methodologies and instruments to evaluate organism status for early detection of diseases.
Unit Leader: Professor Takahiro Itoke

Sustainable Chemical Resource Production Unit
Seeks to establish sustainable production methods for indispensable chemical resources to human society without using petroleum resources, and to establish new industries.
Unit Leader: Professor Masakazu Sekigama

Nanoscale Catalysis Unit
Develops the unique solid electrolyte materials including superionic conductors as the key technologies for implementing all-solid-state batteries, which are expected to be the first choice in next-generation batteries.
Unit Leader: Professor Ryoji Kanno

International Research Center of Advanced Energy Systems for Sustainability
The AES Center and partner entities pursue development of fundamental next-generation energy technology. They aim to realize “smart communities” that fully incorporate renewable energy sources and energy conservation, practices which are central to achieving a low-carbon society.
Center Director: Institute Professor Takaki Kashiwagi

Laboratory for Future Interdisciplinary Research of Science and Technology (FIRST)
FIRST creates and develops new technologies that meet the needs of society through a fusion of various research fields such as mechanical engineering, electrical and electronic engineering, materials science, information engineering, environmental engineering, disaster prevention engineering, and social engineering to realize a prosperous future for all.

For a Super Smart Society
Smart Healthcare, Smart Infrastructure, Smart Manufacturing, Smart Mobility

Innovative Nuclear Reactor, Nuclear Fusion Reactor, Plasma Science and Technology
LANE aims to contribute to sustainable global development through the establishment of nuclear energy systems that harmonize with society. They also work to propose effective solutions to issues related to natural resources, energy, and global environments, utilizing the fruits of science and engineering research conducted for the responsible use of nuclear energy and the development of advanced radiation technologies to support society.

Laboratory for Chemistry and Life Science (CLS)
The CLS aims to create new scientific principles as well as next-generation technology through the deepening and development of fundamental and applied research in molecular-based chemistry and life science, thereby contributing to the advancement of civilization and the realization of a more prosperous and sustainable society.

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Laboratory for Materials and Structures (MSL)
MSL creates innovative materials with unique properties and functions based on inorganic materials via interdisciplinary materials science. These materials offer wide flexibility as they can be designed using almost all the elements in the periodic table. They also offer a wide range of different materials such as metals and organic materials. MSL works to contribute to solutions for social issues, such as environmental and energy problems, by pursuing new unconventional materials.
Strategic Research Hubs

Promotes cutting-edge global research supported by large-scale government funding

Earth-Life Science Institute (ELSI)

Director: Kei Hirose

ELSI is a unique research institute that seeks to discover the "origins of the Earth and life" by bringing together world-class researchers in geoscience, life science, and planetary science from both Japan and overseas. With about half of its nearly 60 researchers coming from abroad, English is the official language of ELSI. The administration office has a dedicated staff to provide daily life support for non-Japanese researchers. They also provide weekly Japanese classes. ELSI was selected by the MEXT World Premier International Research Center Initiative (WPI). (Established in 2012)

http://www.elsi.jp/

Materials Research Center for Element Strategy (MCES)

Director: Hideo Hosono

The MCES creates useful innovative materials from abundant elements such as gravel and cement. The only center for electronic materials in Japan, it was adopted by the MEXT Element Strategy Initiative Project (Core Research Center Formation). (Established in 2012)

http://www.mces.titech.ac.jp/

Research Center for the Earth Inclusive Sensing

Empathizing with Silent Voices (EIESIV)

This research center is handling sensing and AI/IoT edge technologies to solve social and environmental issues for a co-existence of human race with nature of the Earth. Our technologies perform for phenomenon, which were not previously recognized or measured, in four categorized fields of the Earth, "satoyama" (border zone between mountains and arable flat land), human society and beings. Sensed information are going to be provided for us as beneficial knowledges empathizing among nature and human beings. Through these activities to encourage the people to take proactive behaviors, this center targets to achieve a cooperative society of mutual assistance, as well as co-existence and co-prosperity in the global environments.

Selected as a Center of Innovation (COI) by the Ministry of Education, Culture, Sports, Science and Technology

School of Science

Exploring and creating knowledge

The School of Science comprises four departments, the Departments of Mathematics, Physics, Chemistry, and Earth and Planetary Sciences. The School is committed to advancing science as the culture and knowledge of humankind and to taking a leading role in research and exploration at the frontiers of the natural sciences. While scientific research is independent of immediate applications, the concepts developed and the knowledge obtained through scientific activities have not only enriched the culture of human beings but also, eventually after ten or more years, contributed to solving the problems society and nature were facing.

Structure and Research Fields

Department of Mathematics
- Analysis
- Geometry
- Algebra

Department of Physics
- Elementary Particle Physics
- Nuclear Physics
- Astrophysics

Department of Chemistry
- Physical Chemistry
- Organic Chemistry
- Inorganic Chemistry
- Analytical Chemistry
- Volcanic Chemistry

Department of Earth and Planetary Sciences
- Earth and Space Science
- Space Planetary Science
- Earth Internal Science

Approaches to Research

- Pursuit of Natural Laws
- Origin of the Universe and Matter

Department of Earth and Planetary Sciences

- Exoplanet Observation Research Center
- Solar System Materials, Biogeodynamics, Evolution of the Earth's Surface
- Deep Earth Materials, Geomagnetism, Interiors, Deep Earth Dynamics
- Space Earth Science
- Space Planetary Science

Department of Chemistry

- Energy Issues
- Energy, Environment
- Inorganic and Analytical Chemistry
- Volcanic Chemistry

Department of Physics

- Appearance of Natural Laws
- Origin of the Universe and Matter

Department of Mathematics

- Center for Research in the Financial Sciences

Table: institutes and schools

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<tr>
<th>Institute</th>
<th>Domestic Students</th>
<th>International Students</th>
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<tr>
<td>Students in Bachelor’s Program/International Students</td>
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<td></td>
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<tr>
<td>Students in Master’s Program/International Students</td>
<td>50/10</td>
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</tbody>
</table>
Creating new industries and advancing civilization

The School of Engineering comprises the Departments of Mechanical Engineering, Systems and Control Engineering, Electrical and Electronic Engineering, Information and Communications Engineering, and Industrial Engineering and Economics. We promote basic research aiming to expand the subjects in each technological field and promote interdisciplinary research through the establishment of cross-sectional groups with a focus on issues related to future society.

The School of Engineering Industry-University Cooperation Office organizes research teams made up of the best faculty members for each issue to respond to specific needs from industries. Through these systems, we advance technical development to identify solutions for a wide range of social issues and explore new industries such as renewable energy and energy saving technology, diversified spatial-temporal system management, innovative interface devices and information networks that make use of the five senses.

Structure and Research Fields

- **Department of Electrical and Electronic Engineering**
  - Control Theory
  - Measurement Theory
  - Computer Vision
  - Network Control
  - Bio-Machine Hybrid Systems
  - Sports Science and Engineering
  - Energy Conversion Control
  - Electronic Devices
  - Electronic Materials and Properties
  - Wave Communications
  - Circuit System
  - Electric Power Energy
  - Power Conversion Device
  - Electromagnetic Actuators
  - Quantum Sensors
  - Biosensors
  - Spintronics
  - Green Devices
  - Photonics
  - Integrated Circuits
  - Plasma
  - Antennas

- **Department of Information and Communications Engineering**
  - Telecommunication
  - Signal Processing
  - VLSI and Computation
  - Human Informatics
  - Telecommunications Networks and Security
  - Wireless Power Supply
  - Analogously Distributed Network
  - Cloud Computing
  - Human Cooperative AI
  - Machine Learning
  - Big Data Analysis
  - Sensory Sensing

- **Department of Industrial Engineering and Economics**
  - Industrial Systems
  - Human-Oriented Systems
  - Operations and Management
  - OR
  - Mathematical Information Technology
  - Corporate Governance
  - Management Strategy and Marketing
  - Humanomics
  - Clometrics
  - Game Theory and Experimental Economics
  - Macro Economics and Econometrics

Approaches to Research

- **Space Exploration Project**
- **Wearable Devices and Systems**
- **Cyber World**
- **Physical World**
- **Comprehensive IoT Technology**
- **Smart Power Grid**
- **Human-Centric Technology**
  - Supporting enjoyment, comfort, and happiness
- **Intelligent Robotics**
  - Responding to the Needs of Industry

Interdisciplinary Research Group for the Direct Exploration of New Industries

School of Materials and Chemical Technology

Creating a civilization in which all living things can prosper

The School of Materials and Chemical Technology comprises two departments, Materials Science and Engineering, and Chemical Science and Engineering. It is dedicated to creating new functions based on a solid understanding of the structures and properties of matter. It also aims to nurture researchers and engineers capable of discovering principles and methods for controlling the dynamic chemical processes of substances. This is a place for top-level researchers to interact and cooperate, and for the education of young people interested in exploring solutions to issues related to the environment, energy, resources, safety, and health through the application of various materials.

Structure and Research Fields

- **Department of Materials Sciences and Engineering**
  - Energy
  - Organic and Polymeric Materials
  - Inorganic Materials
  - Energy Science and Engineering
  - Human Centered Science and Biomedical
  - Nuclear Engineering
  - Materials Structure and System
  - Environment, Catalysis and Process
  - Synthesis and Transformation
  - Nano and Device
  - Energy Science and Engineering
  - Human Centered Science and Biomedical
  - Nuclear Engineering

Approaches to Research

- **Innovation Center for Materials Science and Engineering**
  - Making Tokyo Tech Chemistry and Materials Science one of the World’s Top 10 Research Departments
  - Collaboration with High-Impact Laboratories and Centers
  - Collaboration with Top Universities in Japan and Overseas
  - Collaboration with Industry-University Cooperation
  - Collaboration with Domestic-International Collaboration

Innovation Center for Materials Science and Engineering

- **New Academic Fields related to Applied Chemistry**
  - Amorphous Processes
  - Analytical Chemistry
  - Environmental Chemistry
  - Life/Health Chemistry
  - Pharmaceutical Chemistry
  - Polymer Chemistry
  - Separation and Refinement Processes
  - Advanced Manufacturing Processes
  - Energy/Environmental Chemistry
  - Synthesis and Transformation
  - Nano and Device

Making Tokyo Tech Chemistry and Materials Science one of the World’s Top 10 Research Departments
Creating a future information society

"Information" is a vague entity. In order to see, analyze, and turn information into something usable, research on advanced mathematical theory, high-performance computing technology, and artificial intelligence is essential. While information can now be processed by computers to enable more efficient application, there are still many theories that have yet to be proven and technologies that have yet to be developed to realize the true potential of information and understand how to make even better use of it. There must be potentially vast applications of information that have yet to be imagined, and the School of Computing is engaged in the establishment of advanced theories of information and the creation of cutting-edge technologies from the perspectives of both science and engineering to fully explore this vast potential. We are working to gain a deeper understanding of what information really is and can be used, and to develop innovative technologies through the application of this knowledge. We are continuously in pursuit of information science and technology that contribute to society.

Approaches to Research

Structure and Research Fields

- Mathematical modeling
- Mathematical Statistics
- Algorithm design
- Programming languages
- Blockchain
- Software Development Environment
- High Performance Computing
- Cybersecurity
- Mathematical Optimization
- Information Visualization
- Distributed Systems
- Topology
- Partial Differential Equation

- Artificial Intelligence
- Natural Language Processing
- Speech/Image Recognition
- Human Interface
- Virtual Reality
- Database
- IoT
- Bioinformatics

Approaches to Research

- Post-Silicon Computing
- Molecular Calculation
- Brain Calculation
- Drug Discovery
- Knowledge Discovery
- Language Recognition
- Security
- Cloud Technology
- HPC
- VR/AR
- IoT
- Big data
- CG
- Bio
- Computational Theory
- Mathematical Science Base

Broad Research Fields Contributing to the Creation of a Future Information Society

Mathematical Science for Information/Computation
Advanced Software/Computational Science
Social Implementation of Advanced ICT

- Mathematical modeling
- Mathematical Statistics
- Algorithm design
- Programming languages
- Blockchain
- Software Development Environment
- High Performance Computing
- Cybersecurity
- Mathematical Optimization
- Information Visualization
- Distributed Systems
- Topology
- Partial Differential Equation

- Artificial Intelligence
- Natural Language Processing
- Speech/Image Recognition
- Human Interface
- Virtual Reality
- Database
- IoT
- Bioinformatics

SmartBio – promoting the integration of life science and biotechnology to become a knowledge creation base for life innovation

The realization of a super smart society (The 5th Science and Technology Basic Plan of Japan) requires the establishment of biotechnology that responds to social needs, through the expansion of life science research. This is what we call smart biotechnology (SmartBio). The School of Life Science and Technology promotes research and education for the creation of new smart biotechnology through the integration of biomolecular science, bioengineering, and bioinformatics based on solid basic research in life science to fulfill its function as a knowledge creation base for life innovation through social collaboration.

Structure and Research Fields

- Department of Life Science and Technology
  - Biopolymers
  - Medical Chemistry
  - Chemical Biology
  - Clarification/Control Technology of Cell Functions
  - Disease Mechanism/Development of New Therapeutic Technology
  - Biomarker
  - Development/Regeneration
  - Brain Science/Neuroscience
  - Bioimaging
  - Bioinformatics
  - Biomolecular Devices
  - Genetic Engineering
  - Protein Engineering
  - Micromachining
  - Biomatatus
  - Biosensors
  - Biomolecule Analysis Technology
  - Bicatalysts
  - Plant Science
  - Biomass Technology
  - Biological Evolution

Approaches to Research

Promotion of Research

We promote a broad range of activities in both basic and applied life science and technology to advance fundamental and innovative research. The following chart shows our faculty’s areas of research.

Promotion of Industry-University Collaboration & Social Collaboration

Supporting interdisciplinary integration and collaboration as the knowledge base for life innovation

Advantages for Collaboration with LiHub

- Access to information on the cutting-edge of international trends in life science bio-industries
- Recruitment of young talents in life science and technology
- Research and screening for new business seeds
- Networking among different areas in academia and industrial sectors
- Support to establish core competencies

LiHub-produced innovative structure for university-industry collaboration: Many research groups – Many companies through flexible and supportive interfaces of LiHub Groups

Conventional Industry-University Collaboration: One Research Group – One Company

School of Life Science and Technology

LiHub

School of Computing

3. Institutes and Schools
Solving complex social issues through the integration of humanities and science for inclusive and sustainable global development

The sustainable development of humanity and society requires that the institute’s students absorb a broad range of humanities and social science knowledge while they learn science and engineering concepts. Furthermore, we expect our students to become individuals capable of applying and developing knowledge to create new technologies and academic fields. To make this happen, in addition to the Department of Architecture and Building Engineering, Civil and Environmental Engineering, and Transdisciplinary Science and Engineering, the School of Environment and Society has established the Department of Social and Human Sciences and the Department of Innovation Science, as well as the Technology and Innovation Management Professional Master’s Degree Program in graduate-level studies. By integrating the humanities and science, we aim to cultivate leading scientists and engineers truly capable of contributing to the global society.

The Institute for Liberal Arts (ILA) carries out interdisciplinary research centering on the fields of humanity and social science. We seek to truly understand what we are and what the world is to discover new bases of intellect and knowledge to enhance lifestyles. At the same time, the ILA also plays a role as a think tank to implement science and engineering knowledge into society, which contributes to large-scale research projects developed by Tokyo Tech.

### Structure and Research Fields

#### Institute for Liberal Arts

**Society 5.0 in 2030**

**For a humane future**

**Dialogue of multiple knowledge**

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**Utilizing logos, pathos, and ethos from the liberal arts**

**Fundamentally and ethically integrating science and engineering knowledge in a comprehensive manner**

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**Tokyo Tech’s Knowledge of Science and Engineering**

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**To future visions**

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**3S Sustainable Safe Smart**

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**Synergistic Environmental Engineering**

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**Metalization**

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**Organization/Integration**

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**Multiplexed development**

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**Information classification**

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**3S - Sustainable Safe Smart**

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**Common Fields**

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**Environmentally friendly goods**

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**Socialization Engineering**

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**Synergistic Environmental Engineering**

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**Engineering designed for harmonization with the natural environment and human society**

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**Socialization Engineering**

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**Synergistic Environmental Engineering**

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**Common Fields**

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**Environmentally friendly goods**

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**Socialization Engineering**

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**Synergistic Environmental Engineering**

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**Synergistic Environmental Engineering**

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**Common Fields**

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**Environmentally friendly goods**

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**Socialization Engineering**

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**Campus Location & Access**

**Suzukakedai Campus**
4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8503 JAPAN
- 5-minute walk from Suzukakedai Station on the Tokyu Den-en-toshi Line
- 70 minutes from Haneda Airport
- 130 minutes from Narita Airport

**Ookayama Campus**
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8550 JAPAN
- 1-minute walk from Ookayama Station on the Tokyo Yamanote Line & Tokyo Oimachi Line & Tokyo Meguro Lines
- 45 minutes from Haneda Airport
- 85 minutes from Narita Airport

**Tamachi Campus**
3-3-6 Shibaura, Minato-ku, Tokyo 108-0023 JAPAN
- 2-minute walk from Tamachi Station on the JR Yamanote Line & Keihin-Tohoku Line
- 25 minutes from Haneda Airport
- 65 minutes from Narita Airport

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