Vision Statement by the Prospective Director

Institute of Transformative Bio-Molecules

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Changing the world with molecules

Molecules are small but essential parts of all life on the planet. Molecules are groups of atoms chemically bound together that behave as a single unit. They are central to the operation of all industries, including pharmaceuticals, agrochemicals, electronic materials, solar cells, displays, petrochemicals, automotive manufacturing, plastics, polymers and many more sectors. It is my strong belief that molecules have the power to change the way we do science and the way we live. A few examples of molecules that have changed the world include penicillin (the first miracle drug, and the beginning of the field of antibiotics), the Haber-Bosch catalyst (necessary for the production of ammonia from nitrogen gas and hydrogen gas, *the* critical step in the synthesis of fertilizer, without which many people would starve), and green fluorescent protein (GFP, the essential imaging tool for bio-related science, that is used to help doctors differentiate cancerous tissue from non-cancerous tissue during surgery). This is a small sampling of cases where a single molecule changed the world. Such innovative molecules are defined as "*transformative molecules*". The focal point of our proposal is to develop *transformative bio-molecules* that will be key to solving urgent problems at the interface of Chemistry and Biology.

Chemists and biologists have the common goal of understanding and manipulating the relationship between molecular structure and function. The placement of atoms relative to one another in a molecule can have a huge impact on the properties and function of a molecule, and understanding and controlling this relationship is one of the key goals of the synthetic chemist. For example, there are two stable forms of C_2H_6O. In the first, the two carbons are bound directly to each other, which makes ethanol (CH_3-CH_2-OH), a liquid boiling at 78 °C, that has intoxicating properties. However, if the oxygen is inserted *between* the two carbons (CH_3-O-CH_3), the product is methyl ether, which is a gas at room temperature and is a refrigerant or a fuel substitute for propane! Even more remarkably, molecules can have dramatically different properties simply by changing the arrangement of atoms in space, without any other differences in bonding. Such changes are so dramatic in terms of biological interactions, that they can turn medicines into poisons. Thankfully chemists are able to control and manipulate the arrangements of atoms in space, and thus can synthesize molecules such as ethanol or methyl ether at will. This type of control of structure, and thus properties, is the basis of a considerable amount of chemistry, and is widely exploited by biologists. Even biological systems, which seem highly complex, are typically comprised of macromolecules (large molecules, such as hemoglobin) interacting with simple "small" molecules, (such as oxygen and carbon dioxide), that function in accordance with well defined laws of science and nature.

Other examples of macromolecules that play a significant role in biology include DNA, which is a well-defined orientation of bases and sugars that twists into a double helix. Proteins are carefully arranged sequences of amino acids, whose detailed molecular structure controls the three dimensional shape of the protein and that shape controls function. For example "mis-folding" of protiens, as observed in prions, can cause dramatically different properties of otherwise identical molecules. Thus it is clear that the organization of these biologically relevant macromolecules, which is derived from atomic level structure, is critical for biological function.

Our dream is to take advantage of the dramatic relationship between structure and function and, by marrying state-of-the-art synthetic chemistry with systems biology, develop new ways of creating designer bio-active molecules with targeted properties. These new synthetic paradigms will permit the design and synthesis of bioactive molecules both in a beaker and actually inside living organisms (*ex vivo* and *in vivo*). Most importantly, our ultimate goal is to solve urgent problems in science and technology that have an impact on society.

The Institute of Transformative Bio-molecules

The core members (partners) of the Center have been selected as a logical consequence of the main goals of the Center. In order to address the next level of collaboration between chemists and biologists that will have a global impact, we have chosen to put plant- and animal-based molecular biologists side-by-side with synthetic chemists. The fundamental problems that will be addressed by this type of collaboration link directly to global issues such as food production and land-use management, which will be of increasing concern as our planet warms and arable land becomes more and more scarce. Most importantly, chemists and molecular plant biologists all speak in a molecular language, with biologists having an understanding of the types of molecules needed to affect a given biological event, and chemists knowing how to make these molecules. With these broad goals in mind, researchers were then chosen for their significant achievements in the field, as described later in this document.

Thus, synthetic chemistry, catalysis chemistry, systems biology, and plant/animal science will be the key components of the Center. These research foci build on existing strengths at Nagoya University, which will be key to the establishment of the new interdisciplinary molecular institute: The Institute of Transformative Bio-Molecules (ITBM), whose aim is to create cutting-edge science with potentially significant societal impact. The *raison d'être* of the Center is *to establish a world-leading molecular research institute for designing and synthesizing molecules directed towards the discovery, visualization, and manipulation of biological systems*. The unique approach of the Center is to apply recent discoveries in molecular activation-transforming catalysis, with the support of molecular design and theoretical chemistry, to solve fundamental and urgent biological problems and to explore advanced systems biology. This is an unprecedented endeavor and the first such research institute in the world.

In this Center, we primarily focus on developing key molecules for two major problems in biology; (1) molecules that precisely control biotic function and production, and (2) molecules that realize innovative bio-imaging. To accomplish these projects, we will (3) develop catalysts that enable incredibly efficient synthesis and molecule activation on demand and under a variety of biologically relevant conditions.

The followings are our representative subjects and target molecules:

(1) Development of Molecules for Enhanced Biotic Productivity and Quality

(a) Molecules that dramatically enhance plant growth [A solution to potential global food crises]

(b) Molecules that improve animal reproduction innovatively [Also directed towards potential global food crises]

(c) Molecules that overcome the genome barriers to produce novel crops [New frontiers in biology]

(2) Development of Molecules for Innovative Bio-imaging

(a) Target biological models [Real-time all-molecule live bio-imaging]

(b) Highly efficient, full-color fluorescent molecules [Real-time all-molecule live bio-imaging]

(c) Specific conjugation technologies [Real-time all-molecule live bio-imaging]

(3) Development of Innovative Molecule-Activation Catalysis

(a) Catalysts activating C-H bonds [Direct transformations of bio-molecules]

(b) Catalysts acting without heavy metals [Environmentally benign molecular transformations]

(c) Catalysts for protein ligation [De novo synthesis of bio-macromolecules]

(d) Catalysts for in vivo chemical transformations [New frontiers in chemistry and biology]

The interface of chemistry and molecular biology has already resulted in important new research fields of significant scientific impact, such as chemical biology and medicinal chemistry, which have in turn led to incredible advances in modern medicine. We plan to bring this to a new level by exploiting newly developed molecule-activation chemistry partnered with fundamental biological systems of plants and animals. This research endeavor will have significant impacts in the closely related fields of chemical biology and medicinal chemistry, but most importantly, on areas that are of urgent global importance including world food production.

The identity of the Center is its capability to develop completely new bioactive molecules with carefully designed functions. With biologists knowing *what* functions they need in molecules and chemists knowing *how* to install these functions, huge advances are predicted from our Center. This unique approach will attract the top researchers worldwide and also nurture the next generation of cutting-edge research, unrestricted by the bounds of traditional disciplines.

Interdisciplinary research is the key

The importance of interdisciplinary research cannot be overemphasized. It is obvious from the history of science and technology that many significant discoveries emerged at the interface of disciplines. Marshaling the accumulated wisdom of all modern science is critically important to solve urgent global issues such as food production, thereby establishing a sustainable society. In addition to working to understand the best ways to mitigate effects of global environmental change, it is absolutely critical that scientists also develop a plan that permits us to adapt to these changes and, moreover, to provide the new materials, techniques and processes that are needed to develop a sustainable society.

The value of sharing knowledge freely, or learning from others with complementary expertise is inestimable. Catalyst-enabling synthetic chemistry with broad directions has been the focus of the Itami lab since it was first established at Nagoya University. By coordinating a broad multidisciplinary effort to generate new functional molecules useful in the development and understanding of bio-related science and materials science, we have been able to make significant advances in a variety of chemistry-related fields. Many of these advances came from interactions with researchers outside our traditional area of synthetic organic chemistry. For example, our lab has been able to synthesize structurally uniform carbon nanotubes, nanographenes, and small-molecule modulators of enzymes, which were inspired by and initiated by discussions with top researchers outside of organic chemistry.

Thus the direction of the proposed institute, in which synthetic chemistry and systems biology, will be married, is a dramatic, but logical leap considering the strength in both of these areas at Nagoya University. Setting up an environment where the best researchers in these disciplines are able to interact frequently and informally is the goal of the current proposal.

Molecule-activation chemistry for advanced systems biology – Perfect match and perfect timing

Recent years have seen a remarkable reintegration of chemistry and biology, particularly in the field of medicinal chemistry and chemical biology. However, the synthetic tools that have been applied in the molecule synthesis part of these collaborative efforts are typically still based on "classical" organic reactions manifesting limited efficiency with lengthy sequences and operations. Remarkably, in many cases the reactions employed are many decades old. Given that the molecule-making step is often the bottleneck in such research, overall synthetic efficiency is critical for almost all areas of chemistry and biology.

Methods that can directly activate and transform simple organic molecules under a variety of conditions are clearly the key for streamlining the synthesis of biologically relevant target molecules. Indeed, the quest for such methods has been the driving force behind enormous recent efforts in the synthetic community including in the Itami lab, culminating in a wealth of useful catalytic systems for reactions directly converting simple building blocks into useful molecular entities. For example, the groups of Itami and Crudden have developed efficient and unique catalysts for activating aromatic and heteroaromatic compounds, which are privileged structures in bio-active molecules. The groups of Ooi and Bode have developed catalysts that can activate bio-related molecules such as amino acid derivatives and peptides. By using these sophisticated catalysts, designed in the labs of our PIs, the rapid synthesis of a number of biologically active compounds and pharmaceutically relevant molecules is now possible. In particular, some of the most recent results from the Itami lab on the *discovery of novel potent inhibitors of histone deacetylases (HDACs) using molecule-activation chemistry* makes it clear that a truly efficient catalyst can have a huge impact in biology. With the advent of this exciting field of catalyst-enabling molecule-activation chemistry, the way that chemists plan and execute chemical synthesis is changing. Indeed, a number of pharmaceutical and agricultural companies as well as chemical industries have already started to use catalysts developed in the Itami labs on a daily basis.

In parallel to the progress of catalyst-enabling synthetic chemistry in Nagoya University, our biology groups have made a number of breathtaking discoveries at a rapid pace while exploring extremely important and fundamental biological issues. For example, Higashiyama discovered key molecules in plant reproduction including pollen tube guidance and double fertilization, which are directly involved in crop production and plant breeding. Kinoshita recently uncovered the long-thought mode of action of the plant hormone auxin for plant growth. Torii discovered several peptide molecules that promote plant growth. Yoshimura identified key hormone TSH regulating seasonal reproduction in animals.

Thus recent discoveries by biologists at Nagoya University have clearly demonstrated the impact of individual molecules on biological systems. The next, critical phase of this research is *designing* properties in specific molecules, *synthesizing* them in a truly practical way and *studying or imaging* their actual interactions in the biological system. In order to engineer such breakthroughs, we plan to partner the discoveries of our biologists with technologies developed by our chemistry groups. In particular, the application of the emerging field of catalyst-enabling synthetic chemistry to systems biology research to solve compelling biological issues such as food production problem and bio-imaging is a timely and important goal.

Our cutting-edge catalysts will be able to activate and transform “seed” or “lead” biofunctional molecules, discovered by our biology groups, into more selective and more active molecules in a single operation. In addition, this new molecule-making and -manipulating technology will allow us to synthesize rationally designed candidate molecules, provided by our theoretical groups, in a straightforward and rapid manner.

Moreover, our molecule-activation catalysts will be applied for the *in vivo* manipulation of biofunctional molecules such that we can employ the existing biochemical machinery for the synthesis of the core structure, and then employ an artificial small-molecule catalyst to decorate and manipulate these products to enhance their activity and control their properties. Finally, in order to understand the action of our molecules in biological systems beyond macroscopic effects, we will use state-of-the-art imaging techniques also developed as part of this program.

Experiment-theory synergy for rational design

In addition to the chemistry-biology collaboration, experiment-theory synergy is also essential to fulfill our goal of developing transformative bio-molecules. Although it is clear that our highly efficient catalysts will dramatically accelerate the development and discovery of key bio-functional molecules, the synthesis-testing experiments alone cannot provide a detailed understanding as to how the molecules, empirically shown to be effective, exert bioactivity at an atomic level. Theoretical support is critically needed to rationally design truly effective molecules with high potency and selectivity. As a pioneer in the quantum chemical study of complex systems, Irle will spearhead this task. He recently established quantum chemical molecular dynamics techniques to study transformative processes in materials sciences on realistic timescales. Parameter development is an integral part of his research, and the method itself is now being incorporated in fragmentation and genetic algorithms that will allow the simulation of small bio-molecules with entire proteins under realistic timescales on the basis of accurate quantum chemical potentials.

In addition to the above-mentioned computer-assisted studies, it is also essential to design the next generation of imaging molecules, by taking advantage of the understanding chemists have of structure-function relationships. In this regard, Yamaguchi is indispensable to this Center. With a strong command of physical organic chemistry, organo-element chemistry, and synthetic chemistry, Yamaguchi has designed and synthesized a large number of structurally unique molecules possessing unusual photophysical and electronic properties. Yamaguchi is an international expert in this field, knowing exactly how to design and synthesize new molecular structures that will display a desired optical property (i.e. fluorescence, luminescence, phosphorescence). Thus, Yamaguchi's molecular design and Irle's theoretical methods will play critical roles in the development of highly efficient full-color fluorescent small peptides for new bio-imaging tools. Very recently, the Yamaguchi–Irle–Itami team established an extremely reliable methodological platform for understanding and designing fluorescent molecules. These newly developed methodologies will be an essential element of our Center.

Our dream team

A team of Principal Investigators (PIs) has been assembled to permit us to address these critical issues in Chemistry and Biology. This is the ideal moment to initiate this urgent research, based on predicted global need, and current advances in both synthetic chemistry and systems biology. There is no doubt that with the team we have assembled, great things will happen within the new WPI-funded research environment. The scientific strengths of our PIs and their roles in the Center are described briefly below.

Kenichiro Itami (41) Prospective Director of the Center, Nagoya University

Organic synthesis, catalysis, molecule activation, pharmaceuticals, organic materials

In addition to holding the role of director, I will also be one of the PIs in the Center and thus will actively collaborate with all PIs, playing a key role in synthesizing molecules using our catalysts. My research group has developed a number of unique and highly efficient molecular catalysts for C-H coupling, an ideal approach to rapidly increase molecular complexity in organic synthesis. Our synthesis-oriented catalyst development campaign has provided opportunities for markedly different connection/disconnection strategies in the construction of useful organic molecules, including pharmaceuticals, natural products, and new enzyme inhibitors.

As the Center Director, I have taken into consideration several important issues that need to be implemented while assembling the team described below: potential for interdisciplinary interactions, excellence in research with a high international profile, ability to nurture young scientists and lay a firm foundation for the continued growth of the Center. The Center must be ambitious but maintain realistic goals, we must routinely assess our progress based on real deliverables, and adapt in order to maximize the success of the institute. I will make every effort to fulfill our mission and to ensure that our Center is ranked the best in the world.

Tetsuya Higashiyama (41) Prospective Vice-Director of the Center, Nagoya University

Plant reproduction, peptides, micro-genomics, cell manipulation, live cell imaging

Higashiyama is one of the most recognized plant biologists focusing on the identification of key molecules of plant reproduction. In particular, his discovery of the long-sought (~140 years) pollen tube attractant molecule “LURE”, which is essential for plant reproduction, has secured his position as a world-renowned biologist. The identification of LURE peptides provide us with a major breakthrough to study and control pollen tube guidance of flowering plants and to break reproductive barriers. Moreover, he has also made significant technical development of micro-genomics and live cell imaging. Currently, he serves as one of the youngest directors of prestigious ERATO funding program supported by the Japan Science and Technology Agency. He will be involved mainly in the development of molecules that can overcome species barriers as well as innovative bio-imaging tools, collaborating with the groups of Yamaguchi, Irle, Torii, Itami, Ooi, Crudden, and Bode.

Jeffrey W. Bode (38) Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland

Organic synthesis, carbene-catalysis, protein synthesis, bioconjugation, oligomerization

Bode is a gifted young rising star in synthetic chemistry. The work of Bode is directed towards the chemical synthesis of molecules and conjugates that are currently outside the reach of conventional synthetic methods. He is developing new chemical reactions and catalysts for making molecules of biological importance such as proteins, glycopeptides, sequence and length-controlled polymers, and covalent conjugates of these large structures. Recently, he developed a novel method for the ligation of unprotected protein segments, producing synthetic proteins very efficiently. He is also known as one of the pioneers of an entirely new branch of catalytic asymmetric synthesis, commonly known as "chiral *N*-heterocyclic carbene (NHC) catalysis". His catalysts will be applied in the development of molecules that selectively induce plant growth and molecules that can overcome species barrier. In addition, collaborating with the group of Ooi, he will also be involved in the development of small-molecule catalysts that can activate and transform bio-molecules *in vivo*.

Cathleen M. Crudden (46) Queen's University, Canada

Organometallic catalysis, organo-element catalysis, nanoporous materials

Crudden centers on the use of catalysis for organic synthesis and materials chemistry. A key focus is the use of boron chemistry to achieve these goals in an efficient and green manner. She will be involved mainly in the development of molecules that selectively induce plant growth as well as in our bio-imaging projects. In addition to her expertise in synthesis and catalysis, Crudden is one of the most visible and capable leaders of the chemistry community in the world. Most notably, she was one of the Canadian organizers for Pacifichem 2010, the largest chemistry conference worldwide, and will continue on as one of two Canadian representatives for 2015. Even more importantly, she is now serving as the President of the Canadian Society for Chemistry. Her visions combined with her enthusiasm and energy are unmatched and essential to this Center.

Stephan Irle (45) Nagoya University

Quantum chemistry, molecular dynamics, approximate density functional theory

The central theme of Irle's work is the quantum chemical study of complex systems. On the basis of approximate density functional theory (DFT) techniques, his group can conduct the routine, fully quantum chemical simulation of large molecular systems containing 1000's of atoms on timescales into the 10's of nanoseconds, and thus provide a theoretical means to understand and design efficient chemical synthesis in complex molecular environments and to characterize and create novel molecules for bio-related applications. In this Center, he will mainly apply his density-functional tight-binding (DFTB) method for the understanding of ligand-protein interactions as well as the rational design of fluorescent molecules for bio-imaging, collaborating with virtually all members.

Toshinori Kinoshita (44) Nagoya University

Plant molecular biology, plant chemical biology, stomata, auxin, plant growth

Kinoshita has been studying signaling pathways of stomatal opening and closing, and molecular mechanisms of plant cell growth in response to the phytohormone auxin. By using genetic, biochemical, and physiological approaches, he has identified the key components regulating stomatal opening and closing reported by Darwin in 1898. More recently, he reported evidence for the existence of an unidentified auxin receptor responsible for plant growth, which became the basis of one of the core projects in this Center. He will be involved mainly in the development of molecules that selectively induce plant growth, collaborating with the groups of Itami, Crudden, Ooi, and Torii.

Takashi Ooi (47) Nagoya University

Organic ion pair catalysis, molecular recognition, molecule activation, pharmaceuticals

Ooi has been creating a bold stream of research on the molecular design of various chiral organic ion pairs and their rational structural modifications for eliciting unique functions as molecular catalysts, providing a solid basis for safe and sustainable supply of useful organic compounds. His accomplishments have had a significant impact on the frontiers of chemistry in terms of developing a fundamental understanding of the relationship between the three-dimensional structure of a chiral organic ion pair and its catalytic and stereocontrolling abilities. He will be involved mainly in the development of molecules that selectively induce plant growth, molecules that improve animal reproduction, and molecules that can overcome species barrier, collaborating with the groups of Kinoshita, Yoshimura, Higashiyama, Bode, and Itami.

Keiko Torii (46) University of Washington, USA

Plant development, cell-cell communication, peptides, receptor kinase, stomata

Through being selected as an HHMI-GBMF investigator of Howard Hughes Medical Institute, Torii has been recognized as “the 15 most innovative plant scientists in the US". Torii has elucidated the molecular and genetic basis of cell-cell communication and dynamics of cellular behaviors that coordinate plant organ morphogenesis and tissue patterning. She has also identified two peptides, EPFL4 and EPFL6, that act as ligands for receptor kinases to promote plant growth. She will be involved mainly in the development of molecules that selectively induce plant growth as well as the bio-imaging project, collaborating with the groups of Higashiyama, Kinoshita, Itami, Yamaguchi, and Irle.

Shigehiro Yamaguchi (43) Nagoya University

Fluorescent molecules, molecular design, physical organic chemistry

Yamaguchi works on a variety of topics in the general fields of main group chemistry and physical organic chemistry. In particular, emphasis is placed on the development of new functional π-electron materials possessing unusual photophysical and electronic properties. On the basis of the new design concepts emanating from his lab, he is able to exploit the features of various main group elements as well as the newly developed synthetic methodologies, various types of functional materials have been developed; including the key molecule in commercial organic electroluminescent devises. He will be involved mainly in the development of innovative bio-imaging tools, collaborating with the groups of Higashiyama, Irle, Itami, and Crudden.

Takashi Yoshimura (42) Nagoya University

Biological clock, systems biology, animal production, pharmaceuticals

Yoshimura's research focuses on the regulatory mechanisms of biological clock and signal transduction pathway regulating seasonal reproduction in vertebrates. The uniqueness of his research lies in the use of non-model animals and the systems biology approach. Most importantly, he has identified a "springtime hormone" that triggers seasonal reproduction and clarified the signal transduction cascade for animal seasonal reproduction. Yoshimura also identified a key gene regulating seasonal reproduction in birds, and later demonstrated that the discovered reproduction mechanism is conserved in seasonal mammalian species. These breakthrough findings became the basis of one of the core projects in the Center. He will be involved mainly in the development of molecules that improve animal reproduction, collaborating with the groups of Ooi, Bode, Irle, and Itami.

Nagoya University – Suitability and support

Nagoya University is the ideal place to establish this new interdisciplinary research institute. This proposal builds not only on the strong tradition of research in chemistry and biology at Nagoya University but also on the free and vibrant academic culture that has traditionally nurtured the creativity of young scientists. This is clearly evidenced in the freedom given to academic stars emanating from Nagoya University, including Osamu Shimomura (Nobel Prize in Chemistry, 2008) and Ryoji Noyori (Nobel Prize in Chemistry, 2001). As evidence of this continuing strategy, Nagoya University is fully supportive of one of its youngest full professors in the University as the leader of this largest research program in Japan.

The enthusiastic support for this initiative offered by Nagoya University is remarkable. For example, Nagoya University has agreed to revise the University rules to give executive authority to the Center Director such that he may make top-down decisions on the important matters of the Center; they have agreed to enable the Center to be independent in the execution of its budget; and will allow the Center to develop its own personnel policies and management. For a Japanese institution, this is remarkable latitude. In addition to establishing an efficient and effective administrate office to ensure both research and administrative business can be carried out in English, Nagoya University has also agreed to provide financial/personnel assistance and building space to the Center.

Last but not least, Nagoya University has agreed to permit Yoshihito Watanabe, a Trustee and a Vice-President of Nagoya University and a Vice-President of the Chemical Society of Japan, to take up the position of Administrative Director of this Center. He has already demonstrated his talents in making the Global COE program in Chemistry a great success as the Project Leader, and also has been responsible for the Internationalization Initiatives of Nagoya University including the Global 30 program. Among his achievements in this mission, he launched international undergraduate and graduate courses, in which all classes are delivered in English. Thus by committing University Trustee Watanabe to this Center, Nagoya University is clearly illustrating its strongest support for the Center, and its willingness to accelerate reforms in the entire system of Nagoya University.

Final remarks

I am simply thrilled to head this ambitious, full-scale collaboration of synthetic chemists and systems biologists that is the crux of this application. What became obvious through extensive discussions between the chemists and biologists that are part of our team was the common recognition that “molecules” are the key not only for chemistry and biology, but also for exploring a new interdisciplinary research fields. With the recent exciting progress in molecule-activation chemistry and systems biology, the time has come to put in place the necessary means to develop a collaboration that will have impacts on science and society for decades to come.

In addition to these impacts, the present WPI project is also critical to further enhance the prestige and international visibility of Nagoya University, and also to lead a remarkable reformation of research culture. The importance of department-based conventional research and education is obvious. However, we believe that our Center will be the lead example in drastically reforming the University in the long term. We will establish the “stage” on which researchers, sharing responsibility and problem awareness, can talk about their dreams freely and can put their innovative ideas into practice immediately. What our future success brings will not be limited to innovations in bio-molecular research. I strongly believe that the Center, with researchers of various backgrounds, will accelerate the mixing/merging of people, ideas, and research, and also help nurture a new generation of scientists unrestricted by the bounds of traditional disciplines. This will surely have a positive influence on the way Japanese universities carry out research and education. In this regard, we must succeed by all means.

The Center will connect molecules, create value, and change the world, one molecule at a time.

Kenichiro Itami

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