RIKEN RESEARCH

OCTOBER
2009 Volume 4 Number 10

To catch a failing star

HIGHLIGHT OF THE MONTH
Forecasting solar-energy harvests

RESEARCH HIGHLIGHTS
Netting new physics from a stellar collapse
Silent strike from thunderclouds
A tight fit helps energy transmit
Giving DNA segments the golden touch
Smoothing the way to superior screens
Roaming receptors
A slight twist with serious consequences
Intercepting the transmission
Tipping the balance of immune response
Joining the dots on stem cell signaling

FRONTLINE
Developing new stimuli-responsive molecular devices

ROUNDUP
First Noyori Summer School held at RIKEN Harima Institute

POSTCARDS
Dr. Hao Liu (Graduate School of Engineering, Chiba University, Chiba, Japan)

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Forecasting solar-energy harvests

Photosynthetic processes in an artificial system can be described accurately by a quantum physical theory

Most life on earth depends on the sun to provide the energy needed to sustain its function. For more than a billion years, photosynthesis—a mechanism that has evolved to perfection—has allowed plants to convert solar energy into chemical energy. Solar energy is by far the most abundant source of renewable energy available to us.

Aiming to reproduce this highly efficient process of energy generation in bid to meet ever-increasing energy demands, researchers have begun building artificial photosynthetic reaction systems based on principles similar to those found in nature.

Now, a team of researchers from the RIKEN Advanced Science Institute in Wako and the University of Michigan, USA, has developed a quantum physical model that accurately describes the function of these artificial photosynthetic systems, and provides an understanding of their reaction kinetics that could lead to significant improvements in their conversion efficiencies[1].

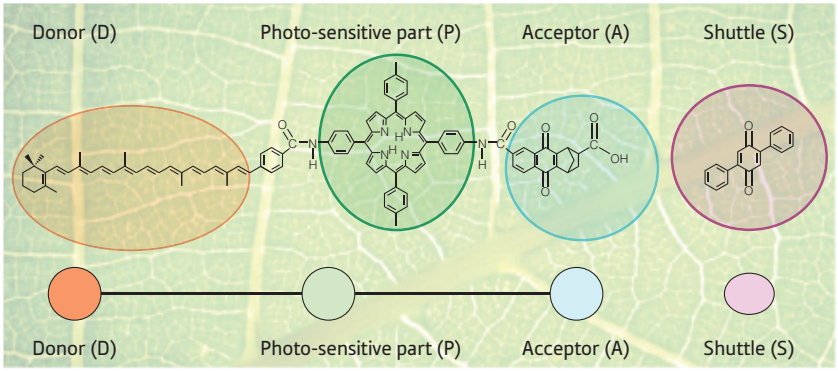

Figure 1: Emulating natural photosynthesis. Photosynthesis occurs in the green chlorophyll pigments found in leaves. As shown in the overlay, an artificial photosynthesis reaction system is based on a molecular triad composed of a donor (D), photosensitive part (P) and an acceptor (A). A shuttle molecule (S) transfers charges across the system.

Copying nature

Emulating plants to harvest solar energy has enormous potential. According to Franco Nori, who leads the team, about 10,000 times more solar energy reaches the surface of the Earth than humankind currently consumes.

Plants convert solar energy based on a cascade of chemical reactions. First, light is absorbed by a photosensitive molecule, chlorophyll, which then creates a pair of positive and negative electrical charges. As these charges become separated, a number of consequent reactions lead to the transport of a proton from one end of a thin membrane to the other. This establishes a concentration difference. The electrochemical energy stored as a result of this separation is then transformed into chemical energy through the conversion of the molecule ADP to ATP. ATP carries the energy that powers almost all biological processes in the cell.

Artificial photosynthetic systems are based on similar reactions, but consist of three different molecules placed within a membrane similar to that found in plant cells (Fig. 1).

The artificial photosynthesis process studied by Nori's team works as a proton pump in which protons are shuttled from one side of a thin membrane to the other (Fig. 2). This creates an electrical potential that can then be used for chemical reactions. In the system investigated, a photosensitive molecule absorbs light and separates the charges at both ends of the triad. A shuttle molecule collects the negative charge from the acceptor molecule, along with a proton from the outer end of the membrane. The shuttle then drifts towards the other end of the membrane and unloads its electron so that it compensates the positive charge on the donor molecule. Similarly, the proton is deposited from the shuttle molecule across the inner end of the membrane. Eventually, the empty shuttle molecule drifts back to its origin ready to restart the process. As a consequence, similar to natural photosynthesis, protons are transported from one end of the membrane to the other, which allows the conversion of ADP to ATP. The overall conversion efficiency of the artificial structures is about 4%, which is half of the efficiency of the natural process.

Bringing quantum physics to life

Theoretical modeling of the conversion process is important for further optimization of the system. To this end, the researchers developed a novel analytical model of individual process kinetics rather than relying on atomic simulations. This approach allows the researchers to reach a better understanding of the individual reactions. "We derived and numerically solved a system of master equations to

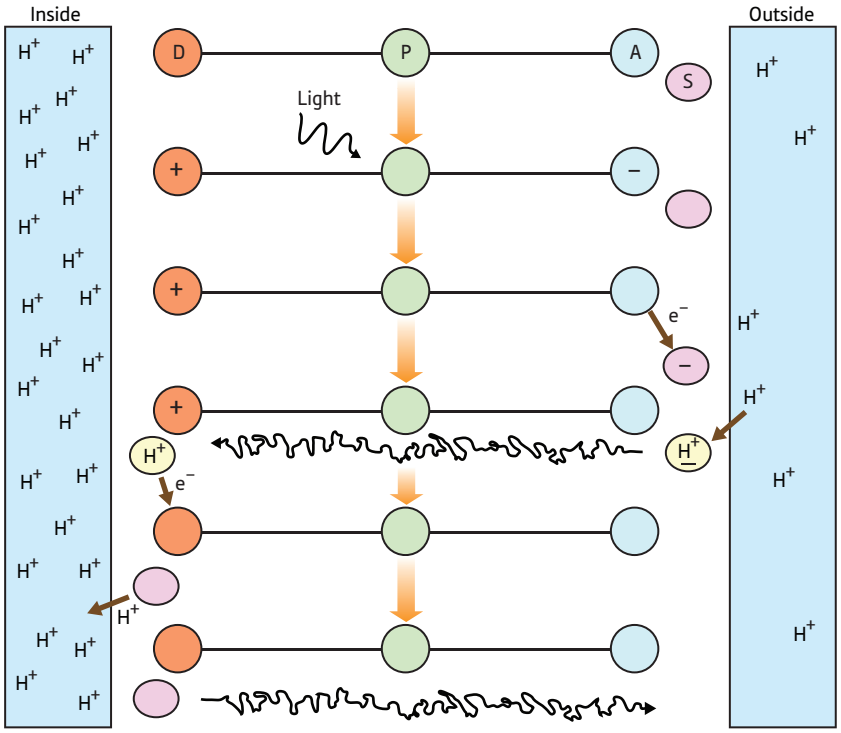

Figure 2: The proton pump. Protons are transferred from the outside (right) to the inside (left) of a membrane through a number of steps. Working from top to bottom, the molecule (P) in the ground state absorbs light, which leads to the separation of positive and negative charges to the donor (D) and acceptor (A) ends of the triad. The shuttle molecule (S) then collects an electron, e^-, and a proton, H^+, before diffusing across the molecule and transferring the electron to the donor, where it recombines with the positive charge. The proton finally gets transferred across the membrane. More information is available online at http://dml.riken.jp/files/photosynthesis.ppt.

describe the kinetics of the process," explains team-member Pulak Ghosh.

To adapt the theoretical model to experimental reality, the researchers included a number of predefined variables such as external light intensity. They then optimized the remaining variables to reach a state where the conversion efficiency of the system is optimized within these given experimental constraints. According to the researchers, these optimized theoretical results were very accurate and confirm experimental observations. "Our model arrives at a correct prediction for the quantum efficiency of the proton pump," says team-member Anatoly Smirnov.

Observation of the interplay between the different processes and careful analysis of the results reveal design deficiencies in the artificial system. In particular, the proton pump process saturates at light intensities that are lower than the standard intensity from the sun, meaning that not all incoming light is harvested, note the researchers.

Performance boost

The model can also be used to study novel artificial devices with a view to improving their performance. For example, Nori and his colleagues are investigating systems designed to directly convert light energy into an electrical current rather than using the indirect method of proton separation. Furthermore, Nori believes that light-harvesting antennae could be added to the molecular structure to collect the solar energy more efficiently and then channel this energy directly to the reaction centers.

Despite numerous advances in artificial systems, nature still has much to teach us. "We will also analyze mechanisms of proton pumping in natural biosystems … with the goal to apply this knowledge for the creation of efficient and powerful artificial light-induced proton pumps," comments Nori.

While it is remarkable that artificial systems have already achieved a light-conversion efficiency that, if optimized, is not too different to biological systems, use of molecular triads in large-scale technological applications remains a challenge. However, the results from this theoretical investigation into the kinetics of the fundamental processes of this artificial system will provide a strong basis for the further exploration of biological processes. Ultimately, this could provide a very efficient blue print for harvesting renewable energies based on nature's own recipe. ■

1. Ghosh, P. K., Smirnov, A. Y. & Nori, F. Modeling light-driven proton pumps in artificial photosynthetic reaction centers. *Journal of Chemical Physics* **131**, 035102 (2009).

About the researcher

Franco Nori does research work in theoretical condensed matter physics, including quantum information processing, computational physics, transport phenomena (e.g., of vortices, electrons, grains), energy-conversion and solar energy, as well as the dynamics of complex systems. His research work is interdisciplinary and is also exploring the interface between atomic physics, quantum optics, nano-science, and computing. He uses models based on physics to make predictions that can be tested experimentally and that can be used to better understand the observed phenomena. In 2002 he was elected Fellow of the American Physical Society, in 2003 Fellow of the Institute of Physics in the United Kingdom, and in 2007 Fellow of the American Association for the Advancement of Science (AAAS). He has received an "Excellence in Research Award" and an "Excellence in Education Award" from the University of Michigan, USA. He has given more than 250 presentations, and published more than 250 research papers, including numerous publications in the highest impact journals. He obtained a Masters and a PhD in Physics from the University of Illinois and completed postdoctoral work at the University of California. He then became Professor at the University of Michigan and afterwards Laboratory Head at RIKEN.

Netting new physics from a stellar collapse

Failed supernovae could provide a strong flux of neutrinos near the detection limit of current observatories

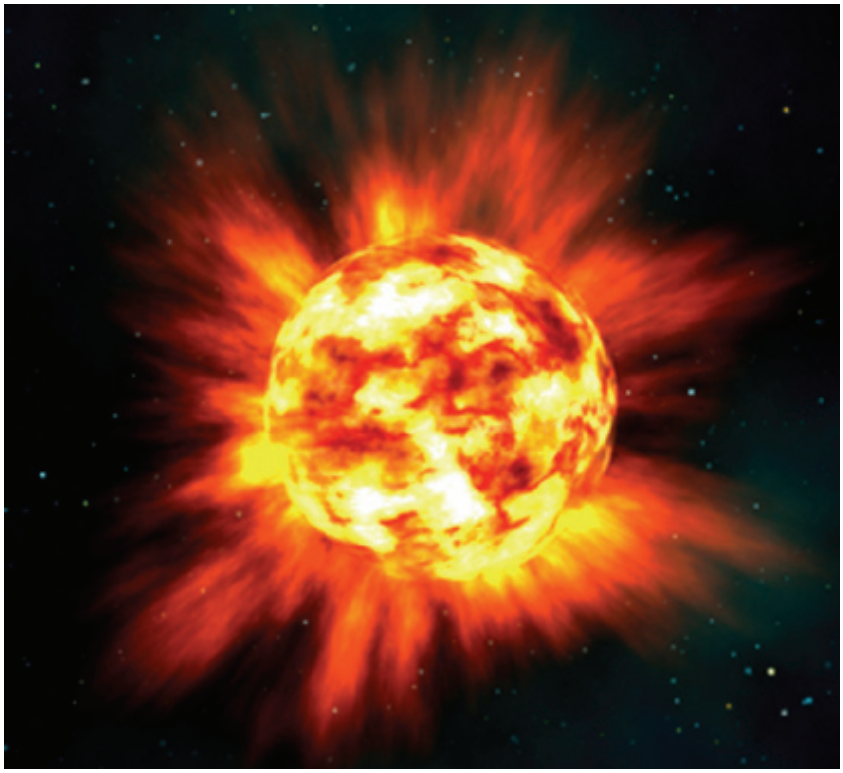

Figure 1: An artist's impression of a star going supernova. However some very large stars may collapse into black holes instead.

Stars more than eight times the mass of our Sun eventually collapse under their own weight, and may explode into spectacular supernovae (Fig. 1). The temperatures and pressures generated in these events are so intense they create a large burst of particles called neutrinos, which eventually reach Earth.

Now, Cecilia Lunardini at Arizona State University and RIKEN BNL Research Center in Upton, USA, has calculated that lots of neutrinos may also reach Earth from 'failed supernovae'—huge stars that collapse without exploding to produce black holes[1].

The neutrino contribution from these failed supernovae could greatly increase the total flux of neutrinos reaching Earth from millions of collapsing stars throughout the universe. Lunardini calls this total the 'diffuse supernova neutrino flux'.

"In the diffuse flux, the contribution of each supernova is very small, but the total is detectable," she says. "We only need to reach the right experimental sensitivity to start detecting it."

Unfortunately, neutrinos are notoriously difficult to detect because they barely interact with other matter. One of the world's best detectors is the Super-Kamiokande ('Super-K') neutrino observatory, situated in a mine beneath Gifu prefecture Japan, and even it requires 50,000 tons of ultra-pure water to scatter the neutrinos.

Lunardini decided to calculate whether a device like Super-K could detect neutrinos from supernovae collapsing into black holes.

"The idea that neutrinos are emitted in black-hole-forming collapses is not new," she says. "The novelty of my work is in showing that these neutrinos can build up to a significant diffuse flux, thus adding to the flux from successful supernovae."

In fact, Lunardini calculated that the Earth may receive up to one neutrino per square centimeter per second from failed supernovae. This is even more than the flux from successful supernovae, but probably beyond the detection limit of Super-K.

There is growing support in the scientific community to build larger, more sensitive neutrino detectors containing up to a million tons of water. Once these bigger detectors are built, Lunardini thinks it is only a matter of time before the diffuse neutrino flux can be measured. The results could reveal some fascinating new physics.

"[Failed supernovae] are very difficult to study with telescopes due to the fact that they do not explode but just disappear from the sky without much emission other than neutrinos," says Lunardini. "The possibility to get information on these objects—even just to test their presence and how many there are in the universe—with neutrinos is exciting." ■

1. Lunardini, C. Diffuse neutrino flux from failed supernovae. *Physical Review Letters* **102**, 231101 (2009).

Silent strike from thunderclouds

Radiation bursts from thunderclouds may not always be associated with lightning

(2009) Dave Rabin

Figure 1: The powerful electric fields inside thunderclouds can produce long-lasting bursts of gamma radiation and charged particles.

Thunderclouds generate very strong electric fields that can accelerate electrons to relativistic speeds. This 'electron avalanche' goes on to collide with atoms and produce an intense burst of radiation, which is sometimes followed by lightning.

Recently, Harufumi Tsuchiya at the RIKEN Advanced Science Institute and co-workers observed a long radiation burst above the mountains of Japan that they believe was associated with thunderclouds, but not with any lightning[1]. Their crucial breakthrough was to measure both charged particles and gamma-rays, giving important information on the origins of the burst.

Most radiation bursts only last up to a few milliseconds, but longer events lasting up to a few minutes have been observed from aircraft, on high mountains and near the coast of Japan. These longer bursts have puzzled scientists because theory suggests that an electron avalanche should last only a few microseconds at most.

Tsuchiya and co-workers have been working to understand these elusive long radiation bursts. In January 2007 they detected a long burst of gamma-rays over the Sea of Japan[2]. More recently, they installed a detector near Norikura Cosmic-Ray Observatory, located 2,770 meters above sea level in the mountains of Gifu prefecture, which regularly experiences thunderstorms.

The new detector contains a plastic scintillator that is very sensitive to charged particles, but not to photons, and a sodium iodide scintillator that is sensitive to both types of radiation. By combining these two signals, the researchers were able to record both charged particles and gamma rays from a burst lasting 90 seconds during thunderstorms shortly after midnight on 20 September 2008.

"Although we made our detector by ourselves, the so-called 'anti-coincidence method' to distinguish between particles and photons is very common in cosmic-ray measurement and satellite observations," says Tsuchiya. Thanks to this simultaneous detection, the researchers were able to calculate that the main source of the burst was only about 90 meters away from their detector, and resulted from a 200-meter-long acceleration region in the thunderclouds.

The charged particles they recorded were probably the most energetic electrons, which survive long distances in the atmosphere. In fact, the researchers estimate that the burst produced around 300 million electrons with energies of over 20 MeV. These are higher energies than previously anticipated, and could go some way to explaining how longer radiation bursts might arise from thunderclouds (Fig. 1).

"We believe this kind of observation would be useful to better understand a fast charging mechanism of thunderclouds, and possibly lightning initiation," says Tsuchiya. ■

1. Tsuchiya, H., Enoto, T., Torii, T., Nakazawa, K., Yuasa, T., Torii, S., Fukuyama, T., Yamaguchi, T., Kato, H., Okano, M. *et al*. Observation of an energetic radiation burst from mountain-top thunderclouds. *Physical Review Letters* **102**, 255003 (2009).
2. Tsuchiya, H., Enoto, T., Yamada, T., Yuasa, T., Kawaharada, M., Kitaguchi, T., Kokubun, M., Kato, H., Okano, M., Nakamura, S. & Makishima, K. Detection of high-energy gamma rays from winter thunderclouds. *Physical Review Letters* **99**, 165002 (2007).

A tight fit helps energy transmit

Mechanically trapped molecules throw light on energy transfer within artificial photosynthetic systems

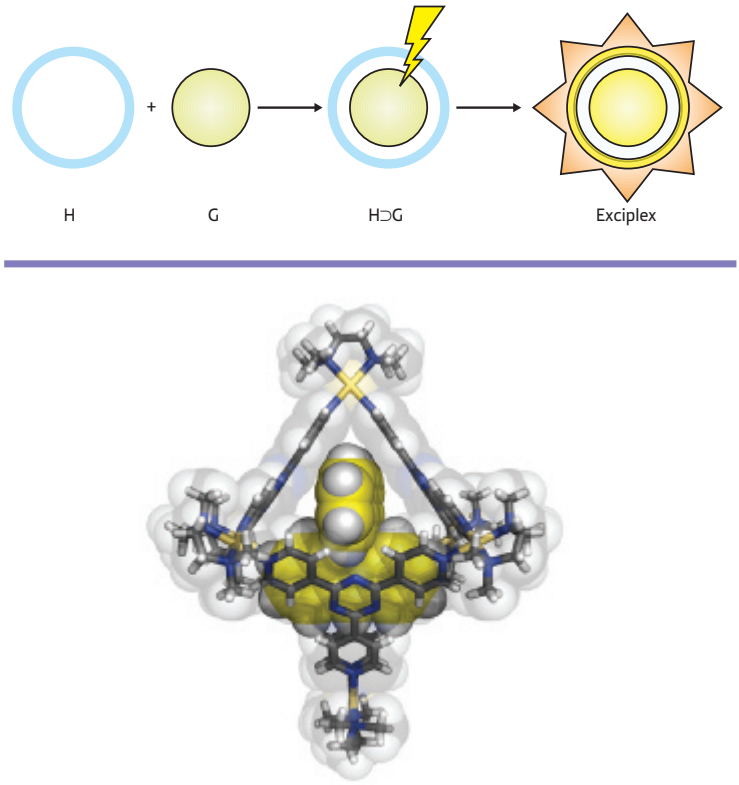

Figure 1: Schematic formation of a mechanically trapped host (H)–guest (G) exciplex complex (top) and the x-ray crystal structure of the host–guest complex (bottom).

Although plants have efficiently captured energy from sunlight for millions of years, producing light-harvesting and energy storage devices based on photosynthesis is no easy task. Now, a research team led by Makoto Fujita from the University of Tokyo and Tahei Tahara from the RIKEN Advanced Science Institute has found a simple way to mimic the initial stage of photosynthesis by mechanically trapping a guest molecule inside a cage structure[1].

Prototypical artificial photosynthetic systems contain donor- and acceptor-type molecules. When light is absorbed by the donor, it becomes photo-excited—its electrons move to higher energy states. The acceptor group can receive and store this energy, but only if the donor and acceptor come together into what is known as an exciplex, or an excited state complex.

The difficulty is bringing together the donor and acceptor groups. An exciplex can form only if the two components are close enough and in the proper orientation during photo-excitation.

Fujita and Tahara's team ensured exciplex formation by locking a photoactive donor molecule called bisanthracene inside a molecular cage acceptor (Fig. 1). The self-assembled cage is highly water soluble as it contains six charged palladium atoms. The cage panels, however, are organic molecules and form a hydrophobic (water-repelling) pocket inside the cage when dissolved in water.

According to Jeremy Klosterman, the lead author of the study, the donor molecule bisanthracene is not soluble in water and, at high temperatures, is driven into the hydrophobic cage pocket. Once the solution cools, the bisanthracene is too large to exit the cage and remains trapped inside.

"Synthetically, our system is incredibly straightforward," says Klosterman. "Simply mixing the host cage and the guest bisanthracene in water and heating causes the exciplex to self-assemble."

Ultrafast laser spectroscopy of the host–guest complex found that the excited bisanthracene donor transferred the majority of its energy, 82%, to the exciplex state. Klosterman says the effective energy transfer is due to the extremely tight fit and strong interactions between the mechanically linked host and guest.

"This study helped us resolve an important question," states Klosterman. "Typically fluorescent molecules are non-emissive upon encapsulation by organometallic cages, but we can now infer that energy transfer into the host–guest exciplex state is an important photophysical process."

By choosing a guest molecule that does not form an exciplex, the researchers have developed a new water-soluble fluorescent dye with a long lifetime—ideal for applications including biological sensing and imaging. ■

1. Klosterman, J.K., Iwamura, M., Tahara, T. & Fujita. M. Energy transfer in a mechanically trapped exciplex. *Journal of the American Chemical Society* **131**, 9478–9479 (2009).

Giving DNA segments the golden touch

Controlled positioning of nucleic acids on gold nanoparticles creates new possibilities for bottom-up nanotechnologies

Metal nanoparticles have radically different electronic, optical and magnetic properties from their larger states, which makes them useful as materials in new, ultra-small devices such as biological sensors. Constructing such devices, however, is difficult because, unlike atoms, nanoparticles lack directional bonds that allow them to be arranged precisely.

One strategy to overcome this limitation is to attach oligonucleotides—single strands of molecules that constitute DNA—to nanoparticle surfaces, and then, through Watson–Crick base pairing of the nucleic acids, join the nanoparticles together. However, manipulating the number and positions of oligonucleotides on the nanoparticles has been impossible.

Now, Kenji Suzuki, Kazuo Hosokawa and Mizuo Maeda from the RIKEN Advanced Science Institute in Wako have developed a method to immobilize oligonucleotides on gold nanoparticle surfaces with precise control over their number and geometric arrangement[1]. Because this procedure can be used for nanoparticles other than gold, it should initiate improved techniques for spontaneous assembly of small materials into complex structures—so-called 'bottom–up' nanotechnologies.

In their proof-of-principle experiment, Suzuki and colleagues combined two oligonucleotides containing reactive thiol (sulfur-hydrogen) groups with a third, non-thiolated oligonucleotide template to create a DNA nanostructure (Fig. 1). This DNA template was then reacted with a gold nanoparticle, forming a complex through the active thiol groups. Finally, the DNA template was separated from the complex, leaving two free oligonucleotide strands on the gold nanoparticle.

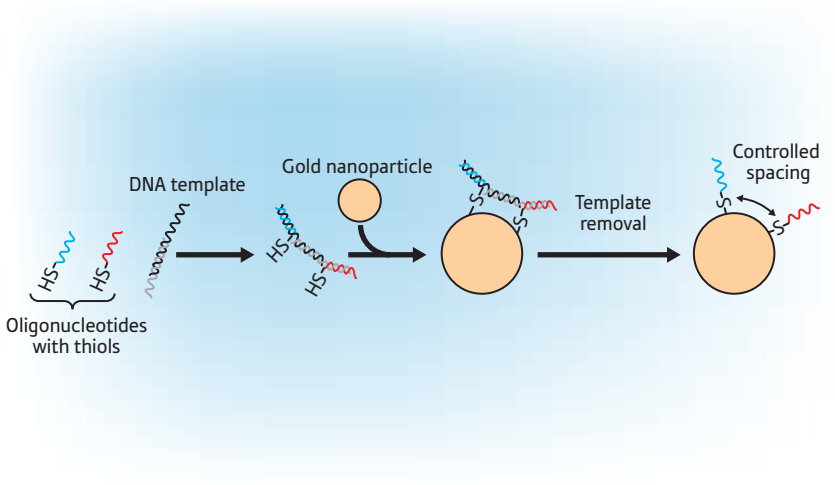

Figure 1: Combining reactive oligonucleotides with a DNA template allows controlled positioning of the nucleic acids on the surface of a gold nanoparticle.

Transmission electron microscopy imaging confirmed the success of the DNA template technique. Without the template, the nucleic acids were observed at random locations on the nanoparticles. With the template, the two oligonucleotides were always seen at distinct geometric positions as arrangements controlled by the specific DNA nanostructure.

Suzuki says that top-down methods such as immobilization by a tip of scanning probe microscope are very precise, but prohibitively slow. In contrast, his team's DNA template is extremely fast and automated, and represents a new type of 'nanomachine.'

"Each nanomachine catches a certain number of oligonucleotides, immobilizes them onto a nanoparticle, and then releases them," explains Suzuki. "Naturally, this task is best suited to a DNA template having complementary sequences to the oligonucleotides, since duplex formation is then completely reversible."

According to Suzuki, creating nanoparticles with atom-like binding capabilities would have advantages beyond developing new types of nanostructures. "I knew that such a result would be welcomed by many other researchers and would accelerate the whole field," he says. ■

1. Suzuki, K., Hosokawa, K. & Maeda, M. Controlling the number and positions of oligonucleotides on gold nanoparticle surfaces. *Journal of the American Chemical Society* **131**, 7518–7519 (2009).

Smoothing the way to superior screens

A double-solvent approach makes electrospray deposition a better choice for fabricating organic light-emitting diodes

Figure 1: OLED displays are strong competitors with LC screens like this one.

Electrospray-deposited polymer films can be used to make organic light-emitting diodes (OLEDs) with better characteristics than those made from spin-coated films, according to Yutaka Yamagata of the RIKEN Center for Intellectual Property Strategies, Wako, and colleagues. These researchers have used a novel dual-solvent concept to make the electrospray-deposited films smoother than before, thereby enabling the superior devices to be built[1].

Organic light-emitting diodes are now entering the market place as screens for mobile phones and televisions (Fig. 1), and mass-production techniques are needed to simplify the manufacturing process and reduce costs and wastage.

Previous attempts to use the electrospray-deposition technique for OLED fabrication have failed to produce polymer films that compete with other fabrication techniques. Yamagata and colleagues decided to use a combination of two solvents to improve this technique, which uses a thin glass capillary with the polymer solution stored inside and a conductive wire inserted in it. When a high voltage is applied between this conductive wire and the OLED electrodes on the substrate, the solution sprays out of the capillary end as atomized droplets that are attracted to the substrate by electrostatic force. This means there is little solution wastage as the spray is highly directed.

They found that the first solvent evaporated rapidly after the atomization of the solution, leaving a small amount of the second solvent, which has a higher boiling point, in the droplets. When the polymer concentrations were finely tuned, the carefully chosen second solvent enabled the not-quite-dry atomized droplets to form a smooth, continuous film of high quality over the OLED electrode. Because the films dry quickly on the surface, it should be easy to fabricate multilayer devices without mixing of materials between layers.

From a series of comparative experiments, the researchers found that devices fabricated from electrospray-deposited films turned on at lower voltages and could support higher current densities than ones made from spin-coated films. At low voltages, the electrospray deposition also enabled higher pixel intensity.

"We have discovered a range of conditions using a two-solvent method that can make extremely smooth thin films using electrospray deposition," says Yamagata. "Using this technology these devices could be manufactured as inexpensively as printing newspapers."

Yamagata also notes that: "The advantage of using electrospray deposition is that we can fabricate both smooth films and nanostructured film using the same technology." In the future he believes that this advantage "will also be useful in controlling the structure of organic semiconductor junctions for organic solar cells." ■

1. Ju, J. M., Yamagata, Y. & Higuchi, T. Thin-film fabrication method for organic light-emitting diodes using electrospray deposition. *Advanced Materials* published online 2 July 2009 (doi: 10.1002/adma.200900444).

Roaming receptors

Neurons communicate more efficiently when neuronal activity causes inhibitory receptors to diffuse away from the synapse

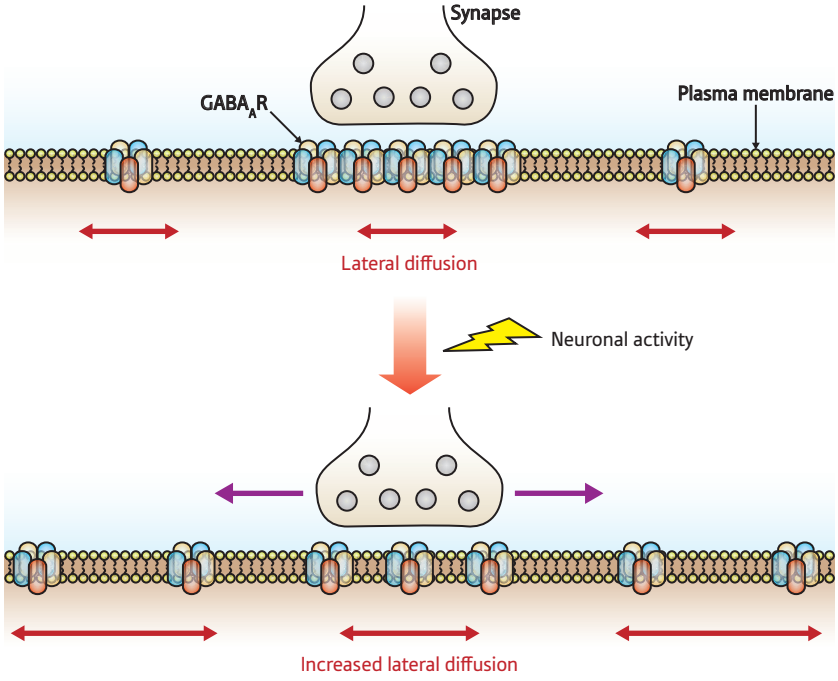

Figure 1: New molecular mechanism to explain the modulation of synaptic strength via lateral diffusion. The diffusion of GABA receptors (GABA$_A$R) away from the synapse reduces the number of receptors (blue, red and yellow clusters), without changing the receptor number on the plasma membrane.

Changes in the synaptic strength of neurons, effected by repeated neuronal activity, drive important behavioral processes such as learning and memory. Continuous simulation of a neuron, for example, can alter the signaling or molecular architecture at its synapses, and make it easier—or harder—for that neuron to activate other neurons with which it communicates.

Synaptic efficacy can be enhanced by increasing the process known as excitatory neurotransmission, or by decreasing its opposing process, inhibitory neurotransmission. These processes trigger or halt the firing of neurons, respectively. Now, an international team of researchers, including Hiroko Bannai at the RIKEN Brain Science Institute in Wako, has shown that neuronal activity drives inhibitory neurotransmitter receptors to diffuse away from the synapse, which substantially reduces inhibitory neurotransmission at those synapses[1].

In many parts of the brain, inhibitory neurotransmission is mediated by a molecule called γ-aminobutyric acid (GABA) binding to its receptors at synapses. When the researchers induced neuronal activity in cultured neurons, they found fewer GABA receptors—and fewer GABA receptor scaffolding molecules—at the synapses of these neurons. This resulted in less efficient inhibitory neurotransmission owing to smaller inhibitory electrical currents through these receptors.

To respond to GABA molecules, GABA receptors must be on the surface of the neuron. But neuronal activity did not change the levels of GABA receptors that were on the surface or that were inside the neuron. Instead, when the researchers labeled the GABA receptors and watched them move, they found that induction of neuronal activity enhanced the diffusion of the receptors along the surface of the neuron. Importantly, it seemed that greater GABA receptor diffusion caused by neuronal activity reduced the amount of time that the GABA receptors spent at the synapse (Fig. 1). This could explain why neuronal activity caused a decrease in inhibitory neurotransmission.

The investigators obtained these results in neurons from the hippocampus, a part of the brain involved in spatial learning. However, other reports have shown that neuronal activity can reduce diffusion and enhance synaptic targeting of receptors for a different inhibitory neurotransmitter called glycine in neurons from the spinal cord. This suggests that different cell types—and different receptors—may respond to neuronal activity in totally different ways.

These findings indicate that "lateral diffusion, regulated through interactions between receptors and their scaffolding proteins, could provide a simple mechanism for rapid and reversible activity-dependent modulation of synaptic strength," says Bannai. "Next, we plan to elucidate the detailed molecular mechanisms controlling receptor diffusion dynamics." ■

1. Bannai, H., Lévi, S., Schweizer, C., Inoue, T., Launey, T., Racine, V., Sibarita, J-B., Mikoshiba, K. & Triller, A. Activity-dependent tuning of inhibitory neurotransmission based on GABA$_A$R diffusion dynamics. *Neuron* **62**, 670–682 (2009).

A slight twist with serious consequences

Subtle structural changes can markedly affect one protein's toxic impact, and may help explain the distinctive pathology of Huntington's disease

Nobody is entirely sure what the huntingtin protein does when it's operating normally, but the effects of its malfunction are all too clear: increasingly severe neurological deficits, affecting motor activity and memory and ultimately resulting in dementia.

Huntingtin typically contains an internal stretch of repeated glutamine residues, but this number increases—sometimes dramatically—in Huntington's disease (HD) patients. This is accompanied by a marked structural change, with the protein aggregating into fibrous clumps within the brain known as amyloid deposits. It is unclear, however, what effect these have on neuronal health or the role they play in HD pathology.

In other plaque-forming diseases, such as prion disease and Alzheimer's, these amyloid aggregates can assume multiple different structures with variable physiological effects. Now, RIKEN Brain Science Institute investigator Motomasa Tanaka and colleagues have found that huntingtin amyloids have similar properties[1].

Temperature is known to affect protein folding, and initial experiments revealed subtle differences between huntingtin fibrils formed at body temperature versus 4 °C. Both samples were rich in structures known as β-sheets, but the lower temperature amyloids proved more fragile and detergent-sensitive, and exhibited higher affinity for labeling dyes. These distinct conformations could also be 'amplified' in cells; when amyloids formed at a particular temperature were introduced into cells expressing huntingtin with disease-specific numbers of repeats, they acted as seeds for the formation of larger aggregates with the same conformation. Surprisingly, the low-temperature aggregates were found to cause significantly higher levels of cell death than those formed at higher temperatures (Fig. 1).

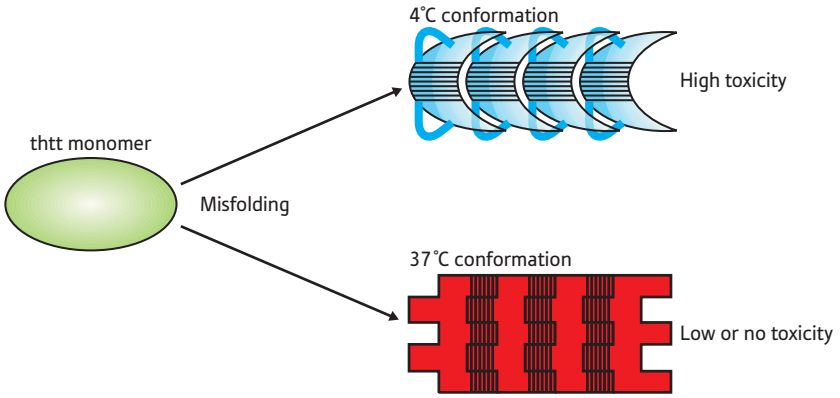

Figure 1: At different temperatures, huntingtin protein (thtt) assumes amyloid aggregates with varying structures. At 4 ˚C (top), it assembles into fibrils with a more 'open' structure, which are more fragile and more toxic to cells. At body temperature (bottom), the fibrils are more rigid and significantly less toxic to cells.

Tanaka's team also found unexpected evidence that huntingtin aggregates isolated from a mouse model of HD assume different conformations depending on the region of the brain in which they formed. For example, amyloids from the striatum resembled low-temperature aggregates, while those isolated from the hippocampus were more similar to aggregates that formed at higher temperatures. These structural characteristics were also reflected in their relative cytotoxicity. Tanaka points out that the striatum is among the brain regions most vulnerable to HD, and suggests that "structural diversity of amyloid may dictate regional specificity of HD."

These new structural insights help explain why different studies have yielded apparently contradictory findings about the extent of huntingtin fibril toxicity, although further investigation will be needed to determine the basis for this differential folding and the altered pathological impact of this alternate conformation. "Our current priority is to understand how the same polypeptide misfolds into distinct amyloid conformations," says Tanaka. ■

1. Nekooki-Machida, Y., Kurosawa, M., Nukina, N., Ito, K., Oda, T. & Tanaka, M. Distinct conformations of *in vitro* and *in vivo* amyloids of huntingtin-exon1 show different cytotoxicity. *Proceedings of the National Academy of Sciences USA* **106**, 9679–9684 (2009).

Intercepting the transmission

A genetically encoded fluorescent sensor offers a real-time glimpse into how a key neurotransmitter relays its message

The nervous system's circuitry is linked together via intercellular junctions known as synapses, and signal transmission across these connections depends on neurotransmitters—specific chemicals that directly deliver excitatory or inhibitory signals from one neuron to another.

L-glutamate, the most widely used excitatory neurotransmitter in the central nervous system, acts in part through proteins in the neuronal membrane called metabotropic glutamate receptors (mGluRs), which belong to the larger family of G protein-coupled receptors (GPCRs). GPCR signaling governs numerous essential cellular functions and has been closely studied, but little is known about the kinetics of mGluR activity.

To dissect the dynamic behavior of these proteins, Thomas Knöpfel's team at the RIKEN Brain Science Institute in Wako collaborated with University College London investigator Païkan Marcaggi to develop an effective tool for monitoring activation for one such receptor, mGluR1, in real time[1].

mGluR molecules act in pairs; each features a large 'Venus Flytrap module' facing outward from the cell, which clamps shut when it binds glutamate and triggers rearrangements that bring the intracellular portions of the two receptor molecules closer together. The team used a method called FRET, in which these intracellular domains were labeled with molecules that only generate a fluorescent signal when in very close proximity to each other (Fig. 1).

Knöpfel and colleagues were able to monitor receptor activity in living cells with unprecedented precision. They found that the receptor was capable of surprisingly rapid, concentration-dependent activation in as little as 10 milliseconds—faster than any other known receptor of this type. Deactivation, on the other hand, was slower, occurring on a time-scale of approximately 50 milliseconds.

Interestingly, they noted that prolonged exposure to glutamate actually increases the sensitivity of the receptor to its ligand, in marked contrast to the desensitization typically observed in such receptors. "Our study reveals a new biophysical property that may be shared by other GPCR receptors," says Marcaggi. Based on this finding and the slow deactivation rate, the researchers were able to develop a model for receptor activity in which mGluR1 signaling behavior relates primarily to overall duration of glutamate release rather than fluctuations in local neurotransmitter concentration.

Beyond these mechanistic insights, Knöpfel hopes that the construct may also prove useful as an all-purpose glutamate sensor. "A particular feature of our sensor is that it is a genetically encoded protein," says Knöpfel. "We are now planning to express it in genetically modified mice to map physiological receptor activation." ■

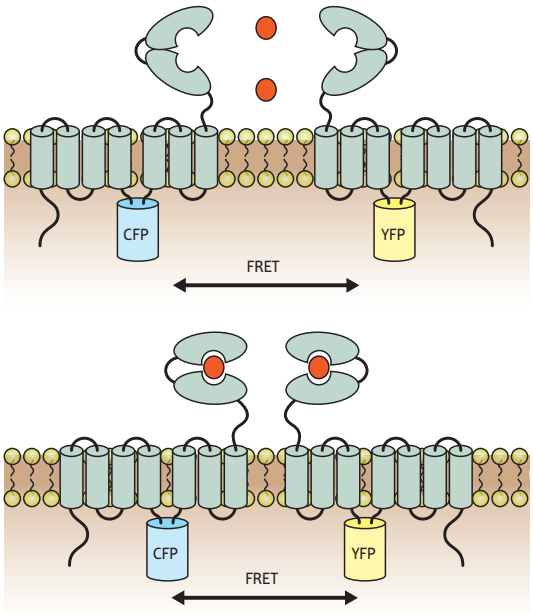

Figure 1: Schematic diagram of the mGluR1 sensor. Cyan (CFP) and yellow fluorescent proteins (YFP) were inserted into the intracellular domain of mGluR1β (top). Receptor molecules form dimers, and binding of glutamate (red dots) induces a rearrangement associated with an increase in fluorescent FRET signal (bottom).

1. Marcaggi, P., Mutoh, H., Dimitrov, D., Beato, M. & Knöpfel, T. Optical measurement of mGluR1 conformational changes reveals fast activation, slow deactivation, and sensitization. *Proceedings of the National Academy of Sciences USA* **106**, 11388–11393 (2009).

Tipping the balance of immune response

Hybrid mice help researchers zoom in on a gene with a potential role in controlling allergic responses

When the immune system encounters a potential threat, antigen-presenting cells deliver chunks of protein from the invading pathogen to naive helper T cells. These naive cells respond by differentiating into one of two classes of mature helper T cells: T_H1 cells, which mobilize the immune system against viruses and other intracellular pathogens, and T_H2 cells, which drive the response against blood-borne threats, such as the parasitic disease leishmaniasis.

Interleukin-4 (IL-4), one of a class of signaling factors known as cytokines, drives T_H2 differentiation and triggers secretion of additional IL-4, resulting in a positive feedback loop that fuels T_H2 production while suppressing T_H1 production. The degree of initial IL-4 production varies considerably between individuals and the resulting 'T_H2 bias' can have serious clinical implications. "T_H2 bias is thought to be a mirror of allergic response, because many T_H2 cytokines tightly associate with pathology of allergy," says Masato Kubo, of the RIKEN Research Center for Allergy and Immunology in Yokohama.

T_H2 bias also varies between different mouse strains, a fact that Kubo, Mark Bix of St. Jude's Children's Research Hospital in Memphis, USA, and colleagues exploited in a recent effort to identify determinants for this trait[1]. It was known that BALB/c strain mice have a high T_H2 bias—producing large quantities of IL-4 following T cell activation—while B10.D2 mice have a 50-fold lower bias. However, a hybrid BALB/c strain generated by Kubo and Bix that contains a chunk of chromosome 16 from the B10.D2 strain also exhibited low bias, suggesting that this segment includes a gene pertinent to this characteristic.

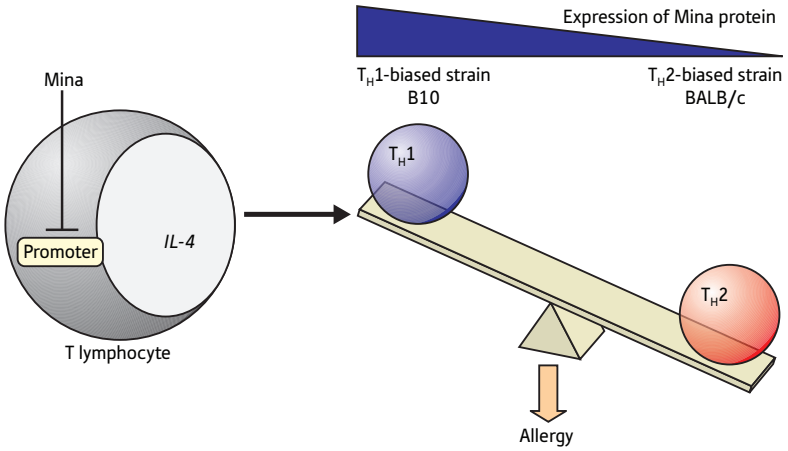

Figure 1: Schematic showing the role of the Mina protein in T_H2 bias. The extent to which the *IL-4* gene is being inhibited by Mina protein (left) affects the maturation of naive T lymphocytes (right). Low levels of Mina mean a greater bias towards T_H2 production, as in BALB/c mice, while higher levels lead to relatively higher T_H1 production, as in B10 mice. Strong T_H2 bias is thought to be a risk factor for allergy.

Closer analysis spotlighted the *Mina* gene as a likely suspect; analysis of various mouse strains revealed that Mina gene activity and levels of Mina protein were inversely correlated with T_H2 bias. Bix and Kubo's team subsequently determined that Mina assembles into a larger multi-protein complex that directly binds to and inhibits the gene encoding IL-4, supporting a key role for this factor in T_H2 bias (Fig. 1).

The team's analysis also identified nearly two dozen sequence variations in *Mina* that correlate with gene activity levels. These so-called single-nucleotide polymorphisms (SNPs) could provide useful diagnostic tools, and Kubo and Bix are now exploring this potential. "We have already done large-scale SNP analysis with Japanese and US populations," says Kubo. "The human *Mina* locus has several SNPs, and some of them have weak correlation with atopic asthma in the Japanese population, but not in the US [population]." ■

1. Okamoto, M., van Stry, M., Chung, L., Koyanagi, M., Sun, X., Suzuki, Y., Ohara, O., Kitamura, H., Hijikata, A., Kubo, M. & Bix, M. Mina, an *IL4* repressor, controls T helper type 2 bias. *Nature Immunology* **10**, 872–879 (2009).

Joining the dots on stem cell signaling

Hierarchical networks of transcription factors maintain self-renewal of mouse embryonic stem cells

Transcription factors, the proteins that control the activity of genes, can be part of a hierarchy of signaling compounds, RIKEN molecular biologists have shown. They have also demonstrated such a hierarchy among the transcription factors and that they keep mouse embryonic stem cells from specializing or differentiating.

The study is important because the role of transcription factors in switching genes on and off is now recognized as a significant part of genetic function. For instance, researchers are now able to turn specialized cells back into a stem cell-like form—induced pluripotent stem cells—through applying transcription factors. Better understanding of how these factors themselves are activated should further this work.

Mouse embryonic stem cells in culture remain in an undifferentiated or pluripotent state if treated with the cytokine or extracellular hormone known as leukemia inhibitory factor (LIF). Inside the cell, such pluripotency is known to be directly associated with three transcription factors, *Oct3/4, Sox2* and *Nanog*. In the past, other researchers have determined the involvement of the intermediate signaling compounds Jak and Stat3, and shown that pluripotency could be maintained without LIF by activating *Nanog* or Stat3 alone. How all these pieces fit together was unknown.

Hitoshi Niwa and colleagues from the RIKEN Center for Developmental Biology in Kobe set about tracing the signaling pathways, and detailed the results of their work in the journal *Nature*[1].

By analyzing data on compounds associated with the key transcription factor *Oct3/4*, they tracked down two other transcription factors, *Klf4* and *Tbx3*. Either of these genes when artificially stimulated is capable, like *Nanog*, of maintaining pluripotency without LIF (Fig. 1). The researchers then created transgenic cells in which each of *Klf4*, *Tbx3* and *Nanog* was activated, so they could study the impact of these transcription factors on levels of other key compounds.

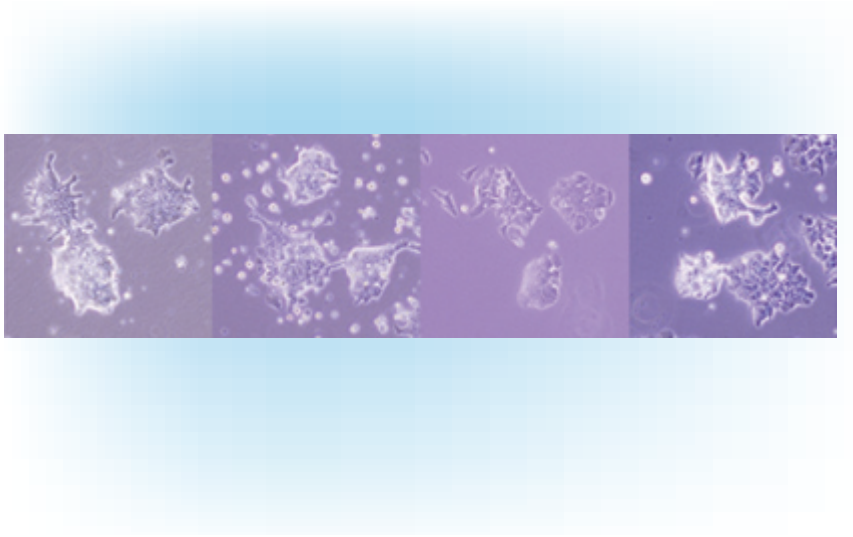

Figure 1: Examples of mouse embryonic stem cells grown without LIF, but with the transcription factors *Klf4* (left), *Nanog* (middle) and *TBx3* (right).

Their work revealed parallel signaling pathways stimulated by LIF of a hierarchical nature. The pathway involving Jak and Stat3 turns out to activate *Klf4* and through it *Sox2* and *Oct3/4*. *Tbx3* is part of another pathway which stimulates *Nanog* and *Oct3/4*. Other signaling compounds are known to connect into this latter pathway. They also found that transcription of all these factors is regulated by the core of *Oct3/4*, *Sox2* and *Nanog*. The complexity of the network confers stability, the researchers say.

"Based on this picture, we will try to establish a precise quantitative model of the transcription factor network that will be applicable for computational simulation," Niwa says. ■

1. Niwa, H., Ogawa, K., Shimosato, D. & Adachi, K. A parallel circuit of LIF signalling pathways maintains pluripotency of mouse ES cells. *Nature* **460**, 118–122 (2009).

Developing new stimuli-responsive molecular devices

Takuzo Aida

Group Director
Emergent Materials Department
Responsive Matter Chemistry and Engineering Research Group
RIKEN Advanced Science Institute

"The appeal of chemistry is that you can create new molecules that do not occur in nature," says Takuzo Aida, group director of the Responsive Matter Chemistry and Engineering Research Group launched in October 2007. Aida has embarked on a completely new research project. "An example is the development of special molecular devices similar to living organisms that can respond to different types of stimuli." What strategies can be used to create molecules with unconventional functions like these? "Like movie actors, molecules are carefully selected to play an important role in creating interesting molecular devices. Thus, a chemist can be compared to a movie director."

The moment blessed with a discovery

One and a half years into the Aida Nanospace Project (2000–2005), a research program supported by the Exploratory Research for Advanced Technology (ERATO) program of the Japan Science and Technology (JST) Agency, Takanori Fukushima (currently team leader of the Responsive Matter Chemistry and Engineering Research Group's Functional Soft Matter Engineering Team) placed some powdered carbon nanotubes into an ionic liquid and set the mixture in an ultrasonicator to disperse them. He went out to eat and came back about an hour later. To his surprise, the mixture had turned into a viscous gel similar to mayonnaise. "It has turned into a gel-like substance," he reported to Aida. Piqued with curiosity, Aida suggested, "Why don't you poke at it with a pair of tweezers." The substance immediately returned to its previous state of a powder in suspension. "If Dr Fukushima had returned from eating 30 minutes later, the carbon nanotubes would likely have returned to their original powdered state, and he would have missed the phenomenon. So we believe that we were blessed just one time. Dr Fukushima did not miss the moment," says Aida.

However, so began a period of difficult work for Fukushima. "I asked him to reproduce the phenomenon, but two months passed without positive results. We thought the gel-forming phenomenon had happened just that once. Dr Fukushima finally said, 'Let's stop investigating that phenomenon, it will never happen again.' However, I persuaded him to continue investigating, since the successful reproduction of the phenomenon would surely lead to the development of a new field of materials. Then three months later, he finally succeeded in finding out how to reproduce the phenomenon." It was a bold method, involving stirring the solution using a mortar.

Carbon nanotubes are of the order of one nanometer in diameter. They are strong, and also excellent conductors of electricity. Many researchers around the world have attempted in vain to disperse carbon nanotubes uniformly to create new substances. Nanotubes tend to

intertwine with each other, preventing them from dispersing evenly. The problem, however, was solved when the solution was simply mixed and stirred in a mortar. This caused the carbon nanotubes to become disentangled and to disperse completely in the ionic liquid, resulting in the formation of a gel-like substance. Fukushima and his team called the new substance 'Bucky gel' (Fig. 1).

A new type of conductive nanotube

Carbon nanotubes are a form of carbon with a graphite structure. Graphite, found commonly in pencil 'leads', is composed of stacked carbon sheets. A carbon nanotube is a cylindrical roll of one of these sheets, and carbon nanotubes are the only type of nanotube known to exhibit good electrical conductivity. "We aimed to create a new type of nanotube that could also conduct electricity."

Aida and his team focused on graphene, which is a small fragment of a single graphite sheet. They created a new type of graphene molecule by adding hydrophilic and hydrophobic moieties, then heated a solution of these molecules to 60 °C. Upon cooling, the molecules combined to form nanotubes of 20 nm in diameter with the hydrophobic moieties on the inside (Fig. 2). "We took advantage of molecular 'self-organizing' behavior to create a new type of nanotube." Self-organization is a mechanism by which molecules combine together naturally to form a complex structure.

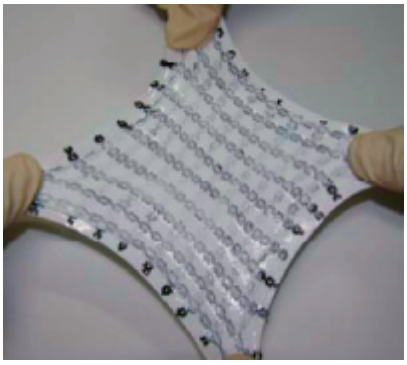

Figure 1: Elastic electronic circuit made of ionic-liquid-based Bucky gel.
In cooperation with Takao Someya and Tsuyoshi Sekitani at the University of Tokyo, Aida and his team are striving to develop a new type of sensor based on elastic electronic circuits made of 'Bucky gel'. These circuits are worn on the skin and can be used for sweat and temperature measurement. The elastic electronic circuit has great potential for use as skin for robots.

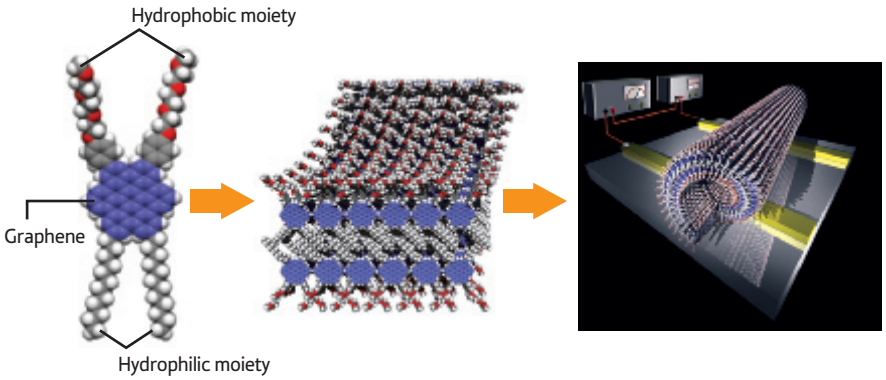

Figure 2: Graphite nanotube.
Graphene molecules bearing hydrophobic and hydrophilic moieties bond together at the hydrophobic moiety, forming molecular pairs that build up in a spiral pattern to creating a tube. The structure of the graphite nanotube was determined by structural analysis at the Structural Materials Science Laboratory of the RIKEN SPring-8 Center.

Today's computer circuits are fabricated using light to print very fine structures on hard semiconductor materials such as silicon. This method of forming microscopic structures, based on printing techniques, is generally referred to as a 'top-down' method. Improvements in computer performance have relied on continuous enhancement of the top-down method, and efforts have been focused on drawing electrical circuit patterns with ever-finer feature sizes. The top-down method, however, is now reaching its practical limit because the width between wire traces is now less than 100 nm, which is far shorter than the wavelength of the light beam used for processing. Thus, 'bottom-up' methods are attracting more and more attention as a means of building up molecules to create fine structures. "The keyword for the bottom-up method is 'self-organization'. This method allows the fabrication of superfine patterns of several nanometers in width. In other words, it can be used to build up molecules, potential allowing the perfect design of devices."

The new graphite nanotube is inherently an electrical insulator, but it becomes a conductor when subjected to a simple chemical treatment. Thus, a new electrically conductive nanotube was realized.

"Later we found that the graphite nanotube can still be formed even when the structural design of the original molecule including graphene is modified. In the case of conventional carbon nanotubes, the addition of moieties to the surface causes the tube structure to collapse, and in most cases, also results in degraded electrical conductivity. One of the advantages of graphite nanotubes is the ability to change the structural design of the original molecules, which allows us to specify what new functions are being created."

For example, Aida and his team, by changing the structure of the original molecule, have successfully created a graphite nanotube that conducts electricity when exposed to light. The expansion of this technique could lead to the construction of highly efficient solar batteries based on organic materials. Conventional solar batteries are mainly made of an inorganic silicon material. The use of organic materials will contribute to cost and weight reductions, and will expand the range

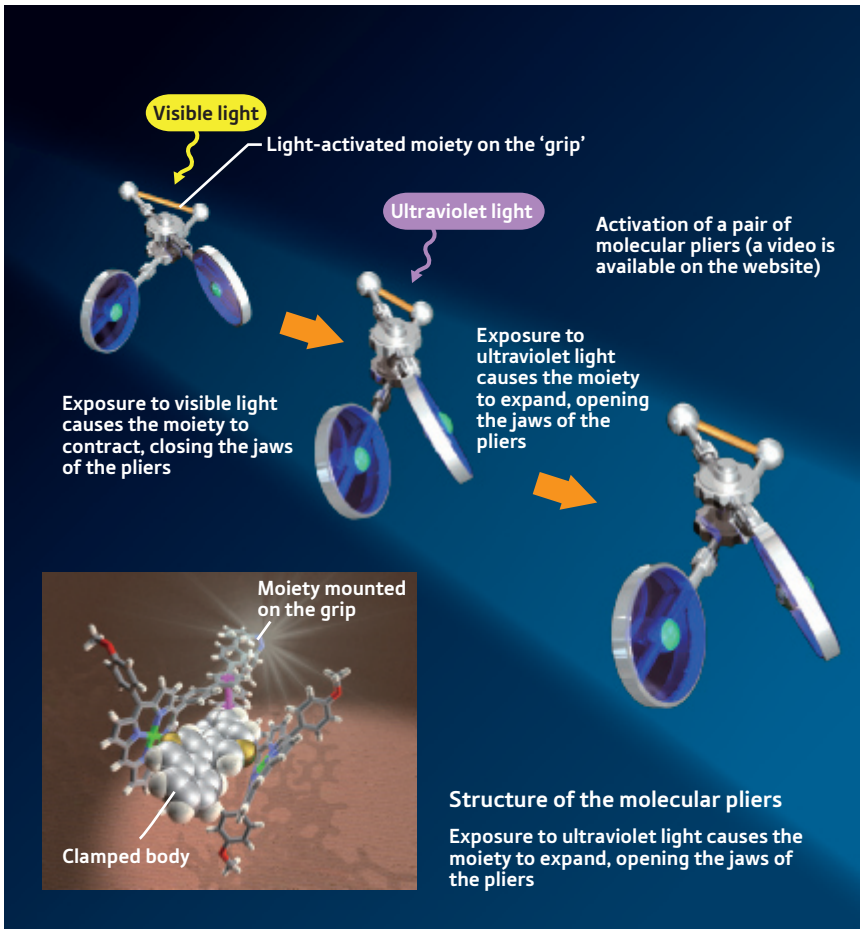

Figure 3: A pair of light-activated molecular pliers.
Exposure to visible light cause the moiety mounted on the grip to contract, clamping the object between the jaws of the pliers. The body can then be twisted. New molecular devices could induce chemical reactions in the object while it is twisted.

of application because they are flexible. For these reasons, there is broad interest in the research and development of organic solar batteries. "The energy conversion efficiency and durability of organic solar batteries will not be better than for inorganic solar batteries such as those made of silicon. Organic materials, however, can be obtained from plants even when oil reserves become depleted. Thus, it is very important for us to establish the basic technology for organic solar batteries because they can be obtained at a low price and resources are inexhaustible."

Molecular devices activated by two stimuli

Aida launched the Responsive Matter Chemistry and Engineering Research Group at RIKEN in October 2007, and Fukushima assumed the position of team leader of the group's Functional Soft Matter Engineering Team. "At RIKEN, I do not adopt research themes that I pursued in other research institutes. Instead, I am proceeding with independent research based on new themes. One example is the development of molecular devices that can respond to various types of stimuli, similar to living organisms."

Receptors on the membranes of cells in living organisms differentiate among various signals and open 'gates' in response to specific signals in order to take in the necessary materials. "We have also created useful molecular devices that can perform a single function in response to a specific stimulus." For example, a research laboratory at the University of Tokyo lead by Aida created a pair of 'molecular pliers' that are activated by light (Fig. 3). "You cannot hold them of course because the pliers are nano-sized. They have a special moiety, mounted on the 'grip', that contracts when exposed to visible light. Using this pair of molecular pliers, we succeeded in clamping and twisting an object.

"We can expand the concept of molecular pliers even further: for example, it could twist when additionally exposed to ultraviolet light, allowing it to twist a clamped object when exposed to ultraviolet light and visible light at the same time, or to twist a clamped object when exposed to ultraviolet light and then to chop it off when exposed to visible light. The device effectively discriminates among various types of stimuli and performs tasks autonomously, similar to a living organism. This is one of the major goals of our project at RIKEN."

In a laboratory at the University of Tokyo, researchers have already succeeded in creating a new molecular device that can be activated by two stimuli through the modification of a biological molecule called a 'chaperone'. The functions of proteins are derived from their three-dimensional structure. Thus, they do not function well when their structure collapses. The cylindrical chaperone molecule takes in collapsed proteins and restores them to their original state. It opens its gate and releases the proteins when exposed to an energy carrier called adenosine triphosphate (ATP). "We added to the outside of the chaperone's gate an artificial gate that opens when exposed to ultraviolet light so that it had a double gate function (Fig. 4). The modified chaperone molecule only opens the double gate completely when exposed to both ultraviolet light and ATP, releasing the restored proteins. By analogy, cars are equipped with a safety system that requires two tasks to be carried out at the same time in order to perform a particular operation. We succeeded in creating a molecular device with this mechanism using the biological chaperone molecule.

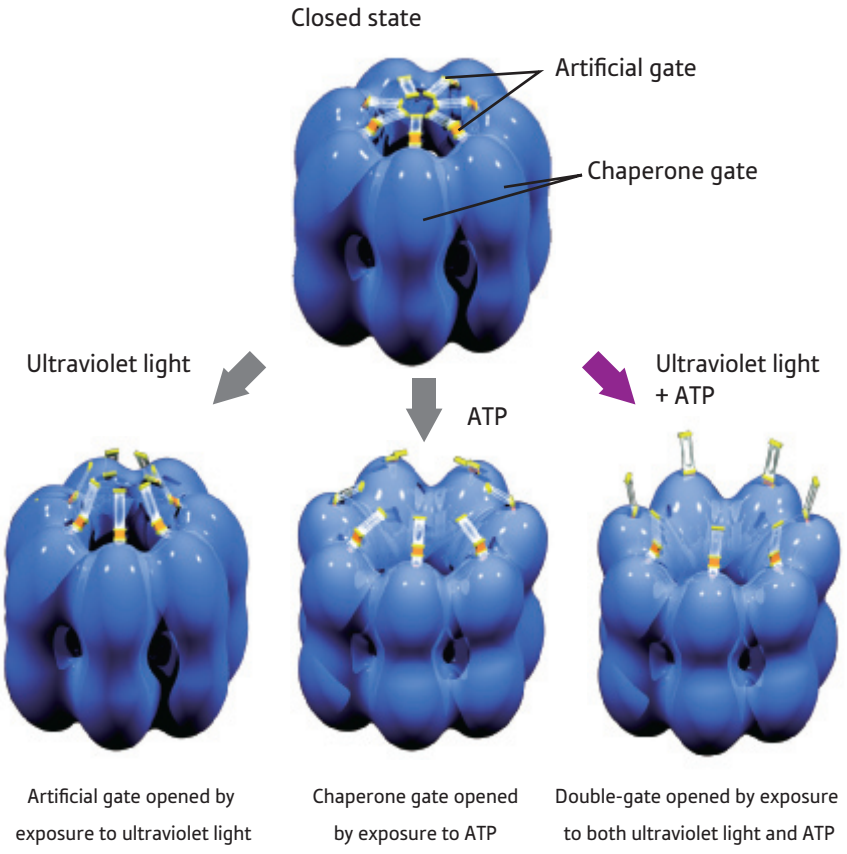

Figure 4: A double-gated molecular machine based on chaperone molecules.
The double gate opens only when exposed to both ultraviolet light and ATP.

to notice positive signs even if they could be the ones leading to the discovery of new functions. I have face-to-face discussions with our researchers, and I sometimes give up on a research theme if the researcher seems to be unable to cope with any more failures. A little more effort may have led to a successful result, but it cannot be helped, because these new devices are being created by real people."

At the Responsive Matter Chemistry and Engineering Research Group, researchers deal in difficult, painstaking work in the creation of new molecular devices with specific functions. "We have produced very exciting results, including a new molecule that exhibits an interesting phenomenon that was never expected. Unfortunately, however, we cannot speak about the phenomenon yet because the results have not been published." Look for the results to be published by the Responsive Matter Chemistry and Engineering Research Group in the near future. ■

At RIKEN, we want to use a molecule designed entirely by ourselves for the creation of a device that can be activated by various types of stimuli."

How can such devices be created? "When you knock over the first in a line of dominoes, it brings down all the other domino pieces in turn after it. This is a good example of an event source affecting the whole system. In an organic material, molecules are arranged in an orderly manner. Thus, we can design the structure of an organic device such that, for example, when a molecule at a certain position is tilted by a certain stimulus, all the other molecules can also be tilted. Furthermore, it is also possible to design the structure of the organic molecular device by controlling the interaction between molecules so that all molecules can be tilted only when the organic material is exposed to two stimuli at the same time. Based on this design concept, we are making efforts to create new molecular devices."

Focus and patience—creating new molecular devices

"The appeal of chemistry is that you can create new molecular structures that do not exist in nature," says Aida. "You need to be very focused when creating new molecular devices. Even very smart researchers who are very careful in experiments are sometimes unable to create new structures, while particularly focused researchers are often quite successful, even if they are not refined researchers. What is the difference? I don't know."

Aida points out that patience is also a must in creating new molecular devices. "We can handle failure many times. In fact, it was not until the fifth attempt in the design of the new graphite nanotube that we finally succeeded in creating it. I was, however, on the verge of losing patience. I think if you have about seven failures in succession, you being to think that your basic idea is flawed. Then, you lose your sense of anticipation, and fail

About the researcher

Takuzo Aida was born in Oita Prefecture, Japan, in 1956. He received a bachelor degree in physical chemistry from Yokohama National University in 1979, and then earned his PhD in polymer chemistry in 1984 at the Graduate School of Engineering, University of Tokyo. After serving as a researcher and lecturer, he was appointed associate professor of the Department of Chemistry and Biotechnology at the same university in 1991, and was later promoted to professor in 1996. He joined RIKEN in 2007, where he pursues his research interests in macromolecular chemistry, supramolecular chemistry and bioscience-related chemistry.

First Noyori Summer School held at RIKEN Harima Institute

With its increasingly international profile, RIKEN faces a growing need to offer opportunities for young researchers from different countries and fields to meet and interact. The Noyori Summer School, held for the first time this year, was created with the aim of answering this need through the support of cross-disciplinary, international interaction.

Roughly one hundred Ph.D. students in the International Program Associate, Asia Program Associate, and Junior Research Associate programs, conducting their research at RIKEN, gathered at the RIKEN Harima Institute on September 4-5 for a program that included presentations, tours and Q&A sessions.

RIKEN President Ryoji Noyori gave his keynote lecture on the second day, entitled 'To my young colleagues'. In the lecture, Noyori drew an analogy between scientific research and stacking stones on a foundation to create a large, majestic structure. He emphasized that Nobel prizes are awarded, however, to the person who puts a stone in a new and different place. "You are the scientists of tomorrow," he said. "Do you have the courage to place a stone outside the grand and beautiful structure that looms above you?"

In a discussion period entitled 'Hear from Dr. Noyori', attendees asked RIKEN's President about success in research, the choices in a scientific career, and the contribution of science to society. "Continuity is at the core of tradition," Noyori explained in response to one question, "but there cannot be new science if we simply believe everything our teachers and textbooks tell us. For you young people, your task is to challenge the accepted theories of today."

While emphasizing creativity and originality, Noyori also highlighted the need to build strong relationships. "It is important that you broaden your perspective while you are still young," he said. "I also urge you to make many friends. Friendships are to be treasured for a lifetime."

One of the attendees, Caroline Rabot from France says "The Noyori Summer School was a great chance to meet with colleagues from different research fields and nationalities. It was very exciting to discuss about their research, to build a network and to hear from outstanding scientists such as Dr. Noyori, and Dr. Ishikawa, director of RIKEN SPring-8 center." Another attendee, Nuttapol Tanadchangsaeng from Thailand agrees saying, "I felt two days seem so short," and continues, "'Although everyone came from the different fields of research, it was a great opportunity at Noyori Summer School to exchange our knowledge and make a staunch collaboration in the future."

New robot to reduce burden on care facilities

In an effort to cope with the challenges of an aging population, a new robot making use of the latest in sensor, control, information processing, mechanical and materials technology has been developed to assist personnel and patients at care facilities. The product of joint research by RIKEN and Tokai Rubber Industries (TRI), the new robot, named RIBA (Robot for Interactive Body Assistance), is the first of its kind in the world, capable of safely lifting and moving a human patient of up to 61 kg from a bed to a wheelchair and back.

The task of lifting and moving a patient, carried out several times a day, is one of the most exhausting for care-givers. In assisting in this task, RIBA brings together cutting-edge sensor and information processing technology developed at RIKEN with materials technology developed at TRI, overcoming safety and performance limitations of its predecessor, an earlier model named RI-MAN. Using human-like arms equipped with high-precision tactile sensors and a body encased in a soft exterior of urethane foam, RIBA's design guarantees patient safety and comfort.

As one part of a larger strategy to pursue advances in robot technology for care-giving support, the successful development of RIBA marks a critical step toward tackling the problems of an aging society. The RIKEN-TRI Collaborative Center for Human-Interactive Robot Research (RTC), where RIBA was developed, envisions bringing robots like RIBA to market in the near future.

New supercomputer sets record for highest performance in PC clusters, Japan

A new supercomputer developed at RIKEN has set a record for computing performance by effectively harnessing the parallel processing power of computer clusters. Named RICC (RIKEN Integrated Cluster of Clusters), the supercomputer is made up of four distinct computer clusters connected through InfiniBand as interconnect, together achieving a performance of 97.94 teraflops on the LINPACK benchmark.

RICC's performance ranks it first among PC cluster systems in Japan and marks an increase in peak performance of 8.5 times over its predecessor, the RIKEN Super Combined Cluster (RSCC). In achieving this level of performance, RICC leverages a complex computing environment made up of four distinct sub-systems: a massively parallel cluster, a large memory capacity server, a multi-purpose parallel cluster, and PC cluster with MD-GRAPE3, a supercomputing system specialized for molecular dynamics simulations. An advanced high-performance job scheduler developed at RIKEN coordinates hierarchical multi-level computing resources (cores, processors, computing nodes, PC cluster sub-systems and the whole system), minimizing job waiting time and maximizing job throughput.

By bringing together computing systems with different functions and purposes into a single supercomputer, RICC is able to cater to the needs of researchers from across a wide research fields. Researchers developing software for RIKEN's Next-Generation Supercomputer, scheduled for completion in 2012, can use RICC to test application programs specifically designed for a massively parallel processing environment. The system will also be capable of processing large volumes of experimental data from advanced DNA sequencers, accelerators, and RIKEN's X-ray Free Electron Laser (XFEL). In addition, RICC is provided with a programmable accelerator (GPGPU) which supplies to user's applications with more powerful computing capability. From the user's perspective, RICC is also very convenient to use, with a front-end system that provide accessibility via ssh terminal, a web-based service and via mobile phone.

As the country's most powerful supercomputing system, RICC promises to accelerate ongoing research as well as open doors to new research possibilities. Routine operation of RICC, which was started test operation on August 3rd, will commence from October 1st.

Dr Ryutaro Himeno
Director
Advanced Center for Computing and Communication, RIKEN
Wako, Saitama, Japan

Dear Dr Himeno,

Time flies. It has already been more than six years since I left RIKEN and moved to Chiba University. I can still immediately recall the farewell party you organized for sending me off—where I received so many warm words from my colleagues and friends at the Advanced Center for Computing and Communication (ACCC), and I felt that I would always remain a member of this RIKEN family. And yes, my feeling was correct. My experience at RIKEN, in a sense, has been a big help for my later career and life in research. I have since retained a very good relationship with RIKEN, as a visiting chief scientist at the ACCC, working together with the Computational Biomechanics Unit and the Whole-Body Organ team in the Next-Generation Supercomputer Project.

My working experience with RIKEN, although for only three years, was very special and has been of much help in my research life. I don't need to mention that the Institute of Physical and Chemical Research at RIKEN is known worldwide as a leading institution associated with natural science in Japan. In 2000, I was very lucky to be able to join your group with its excellent research environment. I loved the RIKEN style, the casual atmosphere and friendship, which I believe is a result of RIKEN's glorious history and essential for doing great research.

I also enjoyed the seminars held almost every week, given by a variety of researchers, from internationally distinguished scientists to young researchers who have just received their degrees. Those seminars covered almost all fields associated with natural science. Sometimes one could enjoy a very fancy lecture by a Noble laureate, or seminars on the hottest state-of the-art topics and cutting-edge techniques from top scientists. And sometimes one even got the chance to hear about the difficult topics that young researchers are touching upon and tackling. The seminars were often organized by different laboratories, and were announced and open to everyone. I very much enjoyed these seminars and there is no doubt that I learnt much from them.

In the first year that I joined RIKEN, I was further lucky to be engaged in a government- sponsored project titled 'Computational Biomechanics', which had been launched just one year before. From this project I experienced much and definitely learnt a lot about how to run a big research project as well as how to work together with young postdoctoral researchers. This has helped me much in my later research life. Here I should also mention that the supporting staff at RIKEN was very well organized and always friendly, providing a very efficient supporting system for running the research projects smoothly.

Finally, I would like to say again that I am very pleased and lucky to have been able to spend three years working with you at RIKEN, which, by all means, has given me not only excellent memories but also a big push for my present and future work. I am also very happy to be able to collaborate continuously with you in the ongoing Next-Generation Supercomputer project, and I am quite confident that together we will produce many excellent outcomes.

Yours sincerely,

Hao Liu
Professor of Biomechanical Engineering
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RIKEN, Japan's flagship research institute, conducts basic and applied experimental research in a wide range of science and technology fields including physics, chemistry, medical science, biology and engineering. Initially established as a private research foundation in Tokyo in 1917, RIKEN became an independent administrative institution in 2003.

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