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Finding the root of potato disease

HIGHLIGHT OF THE MONTH

Biology: A shorter road to growth

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Biology

A shorter road to growth

New insights into a plant hormone synthesis pathway could prove fruitful for agricultural researchers attempting to improve crop robustness and productivity

Figure 1: When overexpressed in *Arabidopsis*, TAA (*TAA1ox*) and YUC6 (*YUC6ox*) act synergistically to stimulate denser lateral root growth (right) relative to plants that overexpress either gene alone (middle) or negative control plants (*pER8*; left).

It is a rare and special treat for scientists when a process turns out to be simpler than expected, rather than more complicated. Nevertheless, this actually appears to be the case for the biosynthetic pathway underlying the production of a plant hormone with an essential role in growth and development.

Indole-3-acetic acid (IAA), a plant hormone belonging to the auxin family, activates a variety of signaling cascades involved with critical functions that include shoot growth, root extension and flowering. Consequently, this molecule has been the subject of intensive investigation for well over 70 years. However, attempts to untangle the mechanisms behind IAA biosynthesis have yielded no clear answers. "Based on the results from biochemical studies conducted from the 1960s to the 1980s, researchers have proposed multiple IAA biosynthesis pathways," says Hiroyuki Kasahara of the RIKEN Plant Science Center in Yokohama.

Of the four mechanisms proposed to date, two have been the subject of particular interest in recent years; one is mediated by the YUCCA (YUC) protein family, and the other by TRYPTOPHAN AMINOTRANSFERASE OF ARABIDOPSIS 1 (TAA1) and a pair of related enzymes. Both pathways work with the same starting material, the amino acid tryptophan, but prior studies have suggested that YUC and TAA1 otherwise represent components of completely distinct and parallel pathways. According to this model, the former process mediates IAA production via the intermediate tryptamine (TAM), whereas the latter employs indole-3-pyruvic acid (IPA) as an intermediate product.

New findings from Kasahara and colleagues, however, have now overturned this model, revealing that YUC and TAA1 instead work together within a single, unified pathway[1].

Intersecting roads

To test the relative contributions of these two factors, the researchers generated a variety of genetically modified strains of thale cress (*Arabidopsis thaliana*), a species commonly used as a model plant. They found that the simultaneous overexpression of genes encoding TAA1 and YUC1 led to increased density of lateral root formation and elevated production of IAA and associated metabolic byproducts, suggesting that these two factors may act synergistically in a common pathway. Experiments in which the researchers overexpressed TAA1 alongside YUC6, a different YUC family member, yielded similar results (Fig. 1).

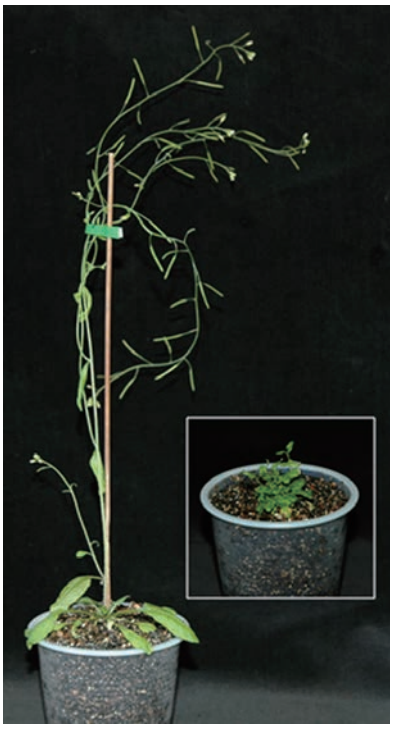

Figure 2: Plants lacking the *YUC* genes fail to produce IAA and thus exhibit stunted growth (inset) relative to their wild-type counterparts.

Given that this synergy is seemingly inconsistent with the hypothesized activities of these two enzyme families, Kasahara and colleagues examined their respective functions more closely. When the researchers knocked out a pair of proteins involved in the TAA pathway, they observed a sharp drop in IPA levels. Likewise, overexpression of TAA1 led to a concurrent increase in IPA production, supporting this protein's established role in converting tryptophan to IPA as a preliminary step in IAA synthesis.

Their findings with YUC proved more surprising. *In vitro* experiments have suggested that YUC may facilitate the conversion of TAM into *N*-hydroxy-TAM (HTAM), which is in turn modified to yield IAA. As expected, YUC-deficient plants showed clear signs of IAA deficiency (Fig. 2), but did not accumulate TAM as this model would predict. "Our paper shows that this initial characterization of YUC enzyme function was not accurate," says Kasahara. Instead, these plants exhibited a nearly two-fold increase in the accumulation of IPA, suggesting that YUC enzymes instead act to drive conversion of this compound to IAA.

Isolation of fully functional YUC has posed a major logistical challenge in the past, impairing the direct assessment of these enzymes' function *in vitro*. By systematically testing different cell culture and protein preparation strategies, however, Kasahara and colleagues were able to obtain purified YUC2 and verify their hypothesis, confirming that this enzyme family acts directly downstream from TAA1 and related proteins to convert IPA to IAA. "Plant biologists have assumed that the IAA biosynthesis pathway is very complicated," says Kasahara, "but we have demonstrated that plants can actually produce IAA in only two steps."

Building a better plant

Although other alternative IAA biosynthetic processes have been identified, the pathway identified here is likely to operate in a wide variety of plants. Indeed, the *YUC* and *TAA* genes are evolutionarily conserved even in distant relatives of *Arabidopsis*, including moss and liverwort. Kasahara therefore believes that this study represents a major step towards understanding the biochemical processes that ultimately govern plant growth. "By identifying this main auxin biosynthesis pathway, it becomes possible to study in detail when and where plants make IAA by analyzing the expression of *YUC* family genes," he says. "This represents an important breakthrough for plant biologists interested in learning how auxin regulates morphogenesis and environmental response in plants."

On the other hand, the extent to which the TAM-associated pathway previously associated with YUC function actually represents a standard mode of IAA production remains an open question. Future investigations by Kasahara and colleagues will carefully explore this and other IAA biosynthetic pathways in an effort to identify novel genes that participate in the manufacture of this essential hormone.

Even at this stage, however, these findings are of more than just academic interest. By learning the core components of the auxin biosynthesis machinery, geneticists and botanists stand to gain valuable tools for manipulating growth behavior and thereby maximizing the utility of plants with essential roles in textile and food production. "One recent study has demonstrated that one can increase IAA levels during ovule development to increase the yield and quality of cotton," says Kasahara. "We may be able to increase the production of crops by modulating expression levels of *YUC* and *TAA* genes, and the IPA pathway offers a novel target for the development of herbicides."

1. Mashiguchi, K., Tanaka, K., Sakai, T., Sugawara, S., Kawaide, H., Natsume, M., Hanada, A., Yaeno, T., Shirasu, K., Yao, H. *et al*. The main auxin biosynthesis pathway in *Arabidopsis*. *Proceedings of the National Academy of Sciences USA* **108**, 18512–18517 (2011).

ABOUT THE RESEARCHER

Hiroyuki Kasahara was born in Fukui, Japan in 1969. He graduated from the Faculty of Science and Engineering at Kinki University in 1992, and received his PhD in 1997 from the same university. He was a research fellow of the Japan Society for the Promotion of Science from 1994 to 1997. After three years' postdoctoral training at the Institute of Biological Chemistry, Washington State University, USA, Kasahara returned to Japan as a research scientist at the RIKEN Plant Science Center (PSC) in 2000, where he started his career in plant hormone research. Since 2005, he has been a senior scientist at PSC. In 2011 he became a research scientist of the Precursory Research for Embryonic Science and Technology (PRESTO) department at the Japan Science and Technology Agency. His research focuses on the regulation of plant growth and development using plant hormones.

Imaging electrons by the slice

A new spectroscopy technique enables the investigation of two-dimensional electron states both at the surface and within crystals

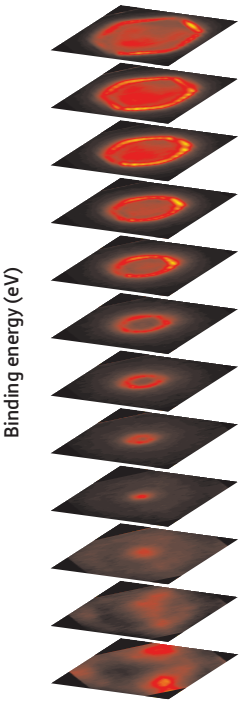

Figure 1: The electronic states at the surface of the topological insulator $Cu_xBi_2Se_3$, which can now be measured. The vertical axis shows the electron energy, the horizontal axes depict the electron momentum in the two-dimensional plane.

Understanding and visualizing the energy states of electrons in a crystal provides important insights into many modern electronic materials, such as superconductors, or other materials that physicists can use to develop novel electronic applications. The electronic states at the surface of a crystal, or the two-dimensional layers within a sample, are of particular interest to materials scientists, but are notoriously difficult to image using conventional techniques.

Now, a technique is available to measure two-dimensional electronic states within a crystal[1]. The technique was developed by researchers at the RIKEN SPring-8 Center, Harima, along with colleagues from the University of Tokyo and several other institutes in Japan, China and the USA. The technique enables in-depth study of these two-dimensional electronic states for the first time (Fig. 1). Many of the materials of greatest interest for novel electronic applications are based on the intricate properties of such electronic states, explains team member Yukiaki Ishida.

One of the most widely used techniques to image a material's electronic states is called angle-resolved photoemission spectroscopy (ARPES). Using this technique, physicists shine a light beam on a crystal and then record the pattern of the photoelectrons that are ejected from the crystal's surface. When they use laser beams of different polarization, they can obtain further important details of the electronic states of the crystal.

When studying ARPES measurements made on two different crystals—$SrTiO_3$:Nb and $Cu_xBi_2Se_3$—Ishida and colleagues discovered that, under some experimental circumstances, there is a common pattern in the photoelectron distribution that is also known as the 'pattern of photoemission'. The catch is that this pattern occurs only when the two-dimensional electronic states probed therein are thin enough.

This technique can provide unique insight into a number of widely studied materials. High-temperature superconductors, for example, are made of thin atomic layers that are crucial to their superconductivity. A recently discovered class of materials, topological insulators, also has promising properties: the electrons of these materials can travel at their surface almost without any losses to the orientation of the electron's magnetic property, which has potential application in new ways of computing.

Beyond the study of novel electronic materials, studying the surfaces of materials may reveal new findings, says Ishida. "How surface states change during catalytic reactions is of major scientific and commercial interest," he explains. "For example, by monitoring the surface states we may be able to investigate how deep a chemical reaction penetrates into the crystal." ■

1. Ishida,Y., Kanto, H., Kikkawa, A., Taguchi, Y., Ito, Y., Ota, Y. Okazaki, K., Malaeb, W., Mulazzi, M., Okawa, M., *et al*. Common origin of the circular-dichroism pattern in angle-resolved photoemission spectroscopy of $SrTiO_3$ and $Cu_xBi_2Se_3$. *Physical Review Letters* **107**, 077601 (2011).

Longer-lasting chemical catalysts

Wrapping palladium nanoparticles inside a self-assembled polymer matrix makes catalysts easier to retain and recycle

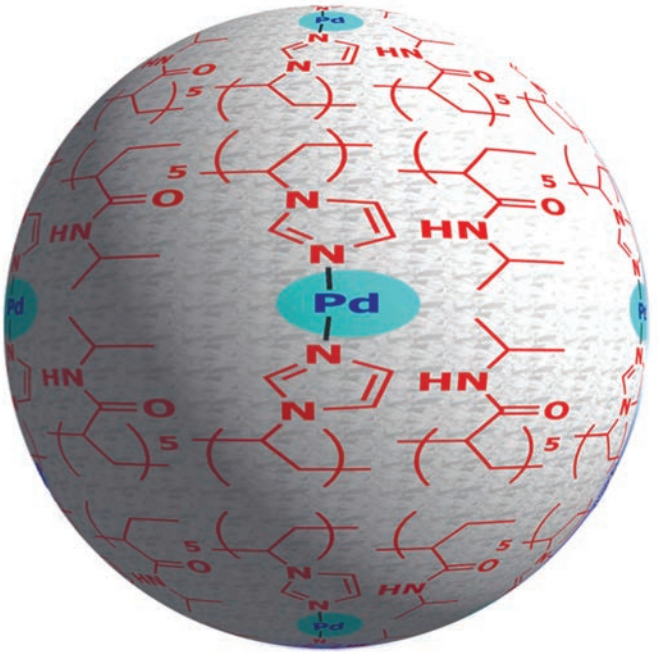

Figure 1: A graphical representation of the retrievable and reusable polymer–metal catalyst, showing the palladium (blue) that links two imidazole polymer units (red) through their nitrogen atoms.

Metal-based chemical catalysts have excellent green chemistry credentials—in principle at least. In theory, catalysts are reusable because they drive chemical reactions without being consumed. In reality, however, recovering all of a catalyst at the end of a reaction is difficult, so it is gradually lost. Now, chemists can retain, retrieve and reuse metal catalysts by trapping them with a polymer matrix, thanks to recent work by Yoichi Yamada at the RIKEN Advanced Science Institute, Wako, Yasuhiro Uozumi at RIKEN and Japan's Institute for Molecular Science and Shaheen Sarkar, also at RIKEN[1].

Attaching metal catalysts to an insoluble polymer support, which is recoverable at the end of a reaction by simple filtration, is far from a new idea. Traditionally, chemists attached their metal catalyst to an insoluble polymer resin. However, the metal invariably leached out of the polymer over time so the catalysts were still slowly lost.

Yamada and his colleagues' approach, in contrast, integrated the metal into the polymer matrix, which trapped it much more effectively. The researchers achieved this level of integration by starting with a soluble polymer precursor instead of an insoluble resin. This material contains imidazole units, a chemical structure known to bind strongly to metals such as palladium (Fig. 1). An insoluble composite material formed only after the researchers added palladium to the mixture because it causes the imidazole units to self-assemble around atoms of the metal—a process that they call 'molecular convolution'.

Scanning electron microscopy revealed that the resulting polymer–palladium globules ranged from 100 to 1,000 nanometers in diameter, which aggregated into a highly porous structure reminiscent of a tiny bathroom sponge. "This sponge-like insoluble material can easily capture substrates and reactants from the solution, which readily react with metal species embedded in the sponge," says Yamada.

The researchers showed that the catalyst is highly active as well as reusable; it is the most active catalyst yet reported for a carbon–carbon bond-forming reaction known as an allylic arylation. They also reused the catalyst multiple times with no apparent loss of activity, and detected no leaching of palladium from the polymer into the reaction mixture.

Yamada and colleagues are now developing a range of composite catalysts incorporating different metals that can catalyze many other kinds of reactions. "These extremely highly active and reusable catalysts will provide a safe and highly efficient chemical process, which we hope will be adopted for industrial chemical process," Yamada says. ■

1. Sarkar, S.M., Uozumi, Y. & Yamada, Y.M.A. A highly active and reusable self-assembled poly(imidazole/palladium) catalyst: allylic arylation/alkenylation. *Angewandte Chemie International Edition* **50**, 9437–9441 (2011).

Applying pressure reaps material rewards

A high-pressure growth technique creates single magneto-electric crystals useful for future generations of electronic memory

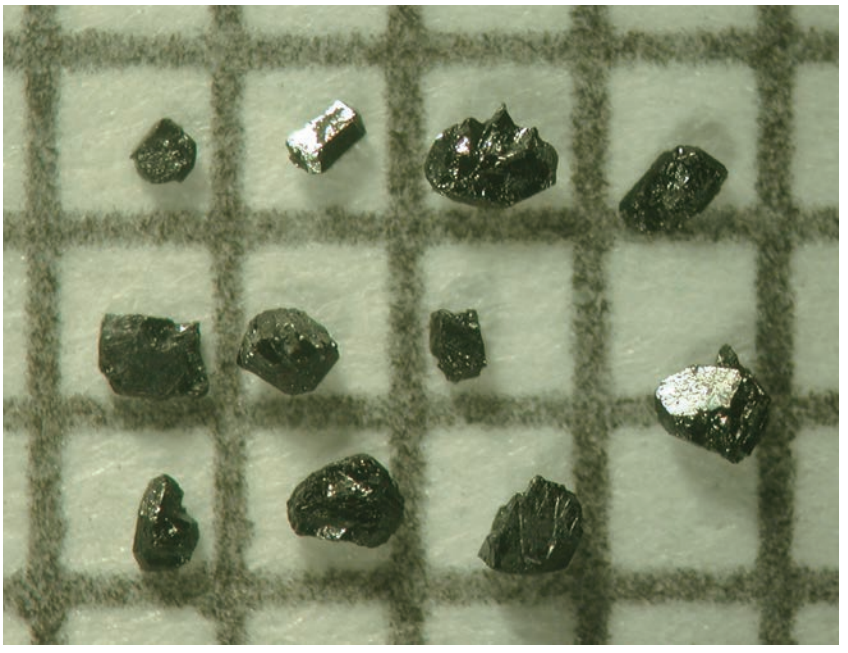

Figure 1: Large crystals of the multiferroic yttrium manganite, a material with important implications for future memory devices, created from a high-pressure growth technique.

Researchers in Japan have succeeded in growing single crystals of yttrium manganite ($YMnO_3$) using a high-pressure material-growth technique[1]. Developed by Shintaro Ishiwata and his colleagues from the RIKEN Advanced Science Institute and the University of Tokyo, the technique reveals how this material's atomic structure gives it multiferroic properties, which hold promise as a route to low-power-consumption electronic memories.

Multiferroic materials have both ferromagnetic and ferroelectric properties that make them ideal for an improved class of memory devices. Ferromagnetic materials are essential for most electronic memory devices because they can retain long-lasting magnetic properties after exposure to magnetic fields. The electrical properties of ferroelectric materials are controllable using an electric field. The combination of these properties means that it is possible to control magnetic memories with an electrical field while reducing heat loss.

Ishiwata and colleagues created an initial sample of $YMnO_3$ by mixing the compounds Y_2O_3 and Mn_2O_3 at 1,300 °C. "This ambient-pressure phase of $YMnO_3$ is a kind of multiferroic, but ... its electronic properties cannot be controlled by magnetic fields," explains Ishiwata. Moreover, the sample was polycrystalline; that is, made up of many tiny crystals. The researchers created larger crystals (Fig. 1) by mixing this precursor with potassium chloride and water and subjecting it to a pressure almost 55,000 times that of atmospheric pressure and temperatures in excess of 1,000 °C for two hours. "The crystal growth of multiferroic $YMnO_3$ is normally hampered by damage caused in the high-pressure cell," explains Ishiwata. "By adding water, we drastically lowered the melting point of $YMnO_3$ and therefore reduced the reaction time."

To provide clear evidence of the strong magneto-electric effects, Ishiwata and colleagues investigated their sample at various temperatures and under an applied magnetic field. A change in atomic structure transformed the precursor $YMnO_3$ into a useful multiferroic material. The precursor had a hexagonal lattice arrangement. The high pressure converted this to a type of crystal known as an orthorhombic perovskite—so named because it has a similar, but slightly tilted, atomic structure to the natural mineral perovskite.

Now that they are able to reliably grow large single $YMnO_3$ crystals, the researchers can thoroughly investigate the properties of this useful material. "It has been predicted that perovskite-type $YMnO_3$ should have a large polarization; that is, a strong atomic-level response to electric fields," says Ishiwata. "The observed polarization is not as large as predicted yet, but it is still the largest of any magnetic-order-driven multiferroic." ■

1. Ishiwata, S., Tokunaga, Y., Taguchi, Y. & Tokura, Y. High-pressure hydrothermal crystal growth and multiferroic properties of a perovskite $YMnO_3$. *Journal of the American Chemical Society* **133**, 13818–13820 (2011).

Unearthing a path leading to diabetes

Discovery of a molecular basis for type 2 diabetes reveals how fatty diets can interfere with control of blood sugar levels

A molecular mechanism that links diet, obesity and diabetes involves depletion of specialized 'transporter proteins', a Japanese–American team has found[1]. Transporter proteins deliver glucose to so-called 'beta cells' of the pancreas, which produce the hormone insulin to help the body regulate its sugar levels. The work opens the way to new treatments for diabetes since ensuring sufficient numbers of glucose transporter (Glut) proteins on their outer surface could improve beta cell function.

In both humans and animals, there is a widespread and accepted connection between high-fat diets, obesity and susceptibility to type 2 (or adult onset) diabetes (Fig. 1). Until now, however, the causal links were not clear, particularly at a molecular level, explains team member Kazuaki Ohtsubo from the RIKEN Advanced Science Institute in Wako.

A hallmark of the condition is a drop in the effectiveness of insulin in lowering blood sugar levels, known as insulin resistance. Previous work by other researchers had determined that type 2 diabetes is accompanied by a loss of sensitivity of beta cells to increasing glucose levels. Rising levels of glucose normally trigger secretion of insulin and are detected by greater amounts of sugar moving into beta cells. A decrease in Glut proteins, hence a lower capacity for glucose transport, could therefore explain defective insulin secretion. Interestingly, mice that lack the enzyme GnT-4a, which catalyzes the linkage of Glut proteins to the cell surface, develop type 2 diabetes. In earlier work[2], Ohtsubo also showed that a high-fat diet can induce a deficiency of GnT-4a.

Figure 1: High-fat diets, obesity and susceptibility to type 2 diabetes go hand in hand in humans and animals.

To investigate these earlier findings in detail, Ohtsubo and his colleagues from the University of California, USA, investigated the sequence of molecular events in pancreatic beta cells of mice and humans. They found that high levels of fatty acids led to nuclear exclusion of the proteins that facilitate transcription of the genes for GnT-4a and Glut. The resulting deficiency of the GnT-4a enzyme led to many of the symptoms of diabetes. This could be alleviated in mice by adding the human gene for GnT-4a. The researchers also observed that the molecular pathways activated in the mice that developed type 2 diabetes were similar to those that were active in human type 2 diabetes.

"We are already searching for small chemical compounds which activate the expression of GnT-4a in pancreatic beta cells under high-free fatty acids conditions," says Ohtsubo. "These compounds could improve beta cell function and should be good candidates for new types of drugs for diabetes." ■

1. Ohtsubo, K., Chen, M.Z., Olefsky, J.M. & Marth, J.D. Pathway to diabetes through attenuation of pancreatic beta cell glycosylation and glucose transport. *Nature Medicine* **17**, 1067–1075 (2011).

2. Ohtsubo, K., Takamatsu, S., Minowa, M.T., Yoshida, A., Takeuchi, M. & Marth, J.D. Dietary and genetic control of glucose transporter 2 glycosylation promotes insulin secretion in suppressing diabetes. *Cell* **123**, 1307–1321 (2005).

Channeling into cell control

A new model of intracellular signaling via calcium ions will assist in understanding the effects of calcium fluctuations

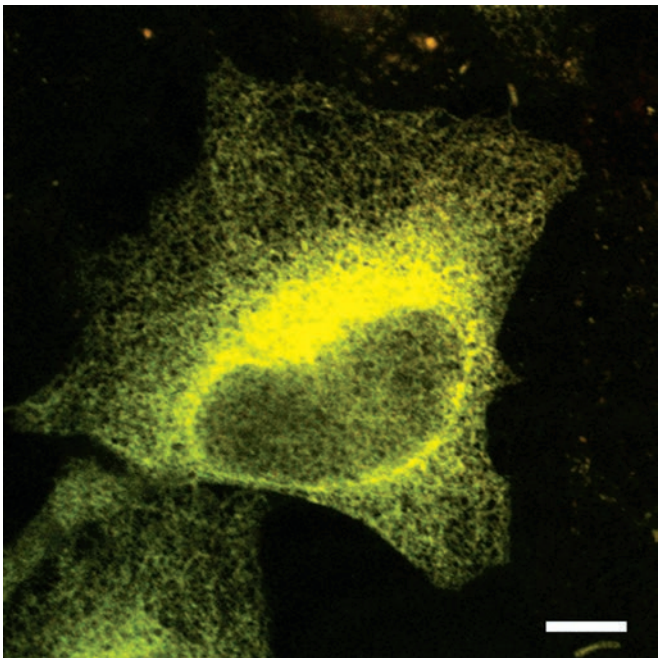

Figure 1: A cell emitting fluorescent signals as a result of attaching specialized proteins to two of its channel-forming IP_3Rs (scale bar, 10 μm).

A research team from the RIKEN Brain Science Institute in Wako has visualized and accurately modeled the molecular changes that open and close the internal membrane channels for calcium ions within cells[1]. The ions moving through these channels act as intracellular messengers, relaying information that regulates the activity of the proteins that control many critical processes of life and death—from fertilization through to development, metabolism and, ultimately, death.

Previous work by the team showed that inositol trisphosphate (IP_3) and calcium ions are involved in regulating channel opening and closing. The channels are formed from complexes of four IP_3 receptors (IP_3R) that bind IP_3 and calcium. At low concentrations of calcium ions, channel opening is stimulated; but at higher levels, it is inhibited. Although cell biologists have proposed models depicting this process, they had failed to collect any definitive evidence supporting a particular the mechanism, until now.

In live cells, Takayuki Michikawa, Katsuhiko Mikoshiba and their colleagues attached fluorescent proteins to two of the channel-forming IP_3Rs because these receptors change shape in response to the binding of IP_3 and calcium, and energy flows between this pair of proteins in a process known as Förster resonance energy transfer (FRET) (Fig. 1). In a detectable way, FRET changes the fluorescent light emitted, so the impact of such links on the conformation of the channel can be studied.

The researchers found there were at least five binding sites on each IP_3R, one for IP_3 and at least four for calcium. Binding IP_3 tended to bring the receptors forming the channel closer together, while calcium tended to make them relax. But the effects of combining the two were not simply additive. At a constant level of IP_3, they observed an optimum concentration of calcium that had the most impact on opening the channel.

From these results, the researchers proposed a model whereby IP_3 and calcium ions compete with one another—the binding of IP_3 prevents calcium linking to certain sites, and vice versa. High concentrations of calcium prevent IP_3 from binding at all. Further, the researchers proposed two different types of calcium binding sites: low-affinity sites responsible for channel activation, and high-affinity sites for inactivation.

"During the past five years, we have succeeded in visualizing IP_3 dynamics and calcium pump activity," Michikawa and Mikoshiba say. "In combination with the model for the calcium release channel described in this study, we are now ready to understand what happens in living cells during calcium ion oscillations." ■

1. Shinohara, T., Michikawa, T., Enomoto, M., Goto, J.-I., Iwai, M., Matsu-ura, T., Yamazaki, H., Miyamoto, A., Suzuki, A. & Mikoshiba, K. Mechanistic basis of bell-shaped dependence of inositol 1,4,5-trisphosphate receptor gating on cytosolic calcium. *Proceedings of the National Academy of Sciences USA* **108**, 15486–15491 (2011).

Unraveling the Chinese cabbage genome

The draft genome of the Chinese cabbage could underpin genetic improvement of brassica vegetable and oil crops

Clues into the evolutionary diversification of brassicas have emerged from the draft Chinese cabbage genome sequence[1]. *Brassica* crops include many agriculturally important vegetables, such as Chinese cabbage, *pak choi*, turnip, broccoli, cabbage and cauliflower, as well as various oilseed crops.

The sequencing focused on Chinese cabbage, *Brassica rapa* subspecies *pekinensis* (Fig. 1), and was undertaken by the international *Brassica rapa* Genome Sequencing Project Consortium. The work was underpinned by the previously published genome sequence of the premier model of flowering plants, *Arabidopsis thaliana*. This species is related to *B. rapa*, with which it shared a common ancestor.

"*Brassica*s come in many shapes and sizes, and even individual species show considerable morphological variation. Genome information helps us understand the genetic basis of this diversity," explains consortium member Hiroshi Abe of Japan's RIKEN BioResource Center, one of the three biggest *Arabidopsis* stock centers in the world. "We developed genomic resources for *Brassica rapa* and contributed to the gene annotation in this project."

New plant species generally arise through hybridization, involving whole genome duplications, followed by rapid DNA sequence divergence under natural selection, chromosomal rearrangements and extensive gene loss. Indeed, plant biologists have observed whole-genome duplication in all plant genomes sequenced to date, including that of *A. thaliana*. In addition, previous physical mapping studies revealed a whole genome triplication event in the *Brassica* lineage, after its divergence from the *Arabidopsis* lineage at least 13–17 million years ago.

Figure 1: The Chinese cabbage, *Brassica rapa* subspecies *pekinensis*.

The genome sequence assembled by the Consortium covers more than 98% of the DNA encoding genes. By analyzing the sequence in detail, the researchers were able to investigate the evolutionary and functional consequences of the whole genome triplication event.

The researchers identified 41,174 protein-encoding genes belonging to 16,917 separate gene families. By comparing the sequences of *Brassica* genes to those of *A. thaliana*, they were able to relate gene structures in these two plants. They found that the extent of gene loss among triplicated genome segments varies, with one of the three copies consistently retaining a disproportionately large fraction of ancestral genes. Based on their finding, the researchers believe that variation in the number of members of gene families present in the genome probably contributes to the remarkable morphological plasticity of *Brassica* species.

"We hope that our findings will contribute to the breeding of improved *Brassica* oil and vegetable crops," says Abe. "The genomic resources for *Brassica rapa* developed at the RIKEN BioResource Center will soon be made available to the wider research community." ■

1. *Brassica rapa* Genome Sequencing Project Consortium. The genome of the mesopolyploid crop species *Brassica rapa*. *Nature Genetics* **43**, 1035–1039 (2011).

Revealing how a potato disease takes hold

Infectious agents released from the late blight pathogen use a sticky patch of amino acids to adhere to potato plant cells

Figure 1: Potato crops are still at the mercy of the plant pathogen *Phytophthora infestans* that causes the disease called potato late blight.

Late blight is an economically devastating disease for potato farmers worldwide, causing tens of billions of dollars worth of damage each year. *Phytophthora infestans*, the causal agent of late blight, has evolved to overcome fungicides and major resistance genes that have been bred into commercial potato cultivars (Fig. 1). In order to dampen the immune response of its host, *P. infestans* secretes molecules called disease effectors at the site of infection.

Now, a research team from Japan and the UK has determined the molecular structure of the disease effector called avirulence protein 3a (AVR3a), which is known to inhibit disease resistance in potato plants[1]. Understanding the molecular structure and function of AVR3a will help plant biologists to elucidate how *P. infestans* causes infection so that they can develop better control measures.

Using nuclear magnetic resonance spectroscopy, a technique employed to study the configuration of molecules, the research team—led by Ken Shirasu from the RIKEN Plant Science Center in Yokohama—identified a patch of positively charged amino acids in the structure of AVR3a. The team found the positively charged section of amino acids is conserved among different versions of AVR3a from *P. infestans* and the model pathogen *P. sojae*, indicating that this part of the overall structure could be important to AVR3a's role in the infection process.

By examining potato plants to determine the final destination of AVR3a within the infected host, the researchers found that the disease effector binds to a lipid molecule called phosphatidylinositol phosphate (PIP), which forms part of the structure of the potato cell membrane.

To determine whether the newly identified section of amino acids is essential to PIP-binding, Shirasu and his colleagues generated AVR3a mutants by substituting the positively charged amino acids found in the newly identified section with negatively charged amino acids. Using a binding assay to investigate the interactions between molecules, the researchers showed that the AVR3a mutants are unable to join to PIP and hence attach to the potato cell membrane. They therefore proposed that AVR3a may bind to PIPs in the cell membrane in order to remain undetected by the immune system of the potato.

The team's next challenge is to determine how AVR3a molecules and other disease effectors from *P. infestans* translocate into the host from the site of infection. "Developing ways to block the action of AVR3a and other disease effectors will provide means to control this damaging crop disease," says Shirasu. ■

1. Yaeno, T., Li, H., Chaparro-Garcia, A., Schornack, S., Koshiba, S., Watanabe, S., Kigawa, T., Kamoun, S. & Shirasu, K. Phosphatidylinositol monophosphate-binding interface in the oomycete RXLR effector AVR3a is required for its stability in host cells to modulate plant immunity. *Proceedings of the National Academy of Sciences USA* **108**, 14682–14687 (2011).

Deciphering the mechanism of an ion pump

Insights obtained from a structural and functional analysis of an ion-pumping protein could benefit future drug discovery efforts

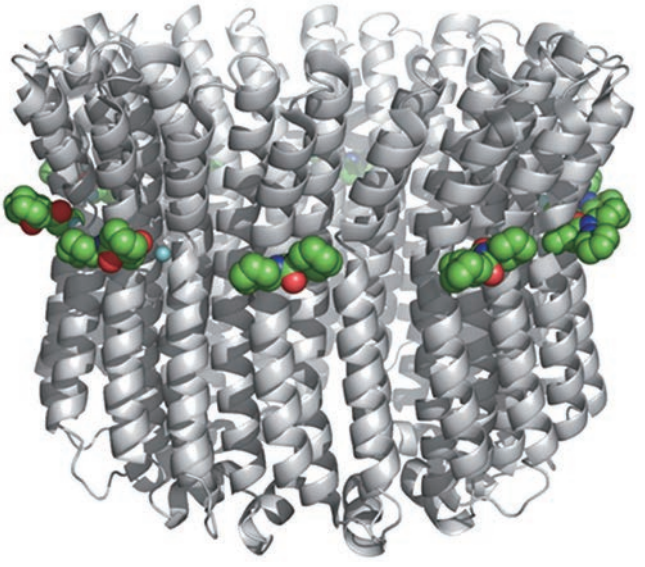

Figure 1: The crystal structure of the *E. hirae* V-ATPase with molecules of DCCD (green spheres) bound to E139 at each individual subunit.

From an analysis of the sodium-transporting vacuolar ATPases (V-ATPases) of the bacterium *Enterococcus hirae*, Takeshi Murata of the RIKEN Systems and Structural Biology Center, Yokohama, and colleagues recently obtained valuable structural and functional information about a process that pumps protons and other positively charged ions across cellular membranes[1].

Adenosine triphosphate (ATP) is the primary energy 'currency' within cells, and numerous enzymes are powered by the metabolic processing of this molecule via a mechanism known as hydrolysis. V-ATPases can exploit this process to pump positively charged ions across cellular membranes. This process occurs at the junction between a rotating 'K' domain and a fixed 'a' domain within the segment of the protein that resides at the cell membrane, although the specifics remain unclear.

N,N'-dicyclohexylcarbodiimide (DCCD), a chemical that selectively reacts with a specific glutamate amino acid (E139) within the sodium-binding pockets of the K ring, proved valuable in assessing this protein's function. The researchers demonstrated that DCCD inhibited sodium binding by nearly 30-fold, but that this inhibition was sharply reduced when the enzyme was pretreated with sodium ions, suggesting that the two molecules interact with overlapping targets within the ring.

The K ring is composed of ten identical subunits, and DCCD efficiently reacts with E139 in each of these individual components (Fig. 1). By gathering structural data from the DCCD-treated V-ATPase, Murata and colleagues obtained a snapshot of what the protein looks like in the absence of sodium, which they could in turn compare against the structure of the sodium-bound form.

Although the two structures were largely similar, DCCD treatment triggered a change in E139 that locked the sodium binding sites into an 'open' structure that prevented ion retention. The negative charge of E139 made an important contribution to the binding of the positively charged Na^+ ion; DCCD appeared to work by neutralizing this charge. The researchers hypothesize that a similar process governs ion release during the transport process; as the K domain rotates, each subunit's E139 interacts with a positively charged amino acid on the domain, triggering ion release and transfer across the membrane.

Confirming this model will require additional structural data. "We would like to obtain the structure of [the] whole complex containing both the rotor ring and a-subunit," Murata says. Nevertheless, these findings could prove immediately applicable to the development of more effective ATPase inhibitors, a class of drugs potentially useful for treating cancer and other diseases. "V-ATPases are of considerable pharmacological interest," says Murata. ■

1. Mizutani, K., Yamamoto, M., Suzuki, K., Yamato, I., Kakinuma, Y., Shirouzu, M., Walker, J.E., Yokoyama, S., Iwata, S. & Murata, T. Structure of the rotor ring modified with *N,N'*-dicyclohexylcarbodiimide of the Na^+-transporting vacuolar ATPase. *Proceedings of the National Academy of Sciences USA* **108**, 13474–13479 (2011).

Untangling a protein's influences

A computational strategy that reveals how environmental interactions affect protein shape could steer more sophisticated approaches to drug design

Most proteins have multiple moving parts that rearrange into different conformations to execute particular functions. Such changes may be induced by molecules in the immediate environment, including water and similar solvents as well as other molecules or drugs that a protein might encounter.

A new computational approach devised by Yohei Koyama and Hiroki Ueda at the RIKEN Quantitative Biology Center, Kobe, and Tetsuya Kobayashi of the University of Tokyo now provides researchers with the means to understand how specific interactions between environmental molecules and a given protein facilitate particular conformational rearrangements[1].

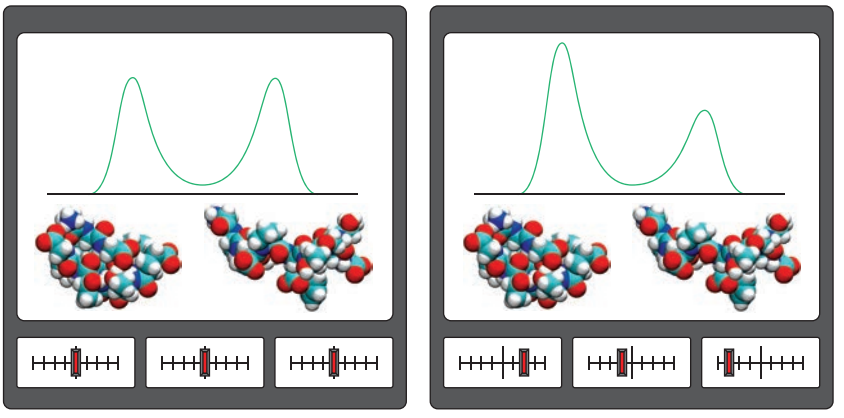

Figure 1: DIPA reveals shifts in protein conformation that arise from the strengthening or weakening effects of perturbing protein–water interactions. The bars along the bottom indicate the relative strength of the perturbations (weak, left; strong, right).

In the past, researchers have focused on the movement of specific atomic coordinates, using a statistical tool called principal component analysis (PCA) to identify segments of the protein that collectively contribute to a given rearrangement. However, such approaches simply map a protein's movements rather than clarifying interactions that contribute to those changes. To address this limitation, Koyama, Ueda and Kobayashi developed a method called distance-dependent intermolecular perturbation analysis (DIPA), which uses PCA to characterize how subsets of environmental molecules contribute to conformational shifts.

"Perturbation analysis is a method to understand complex systems by observing responses to changes in the system," explains Koyama. "For example, to understand the function of a machine without a manual, we sometimes manipulate the controls and observe its response." Accordingly, DIPA simulates the manipulation of different environmental molecules and determines whether they favor particular conformational states for a protein (Fig. 1).

The researchers initially used DIPA to simulate the influence of surrounding water on a chemically capped version of the amino acid alanine and identified three conformational states. In a subsequent analysis, they used a larger molecule called chignolin, a hairpin-shaped polypeptide containing ten amino acids, and observed four states and the environmental influences that stabilize those states. "We observed that molecular states can be identified clearly in terms of intermolecular protein–water interactions," says Koyama.

DIPA is a powerful tool, but the researchers cannot yet apply it to the movements of full-sized proteins, as existing computational hardware is inadequate for such demanding molecular dynamics simulations. "Current simulations are performed over timescales of a few microseconds," says Koyama, "but many proteins manifest their functions over an order of many microseconds or even milliseconds." However, supercomputing initiatives underway at RIKEN—such as the ultra-fast 'K computer' slated for completion in 2012—could help bring these capabilities within reach, at which point DIPA promises to become a potent resource for the rational design of protein-specific drugs. ■

1. Koyama, Y.M., Kobayashi, T.J. & Ueda, H.R. Perturbation analyses of intermolecular interactions. *Physical Review E* **84**, 026704 (2011).

Boosting longevity with good bacteria

A diet supplemented with a specific probiotic bacterial strain increases the lifespan of mice

The mammalian gut is home to hundreds of bacterial species that contribute to food digestion and, in some cases, inflammatory gut diseases. Probiotics, beneficial bacterial species, can enhance gut health by keeping the resident bacteria in check. Now, a team of researchers at the RIKEN Innovation Center in Wako, including Mitsuharu Matsumoto, report that administration of the probiotic bacterial strain *Bifidobacterium animalis* subspecies *lactis* LKM512 to mice can lengthen their lifespan[1].

Matsumoto and colleagues previously showed that LKM512 could reduce inflammatory markers in elderly humans and modify the makeup of intestinal bacteria[2], but the effects of it on lifespan still required investigation. After starting 10-month-old mice on a diet including LKM512 for 11 months, the researchers found that LKM512-treated mice lived longer, had fewer skin lesions, and had better hair quality than untreated mice.

Analyses of the gut of these mice revealed elevated gene expression in some bacterial species compared with control mice, indicating that LKM512 may improve gut health indirectly by regulating the levels of other bacterial species. The LKM512 treatment also prevented some age-related changes in bacterial composition of the gut, suggesting that the probiotic treatment protects the gut from developing characteristics associated with aging.

Acting as a barrier between the bacteria and food within the gut and the rest of the human body is an important role of the gut lining. Breakdown of this lining can cause infectious or inflammatory diseases. The researchers found that the gut of LKM512-treated mice served as a stronger barrier than the gut of control mice. LKM512 seemed to perform this function by increasing the expression of various proteins that maintain the tight connection between gut epithelial cells.

Polyamines are chemicals that reduce inflammation, and their levels decrease as an individual ages. Matsumoto and colleagues observed increases in intestinal polyamine levels in LKM512-treated mice, which may be caused by the greater numbers of bacteria promoted by LKM512. The increase in polyamines caused by LKM512 appeared to reduce inflammation in the body of the mice, as inflammatory markers in the blood and urine were lower in LKM512-treated mice compared with controls. In aged mice treated with LKM512, inflammatory marker levels were similar to those observed in younger mice, indicating that adults can benefit from probiotics.

"In future work, we hope to clarify the effectiveness of LKM512 in humans," explains Matsumoto. If the findings extend to humans, inclusion of LKM512 into the human diet could enhance overall health and increase the human lifespan. ■

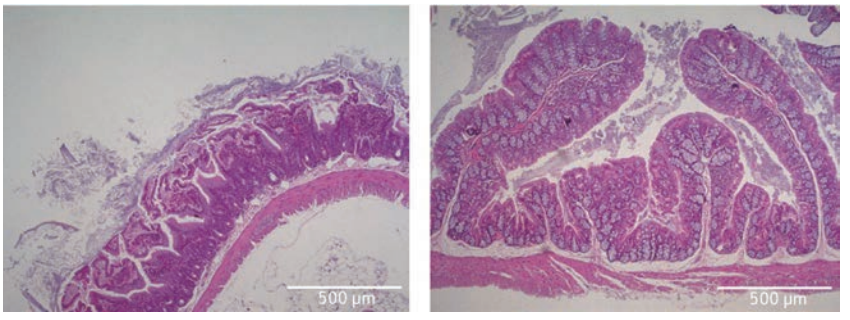

Figure 1: Compared with untreated aging mice (left), LKM512 maintains a healthy gut lining in treated aging mice (right) (scale bar, 500 µm).

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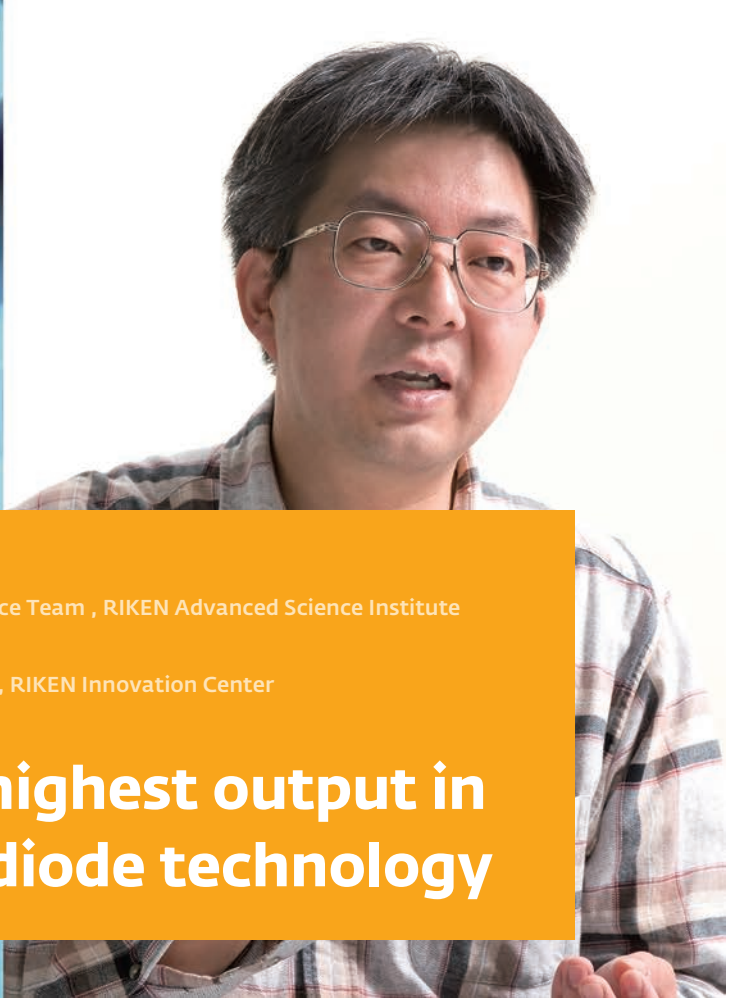
2. Matsumoto, M., Ohishi, H. & Benno, Y. Impact of LKM512 yogurt on improvement of intestinal environment of the elderly. *FEMS Immunology & Medical Microbiology* **31**, 181–186 (2001).



HIDEKI HIRAYAMA

Team Leader
Terahertz Quantum Device Team , RIKEN Advanced Science Institute

Deputy Team Leader
Deep UV-LED Laboratory, RIKEN Innovation Center

Developing the world's highest output in deep-UV light-emitting diode technology

Light-emitting diodes (LEDs) are small, low-energy light sources with a long service life. The LEDs emit infrared rays, visible light, or ultraviolet (UV) rays. In particular, light in the deep-UV band with short wavelengths of between 220 and 350 nanometers has a high sterilizing power that has growing potential in a broad range of applications, including in medicine and in the rapid decomposition of environmental pollutants, such as dioxins. However, deep-UV LEDs (DUV-LEDs) are slow to be adopted because the deep-UV light source is bulky, short-lived, and expensive. Hideki Hirayama, team leader of the Terahertz Quantum Device Team, RIKEN Advanced Science Institute, and Deputy Team Leader of the Deep UV-LED Laboratory, has launched major breakthroughs toward practical applications of this developing technology.

Deep-UV LEDs expected to establish a market of several hundred billion yen

A light-emitting diode (LED) is a light source that enables the production of devices with low energy consumption, long service life, and decreased size and weight. An LED comprises an n-type semiconductor, in which negative charged electrons are the majority carrier, and a p-type semiconductor, in which positively charged "holes" are the majority carrier (see Fig. 1). When a negative voltage is applied to the n-side, and a positive voltage is applied to the p-side, the holes and electrons move and an electric current begins to flow. Upon collision and binding of the holes and electrons in the light-emitting region, they lose their original energy, and the resulting excess energy turns into light energy, thereby producing emission.

In recent years LEDs have been developed that emit light over a broad range of wavelengths, including blue and green colors. However, wavelengths in frontier bands, that is, deep-UV radiation with wavelengths from 220 to 350 nm, remain to be further developed. The only currently available methods for generating deep-UV radiation include those using an ultraviolet laser or gas lamp; however, these approaches produce weak emission, require a large, short-lived light source, and are expensive and impractical. For these reasons, there is strong demand for developing a practically applicable LED that emits deep UV.

"This technology has the potential for very wide applications," Hirayama explains. "For example, a deep-UV radiation with a wavelength of 270 nm can not only be used in medical settings, but also in small sterilizing lamps in refrigerators,

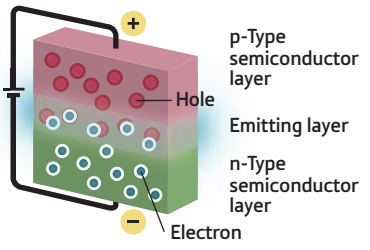


Figure 1: Basic structure of a deep-UV light-emitting diode (LED)
The structure of an LED comprises an n-type semiconductor, in which electrons are the majority carrier, and a p-type semiconductor, in which holes are the majority carrier. When a negative voltage is applied to the n-side and a positive voltage is applied to the p-side, holes and electrons move and an electric current begins to flow. Upon collision and binding of the holes and electrons during migration, they lose their original energy, and the resulting excess energy turns into light energy and produces emission.

	Achievements	Wave-length	Output	Level of achievement for external quantum efficiency ([electron injection efficiency] × [internal quantum efficiency] × [light extraction efficiency])
2007	High-quality AlN buffer layer realized	260nm	2mW	50–80% internal quantum efficiency realized
2008	Quantum well introduced, indium-incorporated InAlGaN deep-UV LED developed	280nm	10mW	
2010	Multiquantum barrier (MQB) introduced	250nm	15mW	80% electron injection efficiency realized
Present	Ongoing attempts to improve the contact layer			8–15% light extraction efficiency (current level). Target level: 70%

Figure 2: Major achievements since 2007

air purifiers, and other appliances in ordinary households. Deep-UV radiation with a wavelength of less than 250 nm can be utilized in a high-density recording laser that can store three to four times more data than currently available optical discs. This capacity enables three to four movies of high image quality to be recorded on one disc. Deep-UV radiation with wavelengths of 270 to 320 nm can be utilized for the treatment of environmental pollutants which are difficult to breakdown naturally, such as dioxins, and those with a wavelength of 340 nm can be utilized for highly brilliant white light lamps instead of fluorescent lamps. The market scale for DUV-LEDs for sterilization-related applications alone is estimated at several hundred billion yen per year."

External quantum efficiency improved by two digits

"An LED is a luminescent semiconductor device, and the wavelength of the light emitted varies depending on the material," says Hirayama. "Aluminum gallium nitride (AlGaN) is recognized as the best material with which to prepare a DUV-LED. AlGaN is a crystalline alloy of aluminum nitride (AlN) and gallium nitride (GaN), and by changing the content ratio of aluminum and gallium, it is possible to produce light in a broad range of wavelengths, from 200 to 360 nm, which includes deep-UV radiation. AlGaN has many other advantages, such as its high durability and long service life, its applicability to both the p-type and the n-type, and the fact that it is environmentally harmless because it is free from arsenic, lead, and mercury."

Engaged in DUV-LED research and development for nearly 15 years, Hirayama has seen LED development come a long way since 1997. "In those days, the external quantum efficiency of AlGaN DUV-LED was about 0.01%, a level falling far short of practical application. Raising the efficiency would lead to the emission of light of a higher energy. External quantum efficiency is the ratio of light energy that can be obtained outside the device relative to the electrical energy input, and this is used as an index of an LED's luminescence efficiency. External quantum efficiency is calculated by multiplying the electron injection efficiency by the internal quantum efficiency and the light extraction efficiency." Electron injection efficiency indicates the ratio of electrons injected into the emitting layer to all those electrons involved. Internal quantum efficiency is the ratio of electrons that have bound themselves to holes and produced light energy, relative to all the electrons injected into the emitting layer. Light extraction efficiency shows the ratio of light energy obtained outside the LED relative to light energy produced by the emitting layer.

"The level of external quantum efficiency that I have just mentioned, namely about 0.01%, is obtained from electron injection efficiency (about 20% ≒ 0.2) by

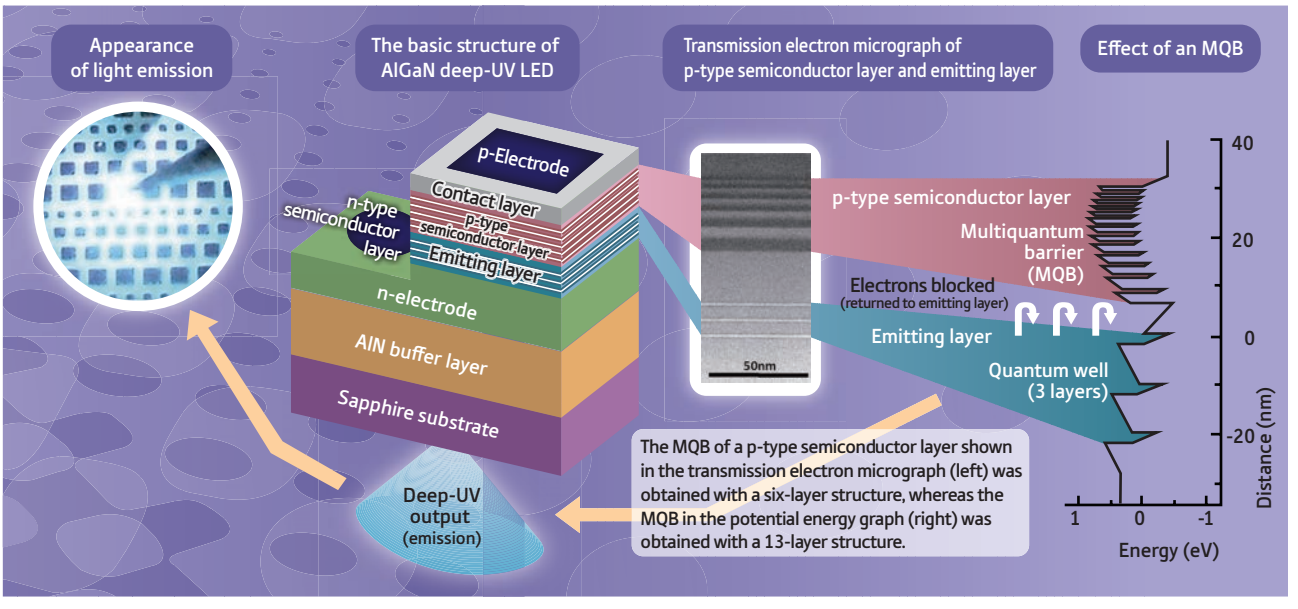


Figure 3: The basic structure of AlGaN deep-UV LED

This is the basic structure of an AlGaN deep-UV LED developed in 2010. Internal quantum efficiencies of 50–80% were realized through some key technical breakthroughs, including improved crystal quality for the AlN buffer layer and introduction of an In-incorporated quantum well into the emitting layer. Introduction of a multiquantum barrier (MQB) into the p-type semiconductor layer resulted in an electron injection efficiency of 80%. Shown above is a CCD camera photograph of how the LED is emitting light. A wavelength of 250 nm with an output of 15 mW was achieved, clearing the requirement for practical use in sterilizing lamps. Although ultraviolet light is invisible, this emission looks bluish white because visible light with longer wavelengths is simultaneously generated at an extremely low intensity. The ultraviolet light shines at an intensity several hundred times greater than the visible light.

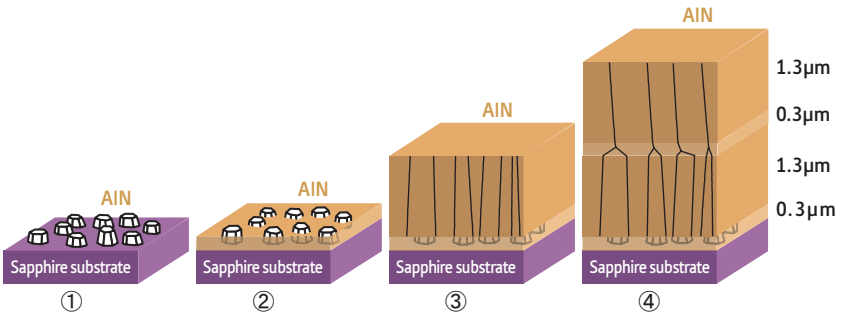


Figure 4: Improving the quality of AlN buffer layer using the ammonia pulse-feed multilayer growth mode

(1) Nuclei of high-quality AlN crystals are generated on a sapphire substrate. (2) The crystals are grown laterally using the pulse-feed laterally-enhanced growth mode to fill the gaps between the nuclei. (3) The crystals are grown rapidly longitudinally using the continuous-feed rapid-longitudinal growth mode. (4) The pulse feed laterally-enhanced growth mode and the continuous-feed rapid-longitudinal growth mode are alternately repeated to grow the crystals in a multilayer structure. This series of steps produces a low penetration dislocation.

internal quantum efficiency (less than 1% < 0.01) by light extraction efficiency (about 8% ≒ 0.08). The electron injection efficiency of the AlGaN DUV-LED that we developed in 2010 is up to 80%, its internal quantum efficiency is 50%, and its light extraction efficiency is 8%. The external quantum efficiency is now about 3%," explains Hirayama (see Fig. 2). These recent developments provide a stark contrast to 1997, when the output from a DUV-LED developed with AlGaN was so low at 20 microwatts that the LED barely emitted any light at all.

New methods in crystal growth increase internal quantum efficiency to 50–80%

Several layers created by the crystallization process are key structural components of an AlGaN DUV-LED. "Generally, numerous semiconductor functions are exhibited by a number of semiconductor layers with different profiles that are several nanometers to micrometers thick, stacked on the surface of a high-quality substrate crystal. An AlGaN DUV-LED also has a similar multilayer structure. A gasified material is sprayed over a sapphire substrate and thermally decomposed to cause crystallization (during vapor phase growth) and creates several important layers in the following order: a buffer layer, an n-type semiconductor layer, an emitting layer, a p-type semiconductor layer, and a contact layer," says Hirayama (see Fig. 3).

The quality of AlGaN crystals contributes to a low internal quantum efficiency of AlGaN DUV-LED. High-quality crystals are characterized by (1) a low density of penetration dislocations (discontinuity of atomic arrangement during crystal growth reaching the crystal surface), (2) the absence of cracks, and (3) the maintenance of crystal surface flatness at the level of one atomic layer. Therefore, a low-quality crystal that does not meet the requirements of (1) to (3) is problematic in that the prevalence of hole-electron bonding without emission (non-radiative recombination) increases, resulting in considerably reduced internal quantum efficiency.

"This problem arises from the difference in the distance between the sapphire substrate and AlGaN in the crystal lattice," explains Hiyarama. "Because they have different lattice distances, their atoms do not become well stacked together, even when forced. If AlGaN crystals are allowed to grow on the sapphire substrate in this state, the penetration dislocation density increases and cracking is likely, so that only low-quality crystals are obtained. As a solution, we interpose an AlN buffer layer to modify the difference in lattice distance, but even this approach does not ensure satisfactory quality. In 2007, we succeeded in solving this problem by developing a new method called the 'ammonia pulse-feed multilayer growth method.'"

This groundbreaking method enables the growth of high-quality crystals (see Fig. 4). "Traditionally, an AlN buffer layer is created on a sapphire substrate by allowing AlN crystals to grow while gaseous aluminum and gaseous ammonia are fed simultaneously and continuously. In our newly developed technique, we use alternative combinations of two methods of crystal growth. Namely, the conventional continuous-feed rapid-longitudinal growth mode, and the pulse-feed laterally enhanced growth mode, in which gaseous aluminum is continuously supplied and gaseous ammonia is fed in pulses."

First, nuclei for high-quality AlN crystals are created on a sapphire substrate (see Fig. 4(1)). Next, the crystals are grown laterally using the pulse-feed laterally-enhanced growth mode to fill the internuclear gaps (Fig. 4 (2)). This process significantly reduces the penetration dislocation density to meet the first requirement. Next, the crystals are rapidly grown longitudinally using the continuous-feed rapid-longitudinal growth mode (Fig. 4 (3)). In this process, the second and third requirements are fulfilled, that is, the maintenance of surface flatness at the level of one atomic layer, and the prevention of cracking. Subsequently, both modes are alternately applied to enable further crystal growth (Fig. 4 (4)).

Hirayama adds, "We were able to reduce the penetration dislocation density of the AlN buffer layer to a level one-eighth-ieth of the conventional level by using the ammonia pulse-feed multilayer growth mode. When we stacked an n-type semiconductor layer, an emitting layer, and other layers onto the AlN buffer layer, we could obtain light with a 260 nm wavelength and an output intensity of about 2 mW. The internal quantum efficiency increased dramatically to 50 times higher than the conventional level."

In addition to these layers, Hirayama and his colleagues introduced an extra three, very thin layers which create a 'quantum well' effect of electron enclosure in the emitting layer, whereby the layer encloses both electrons and holes to facilitate their bonding (see Fig. 3). In 2008, the team succeeded in further improving the internal quantum efficiency by introducing indium (In) to AlGaN, and increasing the hole concentration in a p-type semiconductor layer, thus developing an InAlGaN DUV-LED in the 280 nm wavelength band, which is indispensable to the sterilization of objects and the treatment of environmental pollutants. The LED realized an internal quantum efficiency of 80% and an output of 10 mW. These achievements resulted in a significant improvement of the internal quantum efficiency from less than 1% to between 50–80%.

Multiquantum barrier increases electron injection efficiency to 80%

In a world-first attempt, Hirayama and his colleagues introduced an

electron-blocking multiquantum barrier (MQB) into an AlGaN DUV-LED (see Fig. 3). Later in 2010, they achieved a dramatic increase in electron injection efficiency to more than 80%, succeeding in generating light at a wavelength of 250 nm with a high output of 15 mW.

According to Hirayama, "The low electron injection efficiency was due to a large percentage of electrons injected into the emitting layer. These electrons passed through it and reached the p-type semiconductor layer. Essentially, the electrons injected into the emitting layer should bind to positively charged holes and emit light. If they pass right through the emitting layer, the injected electrons in effect are wasted. To counter this problem, we introduced an electron-blocking MQB into the p-type semiconductor layer in an attempt to reflect the electrons entering the MQB and return them to the emitting layer."

Hirayama and his colleagues first tested a single-layer barrier. Electrons with an energy level lower than that of the barrier were reflected back to the emitting layer, but those with higher energy failed to be reflected and reached the p-type semiconductor layer through the emitting layer. "So we then attempted to apply the MQB to obtain multiple barriers. We found that, due to a quantum physical multiple reflection effect, even electrons with an energy level higher than that of the barriers were reflected back to the emitting layer," says Hirayama. An examination of the MQB using transmission electron microscopy reveals a six-layer structure, with the layer becoming increasingly thicker toward the emitting layer side and thinner toward the p-type semiconductor layer side (see Fig. 3). Of the electrons entering the MQB, those with energy levels lower than those of the MQB are reflected by the first thick layer. The electrons with higher energy levels pass the first layer but are reflected by the second and subsequent layers. "The electron block height of an MQB can be increased to a maximum that is about double that of a single barrier," adds Hirayama.

The introduction of the MQB approach led to a dramatic improvement in electron injection efficiency from less than 20% to over 80%, and the external quantum efficiency increased from 0.4% to 1.5%. The output reached 15 mW in continuous operations at room temperature. These figures currently represent the world's highest levels.

"The major feature of an MQB is that even when a large current is supplied, the barrier effect of reflecting electrons and returning them to the emitting layer does not weaken," explains Hirayama. "In other words, even when the current increases, the efficiency does not decline. This is important in considering the introduction of semiconductor devices into practical applications." This MQB theory is also applicable to LEDs other than DUV-LEDs. In blue LEDs, reductions in output with an increase in the current have been problematic. Use of an MQB enables a sufficient output to be maintained even with large currents, so the theory is likely to be applicable to LEDs for lighting lamps and other devices that require a certain level of output. Another favorable feature of an MQB is that it can be created using existing equipment for LED production.

Aiming for 70% light extraction efficiency

The key challenge remaining for Hirayama's team is improving the rate of light extraction efficiency. Currently the light that travels just below the emitting layer can be extracted from the light issued by the emitting layer, however, the remaining light that is scattered to the other layers is wasted, so that light extraction efficiency only reaches a maximum of 8%.

"Since scattered light is mostly absorbed in the contact layer on the p-type semiconductor layer, we thinned the contact layer. We are also investigating a method in which an aluminum-based electrode having a reflectivity of more than 80% is used as the p-electrode in place of a nickel-gold electrode, with a reflectivity of about 20%. We are also looking at an approach to forming a photonic crystal on the sapphire substrate to increase the amount of light extracted. Currently, the light extraction efficiency is 8–15%, but it seems possible to raise this level to 40% by applying these techniques in combination," says Hirayama. He is also promoting research into a new structure for light extraction to be introduced into the p-type semiconductor layer. Its success would make an efficiency of 70% a reality.

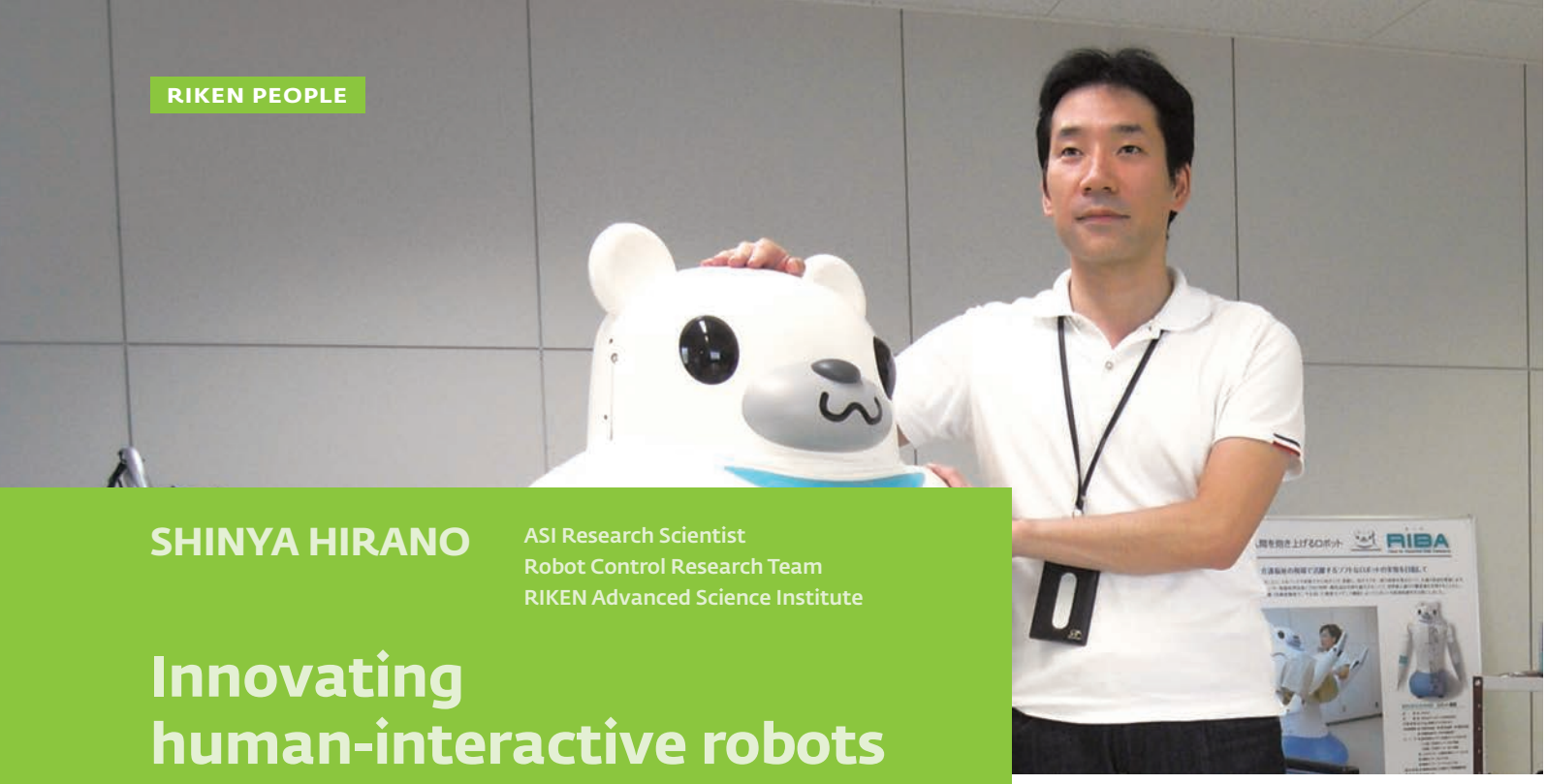
"For DUV-LEDs, we have reached the levels of an external quantum efficiency of 3.8% and an output of 30 mW. However, the external quantum efficiency of a blue LED is more than 80%. The external quantum efficiency of a DUV-LED would not exceed 80% unless the efficiency is 90% or more for electron injection efficiency, internal quantum efficiency, and light extraction efficiency. I want to approach this level for DUV-LEDs. The only problem to be resolved is how to improve the light extraction efficiency. I aim to clear the immediate goal of 70% as soon as possible and bring a DUV-LED into practical application for a broad range of areas."

Aiming to achieve world-class performance for both the shortest and longest wavelength

In addition to his research into deep-UV light, Hirayama is also investigating terahertz light (wavelength range: 3 mm – 30 μm). With its binary aspects of electronic waves (permeability) and light (light collection resolution), terahertz light is expected to find applications for the internal examination of a wide variety of objects. Although deep-UV radiation and terahertz light differ 1,000 times in wavelength, Hirayama hopes to achieve the world's number one performance for both of them. "I am so interested in technical development that I can't help being involved," says Hirayama.

ABOUT THE RESEARCHER

Hideki Hirayama was born in Ibaraki, Japan, in 1966. He obtained his PhD of Engineering from the Tokyo Institute of Technology in 1994. In the same year, he became a research scientist at RIKEN. In 2005, he progressed to the position of team leader of the Terahertz Quantum Device Team, serving concurrently from 2004 as visiting assistant professor at Saitama University. In 2009, he was appointed as visiting professor of Saitama University. He won a Young Scientist Award from the Minister of Education, Culture, Science and Technology in 2005, a Japan IBM Science Prize in Electronics in 2010, and an Ichimura Science Prize in 2011. His research focuses on crystal growth of AlGaN based nitride-semiconductors and development of deep-ultraviolet (DUV) light-emitting diodes (DUV LEDs) and laser diodes (LDs). He is also developing terahertz quantum cascade lasers (THz-QCLs) and terahertz sensing devices based on intersubband optical transition of semiconductor quantum cascade structures.



SHINYA HIRANO

ASI Research Scientist
Robot Control Research Team
RIKEN Advanced Science Institute

Innovating human-interactive robots

What do you do at RIKEN?

I work as a researcher for the Robot Control Research Team at the Advanced Science Institute.

How and when did you join RIKEN?

I first joined RIKEN as a researcher at the Bio-Mimetic Control Research Center (BMC). When I completed graduate school I decided to further my research, which, along with a recommendation from my team leader, was the reason why I applied to join RIKEN. At the time, everybody had their hands full with the development of the human-interactive robot, RI-MAN, which was the forerunner of the nursing-care assistance robot, RIBA. I was full of admiration for my seniors who had created an almost human-sized robot from nothing. I am very lucky to be here because I have always been interested in robots and because robotics is a continually growing field.

How was the transition to life at RIKEN?

After I joined RIKEN, RI-MAN was put into use and, at the same time, work started on a robot similar to RI-MAN as part of a joint project between Tokai Rubber Industries and the Collaboration Center. This robot eventually became RIBA. An extremely large amount of work was involved in developing RIBA, which meant that I had to work late nights for an extensive period. We finally produced a press release in August 2009, after experiencing several setbacks. During these tough times we received support from various people at RIKEN who helped us in areas that we researchers are not so familiar with, such as arranging and ordering parts. I think it was a considerable job on our part because robots comprise of over 1,000 parts.

Please tell us about your research or other work at RIKEN.

We are currently in the midst of starting R&D on the next-generation RIBA. Although RIBA can successfully lift up a person in its arms, we realized during our research that there is still room for improvement. It is very important for the robot to not only lift up a person, but to lift up a person without putting a burden on them. Another key issue is RIBA's ability to adapt to different physiques. Naturally, nursing homes want a robot that is safe and can bear heavy weights, as well as being small and light. Based on these results, we have confirmed the general outline of the next-generation RIBA and are in the initial planning stages. In order to create a small-scale, light robot we are currently focusing on the component technology, and we are developing some of the important parts that will be used in the next-generation RIBA.

What have been the highlights of your time at RIKEN so far?

I specialize in electrical circuits, but in order to create a robot you need to have knowledge from a wide variety of specialist fields. It has been extremely useful to learn more about mechanical and control systems as part of RIBA's R&D. Making robots is a huge systematic process involving various people, which is why during the process I have been able to dramatically broaden my ability to interact with a wide range of people with different points of view.

What is the best thing about working at RIKEN?

Goals for teams and projects are of course set at RIKEN, but individuals are encouraged to pursue their own research and goals too. Although this working style is not usually adopted by regular companies, I believe it is attractive because it cultivates new discoveries and interesting research developments. RIKEN places a great deal of emphasis on basic science, so an engineering-based robotics field is extremely unusual. I am really happy that RIKEN's open-minded approach allows me to conduct research into robots that will create new benefits for society.

What would you say to other people considering joining RIKEN?

Unlike other companies and company-affiliated research centers, RIKEN allows you to pursue your own research themes. Overall, it is a very fulfilling place to work, as well as a great place to further your research.

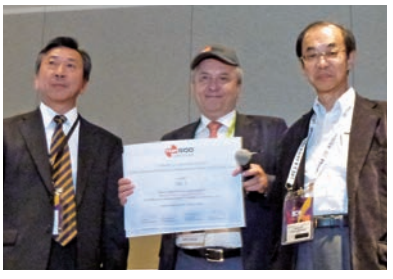
CONTACT INFORMATION

For details about working at RIKEN, please contact the RIKEN Global Relations Office:
Tel: +81-(0)48-462-1225 E-mail: gro-pr@riken.jp

The K computer maintains No.1 position in world ranking

Jointly developed by RIKEN and Fujitsu, the K computer — a new supercomputer named after the Japanese word *kei*, which represents the unit 'quadrillion' or 10 peta — took first place in the 38th TOP500 list announced at the 27th International Conference for High Performance Computing, Networking, Storage and Analysis in November, 2011. This is the second time for the K computer to take first place, having also been ranked number one in the TOP500's June 2011 listing.

In August, 864 computer racks for the K computer — comprising a total of 88,128 interconnected central processing units — were installed, bringing the system to its final configuration. Basic operation tests and design-performance checks were then undertaken in October using the LINPACK benchmarking program. Under test conditions, the K computer performed a remarkable 10.51 petaflops (10.51 quadrillion floating point number operations per second) with a 93.2% operating efficiency.



RIKEN and Fujitsu display their TOP500 certificate as the K computer claims the number one spot of the TOP500 listing

The team of researchers behind RIKEN's K computer were awarded first place in the TOP500 list of the International Conference for High Performance Computing, Networking, Storage and Analysis

In addition to its impressive LINPACK performance, the K computer also took four top accolades at the High Performance Computing (HPC) Challenge Class 1 Awards, which evaluate the overall performance of supercomputers.

In other good news, a group comprising researchers from RIKEN, the University of Tsukuba, the University of Tokyo, and Fujitsu was awarded the annual Gordon Bell Prize for Peak Performance, which honors outstanding achievement in HPC. The prize recognizes the team's innovative work on the computation of electron states of individual atoms within silicon nanowires. Fast-becoming an attractive core material for next-generation semiconductors, the silicon nanowires were used by the team to verify the computational performance of the K computer.

To cap off a tremendous year, the K computer also received a prize from the popular online information resource, HPCwire, winning the HPCwire Editors' Choice Award in the Top Supercomputing Achievement category. ■

Singapore-Japan joint forum on emerging and reemerging infectious diseases

The Singapore-Japan Joint Forum on Emerging Concepts in Microbiology was jointly held by RIKEN, Japan's National Institute of Infectious Diseases and the National University of Singapore (NUS) on 15 and 16 November at NUS. Almost 200 participants, including the Japanese ambassador to Singapore, Yoichi Suzuki, NUS Vice-Provost John Wong and RIKEN Executive Director Maki Kawai attended the event.

This forum addressed the growing demand for further research on emerging and reemerging infectious diseases. The key research themes included disease pathogenesis, susceptibility and control, and advances in the identification of diseases and the development of therapeutic treatments.

In the past decade, the outbreak of SARS and the influenza pandemic of 2009 have brought about calls for greater sharing of information and collaboration between nations in order to more effectively combat infectious diseases on a global scale. In an effort to promote collaborative research between countries, the RIKEN Center of Research Networks for Infectious Diseases (CRNID), headed by Yoshiyuki Nagai, was established in 2005 as the headquarters of the Japan Initiative for Global Research on Infectious Diseases (J-GRID), and today is a key research hub connecting collaborative centers in Singapore and the rest of Asia, and Africa, to a wider research network.

At the November forum, Nagai and other researchers from Japan and Singapore presented their latest research results. Participants at the forum showed an avid interest in the poster sessions and engaged in active discussion with the presenters.

This forum not only marks the growing partnership between Japan and Singapore in the ongoing research of infectious diseases, but also reaffirms ties between RIKEN and its fellow research institutions in Singapore. ■

Presenters from Japan and Singapore gathered at the National University of Singapore to discuss the latest research in infectious diseases

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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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