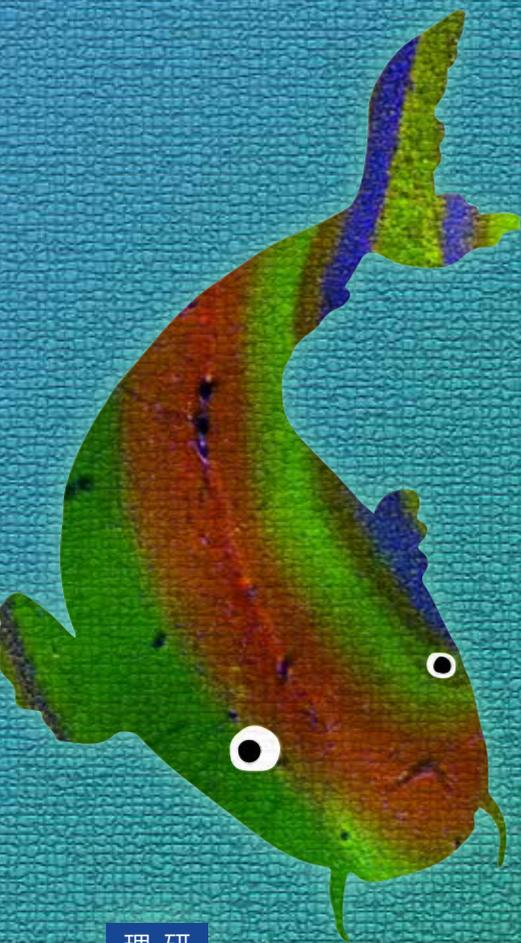


# RIKEN

National Science Institute



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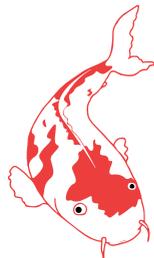
RIKEN CENTENNIAL  
Since 1977

## AT A GLANCE

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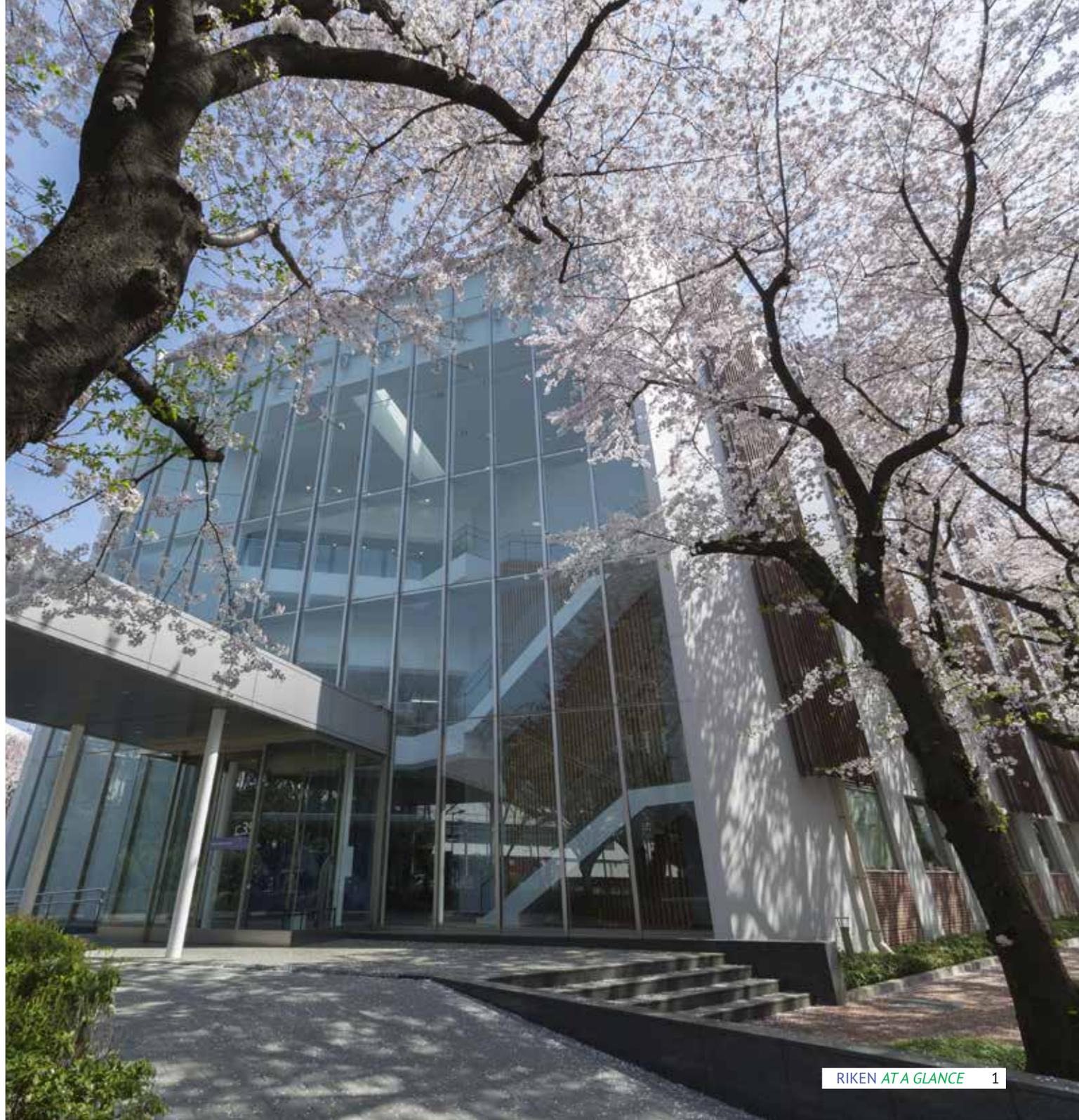


About the cover: In Japan, koi symbolize hard work, boldness, and longevity -- three qualities apropos for our 100th anniversary. Front images: hippocampus, atomic clock, and model of a cell by the K computer. Back images: graphene, A $\beta$  plaques, and retinal pigment epithelial cells grown from iPS cells.

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“ RIKEN is a place for scientists with a vision.”

## Message from President Hiroshi Matsumoto

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Though curiosity-driven basic research is a wonderful thing—and something that we strongly support at RIKEN—scientific research must also work to ensure the continued survival of the human race. The development of science and technology in the 20th century led to major improvements in our standards of living, but it has left us struggling with global issues such as population growth, resource depletion, and climate change.

Developing science and technology that can contribute to solving these complicated issues will require young, talented scientists with, above all, a vision of how the world could be made better a hundred years from now, and the will to work toward that vision. Scientists must pursue science, of course, but they must also pursue philosophy.

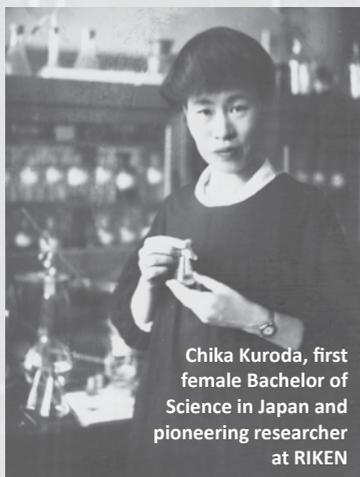
At RIKEN, we have wonderful facilities, we have a research environment that helps researchers to unleash their potential, and as a comprehensive research institute in the natural sciences, we have a system that stimulates interdisciplinary collaboration and encourages researchers to become pioneers in new fields of research. RIKEN is a place for enthusiastic scientists with visions of the future and we are actively nurturing researchers who will become leaders of the future.

## A hundred years on the cutting edge

“To turn the country from imitation to creative power, there is no alternative but to promote research in pure physics and chemistry, and for this we must establish an Institute of Physical and Chemical Research.”

So wrote prominent businessman and industrialist Eiichi Shibusawa in a September 1917 article describing the steps leading to the creation of RIKEN.

Four years earlier, Shibusawa and well-known researcher Jokichi Takamine had begun the process by speaking with leaders from the private and public sectors, and convincing them that to compete in the international world, Japan had to create a research institute of its own.



Chika Kuroda, first female Bachelor of Science in Japan and pioneering researcher at RIKEN

Thus, RIKEN, the Institute of Physical and Chemical Research, was founded in 1917 by Shibusawa and leaders from various fields of research.

### A paradise for scientists

In 1921, Masatoshi Okochi became RIKEN's third director. Full of vision and determination, Okochi set up a new structural system, which exists to this day at RIKEN. Each independent laboratory was directed by a Chief Scientist who was given considerable autonomy to manage research topics, personnel and budget. The new atmosphere was described by Nobel prize-winner Shinichiro Tomonaga as a “paradise for scientists.”

### The war years

During WWII, Yoshio Nishina's lab was entrusted with the enrichment of uranium as RIKEN worked on developing an atomic bomb.

But American air raids in April 1945 destroyed two-thirds of RIKEN's buildings and facilities, including Nishina's apparatus for enriching uranium, thus ending the project.

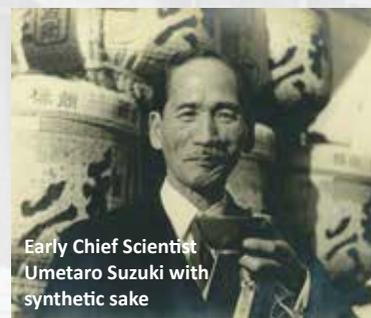
After the war the US destroyed the two cyclotrons Nishina had spent 10 years building and dumped them into Tokyo bay.

### Collapse and rebirth

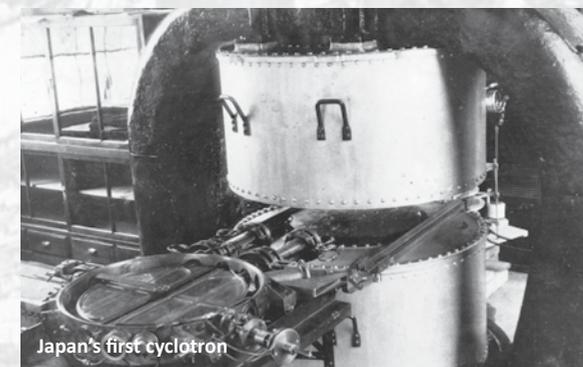
The end of WWII marked a sudden and devastating end to an era of rapid expansion at RIKEN. The conglomerate was dissolved, and eventually reopened as a private company under the name KAKEN in 1948. Its leaders tried to make ends meet by selling pharmaceuticals and licensing discoveries, but it was a difficult time. Things picked up in 1958 when it became a public corporation and changed its name back to RIKEN.

### RIKEN moves

In 1967, just as it celebrated its 50th anniversary, RIKEN relocated to a large state-owned land in the city of Wako, in the outskirts of



Early Chief Scientist Umetaro Suzuki with synthetic sake



Japan's first cyclotron

Tokyo, and began to establish satellite institutions at other locations in Japan.

Modeled on the Max Planck Society in Germany, the satellite institutions were to be located across the country, each focusing on specific fields of research. Over the years, this vision has become reality, with the opening of multiple centers in Tsukuba, Sendai, Nagoya, Yokohama, and Kobe.

### National Research and Development Institute

In April 2015, RIKEN acquired a new status, this time as a National Research and Development Institute, and in 2016 was given new prestige as one of three Designated National Research and Development Institutes, just in time for the celebration of RIKEN's centennial, which takes place in 2017.

## A hub for science and technology

*In May 2015, soon after taking over the reins at RIKEN, President Hiroshi Matsumoto announced an ambitious initiative, which called for RIKEN to become an international hub for science and technology. The goal is for RIKEN to be a place where partners both inside and outside Japan come to solve the great challenges facing humanity.*

The plan was based on five major strategies. First, it called for RIKEN to pioneer a research model that would ensure the maximization of research and development results, and as part of this, proposed an integration of the currently divided personnel system, which is being carried out.

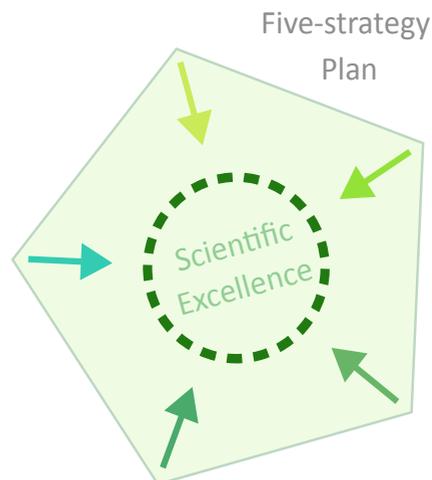
It called for the institute to lead the world in achieving new research and development outcomes, by making the best use of its interdisciplinary nature and leading-edge facilities.

Third, it proposed that RIKEN become a hub for science and technology.

Fourth, it proposed that the institute act as a focal point for global brain circulation by increasing its attractiveness for international researchers.

And finally, it called on the institute to foster world-class leaders by designing a new long-term, stable employment system for researchers.

For the official English text of the RIKEN Initiative for Scientific Excellence, see [http://www.riken.jp/en/pr/topics/2015/20150522\\_3/](http://www.riken.jp/en/pr/topics/2015/20150522_3/)



Over the last year and a half, RIKEN has begun making this goal a reality. Early in 2016 RIKEN launched the Cluster for Science and Technology Hub, which provides a framework for strengthening RIKEN's science and technology capacity and encouraging innovation by enhancing collaboration beyond the borders of disciplines, organizations and sectors.

Additionally, two new programs, the Medical Sciences Innovation Hub Program and the Compass to Healthy Life Research Complex Program, have been set up under this framework.

The first of these programs aims to develop personalized

preventive medicine based on customized prediction. The program aims to acquire patient data through collaboration with hospitals and to use AI technology—including machine learning—to significantly improve the understanding of diseases.

The objective of the second program is to establish a platform that will bring together a range of researchers to investigate diverse aspects of human biology and health, which will ultimately improve the quality of life.

*“The RIKEN Initiative for Scientific Excellence is not a strategy aimed at benefiting RIKEN alone. Rather, it is an attempt to share and expand RIKEN’s scientific knowledge and skills to universities, other research institutes, and industry, to forge collaborations that will advance Japan’s scientific prowess as a nation. Further down the line, it is my hope that we can share Japan’s scientific excellence with the world, including developing countries and regions, and thereby contribute to the welfare of humanity in general.”*

— President Hiroshi Matsumoto

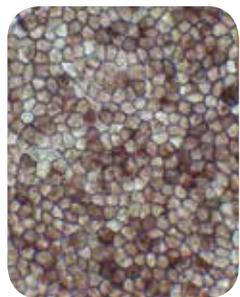


## Advances in life sciences and medicine

*RIKEN carries out research in a broad range life sciences, from developmental biology and neuroscience to omics-based research and plant science, with an overarching goal of giving people better health and creating a better environment. Additionally, RIKEN scientists are at the forefront of the ongoing revolution in regenerative medicine and are striving to understand and find therapies for a variety of diseases.*

### Regenerative medicine, organogenesis, and iPS cells

In 2013, CDB researchers initiated the world's first clinical study using induced pluripotent stem (iPS) cells in human patients, and in 2014, the leader of the project, Masayo



iPS cell-derived retinal pigment epithelium cells @ CDB

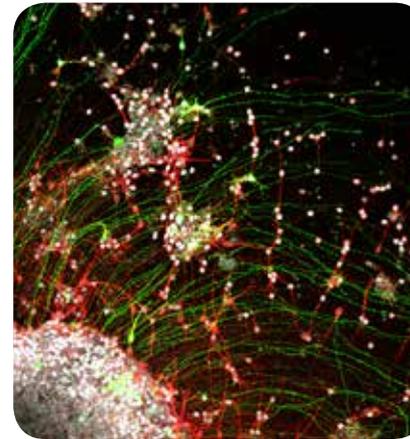
Takahashi, performed the first transplant of iPS-cell derived laboratory grown tissue into a human patient. This pilot study is testing the safety of iPS cells as a treatment for age-related macular degeneration—a leading cause of vision loss in elderly people. To date, the treatment has had no ill effects.

Since then, the group has made

further advances using animal models. In 2016, they grew retinal pigment cells from monkey-derived iPS cells, and succeeded in transplanting them into another monkey without rejection. In 2017, they showed that mice who received iPS cell-derived retinal transplants could see light and use the visual experience to modify their behavior.

Other CDB scientists are leading the way towards growing different types of human tissue in the laboratory. In early 2015, researchers from CDB succeeded in inducing human embryonic stem cells to self-organize into a three-dimensional structure similar to the cerebellum.

In 2016, CDB scientists reprogrammed iPS cells and successfully grew complex skin tissue—complete with hair follicles and sebaceous glands—in the laboratory. They were then able to implant these three-dimensional tissues into living mice, and the tissues formed proper con-



Migrating hESC-derived granule-cell neurons in the developing 3D cerebellar-like structure @ CDB

nections with other organ systems such as nerves and muscle fibers.

These first steps toward creating living 3D tissue in the laboratory are truly groundbreaking. RIKEN is leading the way in this field that was considered science fiction just a few years ago, and which could ultimately create a world in which injured tissues can be replaced with tissue grown outside the body.

iPS cells can also be used to study disease development. In 2016, CDB scientists used iPS cells derived from patients with spinocerebellar ataxia, and grew three-dimensional mature Purkinje cells. They found that patient-derived cells became vulnerable when deprived of thyroid hormone. This new model system

can be used to develop drug therapies for genetic disorders.

Researchers at BSI grew neurons from iPS cells that came from patients with schizophrenia, and which were lacking a region on chromosome 22. Their study connected one of the missing genes in that region to abnormal differentiation of neurons and an imbalance between the number of neurons and astrocytes in the brain.

### Brain circuitry and optogenetics

Optogenetics is a powerful tool for studying neural circuitry and functional anatomic connections. By inserting light-gated ion channels from algae into specific neurons, scientists can excite or inhibit targeted circuitry with light.

In 2013, scientists from the RIKEN BSI-MIT collaboration used optogenetics in mice to transform good memories into bad ones, and vice versa, demonstrating for the first time that memories can be changed. In 2015, the collaboration showed that chronic stimulation of “happy” memories can reduce stress-induced depression in mice.

The RIKEN BSI-MIT collaboration has also used optogenetics to retrieve “lost” memories in amnesiac mice and in mouse models of Alz-

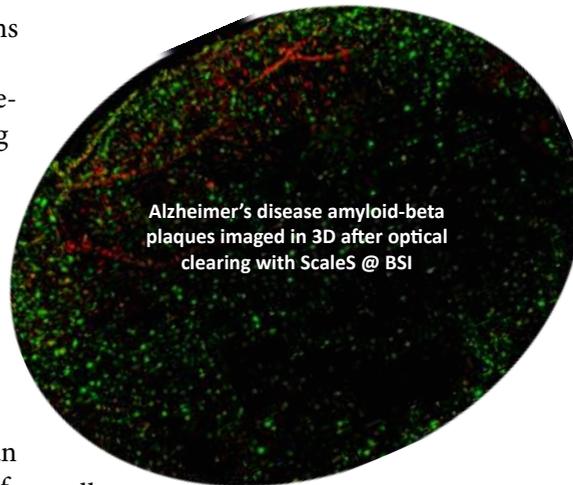
heimer's disease, to identify neurons that code environmental context into memories, and to discover a region of the brain devoted to storing memories of social encounters.

Another BSI laboratory has used optogenetics in mice to show that some forms of tactile memory require feedback circuits from motor to sensory cortex. In another study the group showed that impaired memory consolidation resulting from sleep deprivation can be alleviated by stimulating a specific circuit during non-REM sleep.

Other labs use optogenetics to study neural circuitry governing threat avoidance in zebrafish, fear-learning, and even parenting behavior in mice.

## Fluorescence and tissue transparency

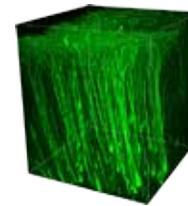
Imaging biological systems is a fundamental aspect of research in the life sciences, and RIKEN is doing this both through the development of new fluorescent markers—which can indicate which genes are currently being expressed in different



cells—and clearing agents, which allow us to see deep structures inside tissue by making the tissue transparent.

A team led by Atsushi Miyawaki at BSI has developed a new marker that glows green in the presence of bilirubin—an indicator of abnormal liver function when high. Most recently, the team has developed two optical clearing agents that allow scientists to look inside mammalian brains. The latest was instrumental in creating 3D images of amyloid-beta plaques in Alzheimer's diseased brains.

Research groups at two other RIKEN centers—CDB and



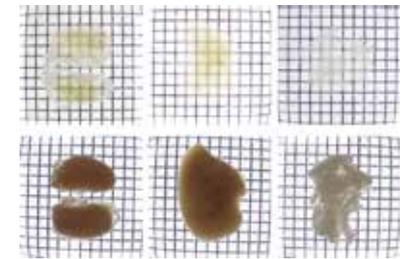
Neurons visible in the cerebral cortex of mice using SeeDB2 @ CDB

QBiC—have also developed agents that make tissue transparent. The reagent created at QBiC in 2014 allows whole bodies to be imaged, as the solution elutes

heme. In 2016, researchers at CDB formulated SeeDB2 (See Deep Brain 2), which allows researchers to obtain super-resolution 3D images of delicate neuronal structures in the brain.

## Transplant technology

In another important area of medical research, scientists at CDB recently developed a new procedure for preserving organs for transplants. The procedure cools organs down to 22 °C and uses a perfusion system to supply oxygen to the tissue. The result is more successful transplants and longer lasting organs than what was previously possible using standard methods. Clinical tests with humans are expected in the future.



Transparent organs (upper panel) compared to those treated with saline (lower panel) @ QBiC

## Gut bacteria & the immune system

Several studies carried out at RIKEN have focused on the role that gut bacteria play in maintaining a healthy immune system. In 2014, researchers at IMS showed how the diversity of gut microbiota and the health of the immune system have a two-way relationship. Other research at BRC has shown that bacteria and immune cells work together to create a protective coating for intestinal epithelial cells.



A new method for organ preservation was used to keep livers healthy for long periods of time before transplant @ CDB

## Genetic diseases

In 2015, IMS researchers identified a gene that increases susceptibility to adolescent idiopathic scoliosis, a condition characterized by curvature of the spine.

Other research has targeted rare diseases such as Menkes disease, a genetic condition marked by impaired copper usage. The standard treatment today is to inject copper, but this therapy has limited efficiency. Using PET, CLST researchers discovered how the drug disulfiram can promote the accumulation of copper in the brain, while preventing it from entering the kidneys where it can become dangerous. Babies born with this illness rarely live beyond a few years, and achieving effective copper supplementation could offer hope for people with this deadly disease.

A rare human genetic disorder with severe consequences was recently found to be linked to a mutation in the human *NGLY1* gene. In a big step towards understanding the effects of this mutation, research by scientists at the RIKEN-Max Planck Joint Research Center implicated the enzyme ENGase as the factor responsible for deficient protein degradation that occurs in the absence of mouse *Ngly1* gene expression.

## Sleep and circadian rhythms

RIKEN researchers are also actively studying factors that affect sleep and circadian rhythms. In 2016, scientists at QBiC developed a non-invasive, automated sleep cycle monitoring system for mice. Based on mouse respiration, it has already allowed the team to discover a short-sleeper gene whose deletion causes mice to sleep much less than normal mice.

The team has also recently found seven additional genes in mice that regulate sleep duration, all of which allow calcium-dependent changes in neurons. These genes could become targets for drugs that treat sleep disorders or certain psychiatric disorders that occur with sleep dysfunction.

Most recently, the team has used a new technique for generating



Automated sleep monitor for mice @ QBiC

mouse lines with different mutations, and discovered a region on the *Cry1* gene that regulates the duration of the circadian rhythm in mice.

## Cognitive & developmental disorders

Depression, Alzheimer's disease, ADHD, and autism spectrum disorders are just a few brain-related disorders that RIKEN scientists are tackling. In 2016, researchers at BSI used *in vivo* calcium imaging and transgenic mice to determine that the benefits of transcranial direct stimulation (TDS) of the brain in treating depression are due to calcium surges from astrocytes that are induced by the stimulation. This discovery could place astrocytes as a major therapeutic target for depression and other neuropsychiatric diseases.

In 2014, following 12 years of work, scientists at BSI led by Takao-mi Saïdo developed an innovative model mouse that closely resembles the human form of the Alzheimer's disease. This mouse model has led to promising investigations of new therapies that prevent or slow the onset

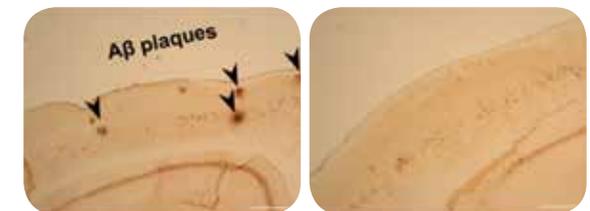
### **i** Did you know ...

Umetaro Suzuki, one of RIKEN's earliest scientists, **discovered vitamin B1**, but was never given credit for the work. 100 years later, RIKEN is still on the leading edge of vitamin research. CLST scientists were able to "tag" vitamin B1 with a radioisotope, allowing it to be imaged throughout the body using PET.

of the disease.

Using these mice, a group of researchers at the RIKEN-Max Planck Joint Research Center discovered a key protein called G<sub>n</sub>T-III whose elimination prevents the formation of amyloid-beta plaques, the hallmark of Alzheimer's disease.

Researchers at BSI are also focused on hyperactivity and social abnormalities, characteristics of ADHD and autism spectrum disorders. One group has identified a protein called IRBIT as a key player in preventing excessive dopamine



The number of amyloid-beta plaques was greatly reduced when the mouse model for Alzheimer's disease lacked G<sub>n</sub>T-III (right panel) @ BSI

production and limiting the development of these behaviors in mice.

## Glycobiology

The research on the *NGLY1* gene and GnT-III at the RIKEN-Max Planck Joint Research Center are examples of research into glycobiology—the study of how carbohydrate chains modify other molecules and affect biological processes. In 2016, researchers at the RIKEN-Max Planck Joint Research Center continued to discover new ways in which modification of proteins through glycolysis leads to import-

ant functional changes that affect physiology, cognition, and behavior. In one study, researchers discovered that fat cell differentiation and obesity are associated with reduced glycolysis of a particular protein located in internal organs.

Another group has developed a way to engineer glycan complexes such that the molecules can be transported preferentially to specific organs of the body. This work could lead to the development of glyco-cluster-based diagnostic tools with better selectivity and precision than current tracers based on peptides and antibodies.

## What makes up the universe? *basic research in physics and chemistry*

*RIKEN has a long tradition of excellence in fundamental physics and chemistry. On December 31, 2015, that work was rewarded when the International Union of Pure and Applied Chemistry announced that a RIKEN-led team had officially discovered element 113—the first chemical element to be discovered outside of the West. This work goes back to the seminal research conducted by RIKEN including the construction of the first cyclotron built outside of the United States.*

### The discovery of nihonium

In 2004, a group headed by Kosuke Morita of the RIKEN Nishina Center for Accelerator-Based

Science, used the center's linear accelerator to successfully bombard zinc ions into a bismuth layer, creating a new element, number 113. Two more atoms were created,

87	112.41 mercury <b>80</b> Hg	114.82 thallium <b>81</b> Tl
97	200.59 copernicium <b>112</b> Cn	204.38 nihonium <b>113</b> Nh

in 2005 and 2012, and the group was granted the right to name the new element, which is now known as nihonium.

### Nuclear physics

RIKEN's early work in nuclear physics was led by Yoshio Nishina, who built Japan's first cyclotron. Following in his footsteps, scientists from the Nishina Center are working with partners around the world to better understand how the universe began and how it is composed at the nuclear level. Scientists at the Nishina Center continue to search for the "island of stability"—a realm where we can find longer-lived nuclei than those in the area currently explored, and are also looking at the feasibility of using the

center's heavy ion beam to transmute troublesome nuclear waste into more easily managed isotopes.

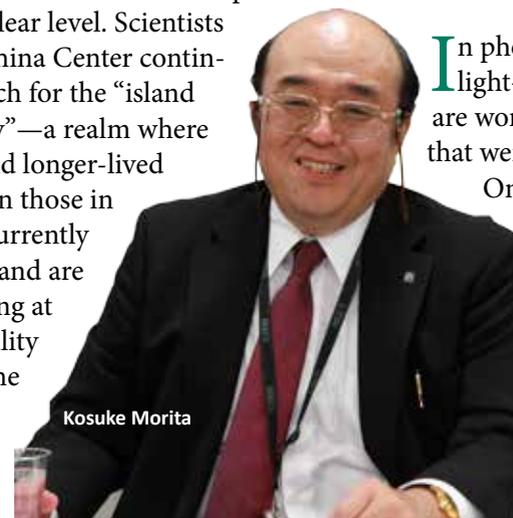
### Antimatter

One of the key questions in physics today is why there is so little antimatter. In 2010, members of an international collaboration including RIKEN managed to trap antihydrogen atoms for 1,000 seconds. Recently, an international collaboration led by RIKEN used sophisticated equipment at CERN's Antiproton Decelerator in Europe to measure the magnetic moment of the proton, and in 2015, took the world's most precise measurement of the difference between a proton and an antiproton, finding them to be the same to within 69 parts per trillion.

### Photonics

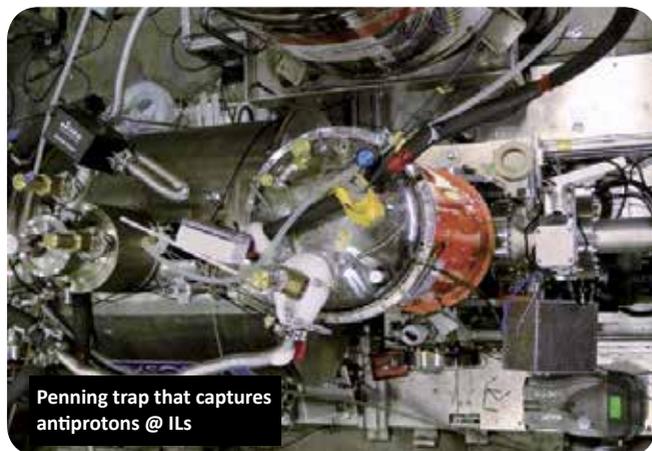
In photonics—the study of light—RIKEN scientists are working to see things that were previously invisible.

One avenue of research is to develop lasers and other light devices with ever more powerful and rapid pulses, with



Kosuke Morita

the aim to develop attosecond lasers that will be able to look at the positions of individual electrons within materials. Recently, scientists used the powerful SACLA x-ray laser in Harima to analyze the first moments when a photoreceptor used the power of light to move protons outside of a cell.



Penning trap that captures antiprotons @ ILs

Scientists at RAP are also working to develop lasers that operate in the terahertz range—a long neglected portion of the electromagnetic spectrum that will allow explosives and illicit drugs to be imaged within luggage, making security checks more rigorous. Recently, RIKEN scientists developed nonlinear optical materials that can convert terahertz light to higher frequency infrared light, which can be detected more efficiently.

## Dissipationless electronics

Another major area of physical research for RIKEN is solid-state physics, where scientists are engineering devices to take advantage of the special emergent properties of electrons. Spintronic devices and quantum computers are some of the potential future applications of this work.

CEMS researchers have recently demonstrated the existence of stable skyrmions—tiny magnetic vortices in materials

that could be manipulated to create low-power memory devices—at room temperature, as well as producing pairs of spin-entangled electrons and demonstrating, for the first time, that these electrons remain entangled even when they are separated from one another on a chip. This research could contribute to the creation of futuristic quantum networks operating using quantum teleportation.

## New, better materials

In recent years, RIKEN scientists have been doing work with hydrogels—a type of polymer that is made up mostly of water but which, due to its chemical structure, adopts interesting properties. In 2015, a group at CEMS created a hydrogel that lengthens and contracts, like a muscle, in response to rises and falls in temperature. They were able to shape the gel in such a way that, when placed in a water tank, it could actually wade through the water. They also created a tiny film that responds to minute changes in humidity, actually leaping into the air in response to the presence of small amounts of water in the air.



Hydrogel @ CEMS

## New catalysts

RIKEN scientists from CSRS recently made the news for “breaking benzene.” Aromatic compounds are found widely in natural resources such as petroleum and biomass, and breaking the carbon-carbon bonds in these compounds plays an important role in the production of fuels and valuable chemicals from natural resources.

## *i* Did you know ...

In 1937, RIKEN scientists thought they had discovered the muon, an important particle, but it turned out that a paper was published just five years before their discovery, by American physicists. The RIKEN measurements, however, were much closer to the actual mass of the muon.

However, aromatic carbon-carbon bonds are very stable and difficult to break. In the chemical industry, the cleavage of these bonds requires the use of solid catalysts at high temperatures, usually giving rise to a mixture of products, and the mechanisms are still poorly understood. But in 2014, CSRS scientists showed a way to use a metallic complex, trinuclear titanium hydride, to accomplish the task

of activating benzene by breaking the aromatic carbon-carbon bonds at relatively mild temperatures and in a highly selective way.

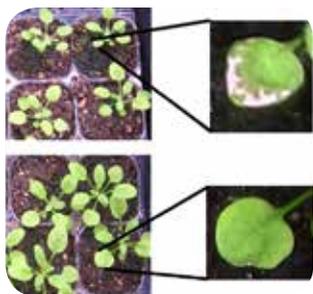
## Science to save humanity

*Though RIKEN's work begins with basic research, we are aware of the need for our research to contribute to the survival of humanity in the face of a slew of problems—climate change, resource depletion, malnutrition for example—that can lead to conflicts and ultimately threaten our continued existence.*

### Fukushima aftermath

A number of RIKEN researchers are doing work aimed at mitigating the damage from the 2011 Great East Japan Earthquake, including salt damage to land and contamination from the meltdowns at the Fukushima Daiichi Nuclear Power Plant. At the Nishina Center, scientists are using the heavy ion beam to create new rice strains that could grow in soil with a high salt content.

In 2015, in collaboration with a private company, a group of astrophysicists used technology original-



Plants grown in contaminated soil treated with CsTolen A (bottom) remain healthy @ CSRS

ly designed to detect cosmic rays to build a device for testing food for radioactive cesium—a major social need following the nuclear power plant accident. Also, scientists from CSRS identified a chemical compound that prevents plants from taking up cesium, thus potentially protecting them—and us—from its harmful effects.

### Alternative materials and fuels

Reducing society's reliance on fossil fuels is an important step towards sustainability and RIKEN scientists are at the forefront researching promising alternatives.

One such effort is using cyanobacteria to produce bioplastics. CSRS scientists succeeded in achieving a threefold increase in the yield of PHB bioplastics by modifying cyanobacterial genes.

CSRS has also collaborated with JAMSTEC, a marine-science research institution, to generate electricity from a fuel cell placed next to

a geothermal vent on the bottom of the ocean off Okinawa. The electricity is generated from the difference in redox potential between the cold sea water and the hot hydrothermal fluid emitted by the vents.

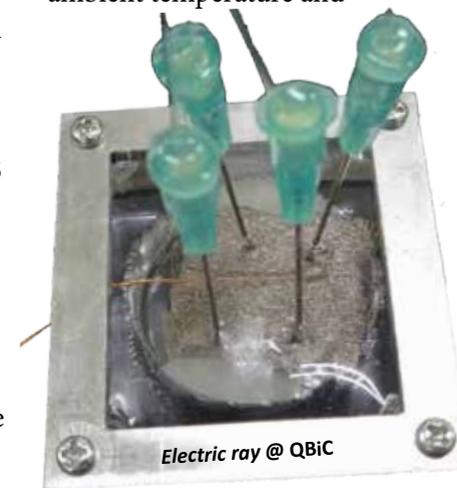
Better electronic devices also promise to help humanity overcome the challenges we face. CEMS researchers recently improved polymer solar cells—a hot area of research due to both their strong potential and the significant challenges they pose—by using carefully designed materials and an “inverted” architecture, to boost the efficiency to 10 percent, bringing these cells close to the threshold of commercial viability.

RIKEN scientists have also been innovative in learning from nature to pursue imaginative avenues for producing energy. One group from QBiC used the electric organs of electric rays—which give the fish the ability to stun prey and predators—to generate usable electricity.

### Sustainable production methods

Several research streams are working towards more sustainable industrial production methods that use less energy and resources and produce less pollution. In 2015, CSRS scientists announced that

they had devised a metal compound that can split nitrogen molecules and attach them to hydrogen under ambient temperature and



pressure—a process required to produce ammonia, which is the basis for fertilizers and other industrial products.

Similarly, CSRS researchers collaborated with colleagues at McGill University in Canada to develop a catalyst that uses iron rather than rare and more polluting heavy metals to promote the hydrogenation chemical process used in many industrial applications.

### Fighting droughts and pests

RIKEN is also focusing on agriculture and hopes to develop plants that are productive in poor

water and nutrient conditions.

In efforts to fight pests, scientists from the RIKEN Innovation Center have developed SaFE (Safe and Friendly to Environment) pesticides, which are already being used by farmers. These pesticides are based on ingredients that can be safely consumed by humans.

In 2015, CSRS researchers found a way to cultivate cyanobacteria in seawater by adding a mixture of nitrogen and phosphorus and buffering the pH. This could allow for the development of more environmentally friendly biorefineries.

## Plant science

Though much of RIKEN's work in biology focuses on animals, plants are another major focus, with a major goal of ensuring the survival of humanity. RIKEN has long been involved in international efforts to understand *Arabidopsis*—a model plant—and we rank among the top research institutes in the world in this area. In 2014, the ISI Web of Knowledge ranked RIKEN number three in the world in terms of citations per paper in the category of plant and animal science.

A group at CSRS has shown that brassinosteroids, a class of plant steroid hormones, play an import-

ant role in promoting plant growth as well as a host of developmental processes including cell elongation and division, development of the xylem—which is used for water and nutrient transport— and adaptation to differing light conditions. A group has also developed a potential road for better production by showing that torrefied biomass—plant mass decomposed at high temperatures and in the absence of oxygen—can improve the quality of poor soil found in arid regions.

## Breeding better plants

At the Nishina Center, researchers are developing new plant varieties using heavy-ion breeding. This technique involves using heavy-



*Arabidopsis* plant @ CSRS

ion beams to induce mutations. The group is focusing on creating new strains of sakura and other

decorative plants, but is also dedicated to developing a strain of rice that is highly resistant to salt, and a fast-growing variety of the edible seaweed wakame.

At CSRS, researchers have recently discovered how vitamin C is transported into chloroplasts. As vitamin C is known to alleviate stress caused by excessive sunlight, this may lead to the development of crop plants with higher tolerances to environmental stress and reduce the damage to farmland in regions with strong light.

## Extreme engineering

*While making discoveries that will contribute to the knowledge and welfare of humanity is the ultimate goal of science, this also requires the development of instruments to make these discoveries possible. While RIKEN has never engaged in building bridges or large airliners, we have always been at the forefront of engineering, designing and building scientific instruments that go beyond the now into the unknown.*

## An atomic clock

Today, RIKEN's engineering feats continue. A team from RAP has built a pair of optical lattice clocks that can keep time with incredible precision. While a typical quartz watch can vary by about 15 seconds every month, these clocks will only go out of sync by a second in around

## Biofuel

In 2015, CSRS scientists devised a new strategy for selectively delivering genes into the mitochondria of plant cells, opening up a path for creating a new field of "mitochondria engineering." This technology could enable the creation of mitochondria-based plant cell factories, which can be used for producing bio-polymers and biofuels.

### **i** Did you know ...

Early in RIKEN's history, Yoshio Nishina, the namesake of the Nishina Center, developed the first cyclotron in Japan—only the second in the world. His work helped propel Japan to a leadership position in nuclear physics.

16 billion years—more than the universe has existed so far. Using it, scientists plan to open the era of “relativistic geodesy,” where the shape of the earth can be precisely measured by clocks going faster or slower following Einstein’s theory of relativity. Using a dedicated optic fiber, they have successfully measured the altitude difference between two clocks set at the RIKEN Wako campus and the University of Tokyo—15 kilometers apart—with a precision of just 5 centimeters.

## Robots

As part of a project that uses our understanding of the human brain to create new technologies that contribute to vehicle operation and rehabilitation for stroke victims, BSI scientists have developed a robot that learns to walk using a programmed desire to

keep its motion sensors from moving abruptly. Unlike other walking robots, it walks at a very high efficiency, with a gait that approaches that of people.

## Looking at the very small

The SACLA x-ray free electron laser in Harima allows us to look at the world on the smallest scale. Despite being just 700 meters in length it produces laser beams with a wavelength under 1 angstrom, the shortest in the world. These pulses are being used to see how bonds between atoms are formed to create molecules, and thus helping to answer fundamental questions about how matter is put together. Using the instrument, scientists have shown how photons initiate a cascade that pushes protons out of a cell, creating an electric charge difference that is subsequently used to power the cell’s



Robot @ BSI

activities.

Even smaller-scale facilities can contribute. Using a tabletop light source, scientists from RAP led by



The Hokusai computer @ ACCC

Katsumi Midorikawa achieved a peak power of 2.6 gigawatts, emitting attosecond pulses that will be able to look at rapid processes such as the forming and breaking of molecular bonds.

## Supercomputing

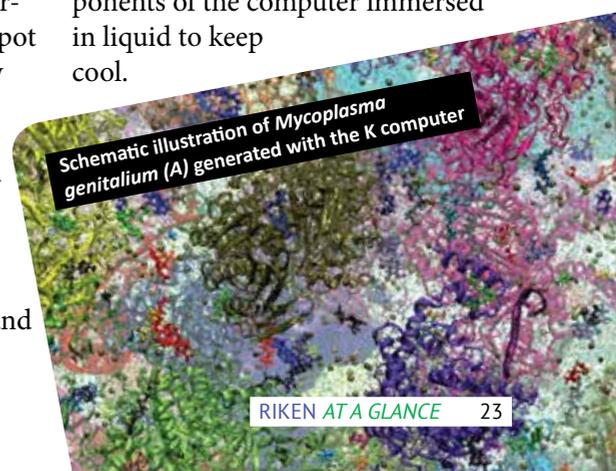
RIKEN made a big mark in 2011 when the K computer, developed in partnership with Fujitsu, took top place in the world’s supercomputer rankings, holding the spot for a year. The K computer is now performing some of the world’s most complex simulations, and RIKEN has been chosen to develop Japan’s next generation supercomputer. The knowledge gained so far will be put to good use in areas such as drug development and

material analysis.

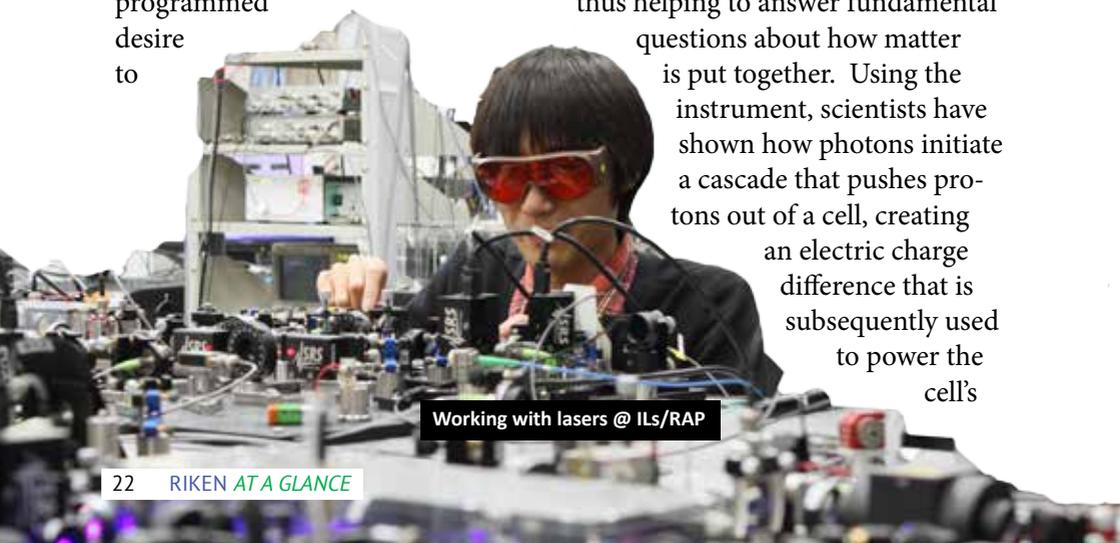
AICS scientists have used the K computer to conduct the largest simulation to date of global weather.

An enormous simulation—running 10,240 variations of a model of the global atmosphere divided into 112-km sectors—generated a model that closely fit real data between November 1 and November 8, 2011. In 2016, a group led by AICS scientists proposed a new way to efficiently program simulations on supercomputers, earning them a finalist spot in the prestigious Gordon Bell Award.

The Shoubu computer, developed by ACCC in collaboration with Japanese venture companies, has made a mark of a different kind, being declared in 2015 to be the world’s greenest supercomputer in the Green 500 ranking. It employs a unique architecture, with the components of the computer immersed in liquid to keep cool.



Schematic illustration of *Mycoplasma genitalium* (A) generated with the K computer



Working with lasers @ ILs/RAP

## Interview with Colin Blakemore

**Based on your discussions at the 10th meeting of the RIKEN Advisory Council last December, could you tell us what image you have of RIKEN today and in the past?**

Well, it's easier to evaluate history than the present. RIKEN has a very distinguished and successful record contributing to Japanese science.

I think that RIKEN can take credit for having established, in Japan, the principle that fundamental research—meaning research which does not necessarily have an immediate practical application—is essential. But RIKEN's record also shows that fundamental research is very often used as the basis for practical applications. One example is the work on metal structure—fundamental research—that was carried out at RIKEN by Kotaro Honda in the 1920s. This work led to the development of magnetic steel, which has been enormously useful in industry.

Today, RIKEN remains a national treasure, and continues to understand that you can't have today's innovation and tomorrow's products without yesterday's fundamental research. RIKEN's science is the seed corn of future productivity and must be preserved.

**RIKEN is likely also seen as a special institution in Japan because of the breadth of the research that we perform.**

Absolutely. It's a unique environment—I would say unique in the world—for the breadth of its research. Its buildings are spread across many different sites, and it's divided into a large number of centers, with particular missions and disciplines. But, they are all part of the RIKEN family, and the mobility and flexibility of researchers is remarkable. The efforts of RIKEN to utilize its enormous range of scientific strength to stimulate new interdisciplinary research are commendable.

**What would you tell a young researcher considering coming to RIKEN?**

Colin Blakemore is a professor of neuroscience and philosophy at the University of London. He has been a member of the RIKEN Advisory Council since 2007, and has been the chair since 2016.

If I were a young Japanese researcher, this is where I would want to be. It's a fantastic environment to work in. There's excellent support for young researchers, who have amazing opportunities to explore their own ideas, with strong infrastructure and services of the highest quality. So, it is a great place for a young researcher to be.

If I were a young woman scientist, I might be surprised by the low proportion of women working at RIKEN. But this could offer a real opportunity. RAC has recommended that RIKEN should make special efforts to increase the numbers of women scientists and foreign researchers. I hope that female researchers and foreigners can be confident that they will be welcomed into RIKEN and that they will be able to benefit from the wonderful environment that RIKEN offers.

**If you were the president of RIKEN, is there anything special you would like to accomplish?**

I would want to do exactly what President Matsumoto is aiming to do—to maintain RIKEN's traditional status as a world-leader in basic research, but also to do all that it can to contribute to Japanese society, through stronger partnerships with universities, hospitals and industry, in order to facilitate the translation of discovery into innovation and application. RAC has made a strong case that RIKEN needs and deserves an increase in its budget in order to achieve this.

**What expectations you have of RIKEN for the future?**

Given its history, we can expect that RIKEN will maintain its position as one of the world's top research institutions. But I think that our hope should be greater than that. We should expect that the vision of President Matsumoto will be realized and that RIKEN will play a fuller and stronger role in stimulating the translational process and the development of products, processes, treatments, healthcare—but without endangering its role in basic research. That would be my expectation and my hope.



## A welcoming environment

*In addition to our state-of-the-art research facilities and open research environment, we aim to provide a comfortable and congenial environment for researchers and their families from around the world. A wide range of programs, services, and welfare benefits are available to all RIKEN employees, regardless of gender or nationality.*



### A bilingual work and social environment

Many of RIKEN's laboratories are completely bilingual with Japanese and non-Japanese scientists and technical staff working side by side to achieve common goals. RIKEN also offers a bilingual administrative environment that provides needed information in a timely fashion in both Japanese and English. In addition, all full-time RIKEN employees are members of the RIKEN Employee Mutual Aid Society which sponsors a wide range of employee club activities and events, both cultural and sports-related.



### Help staff

Friendly bilingual staff are on-hand at the major RIKEN campuses to provide information and support to help researchers deal with healthcare, housing, childcare and schooling, and the practical issues of daily life.

### Housing

The main Wako campus has both single and family apartments while other RIKEN campuses have a range of accommodation available, either on or

off campus. For long-term stays, we can provide introductions to local real estate agencies and, when necessary, assist with procedures.

### Events

The Mutual Benefit Society organizes events on the different campuses and provides funding for club activities to help our personnel build human relationships and enjoy their time off.

### On-campus childcare

To help researchers focus on their work without having to worry about bringing their children off-campus, daycare programs are available for infants, toddlers and preschool aged children at the Wako, Yokohama and Kobe campuses.

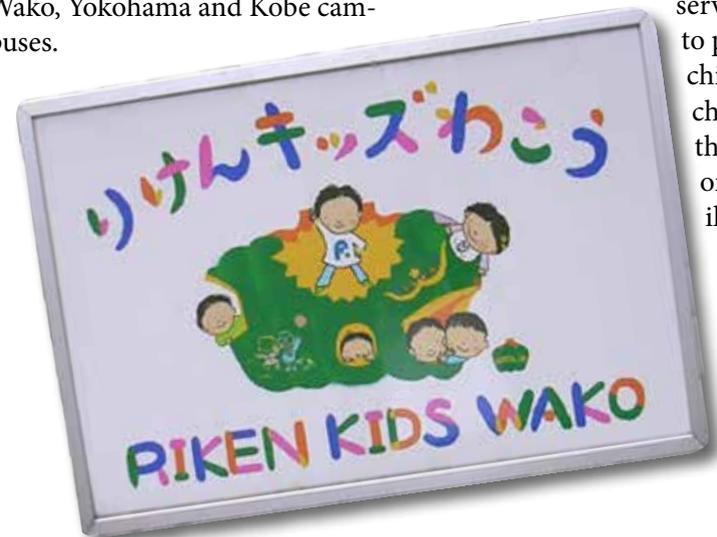
Visit the Community page on the RIKEN website to find more detailed and practical information on life in Japan, immigration, housing, health, partners and spouses, and children. [www.riken.jp/en/community/](http://www.riken.jp/en/community/)

### Special leave for family care

RIKEN offers special leave, in addition to its regular paid leave, for caring for sick children or other family members.

### Personnel Support Coordinators

RIKEN is a strong advocate of gender equality and has Personnel Support Coordinators who provide individualized guidance on RIKEN's support programs and services related to pregnancy, childbirth, childcare, and the care of sick or elderly family members.



## Special Postdoctoral Researchers Program

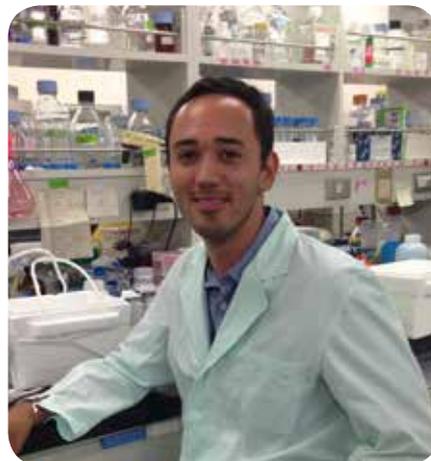
*In the Special Postdoctoral Researchers (SPDR) program, young and creative scientists are given the opportunity to be involved in autonomous and independent research under the direction of their host laboratory's primary investigator. The program helps promising young scientists to establish global careers with up to three years of funding, subject to favorable annual reviews. A generous remuneration package is supplemented with an annual research budget of 1 million yen (about US \$8,000) allocated to the host laboratory.*

The program is open to researchers in physics, chemistry, biology, medical science or engineering who have a doctoral degree and fewer than five years of postdoctoral experience. This is one of RIKEN's initiatives aimed at opening our facilities and resources to the world and creating a stimulating research environment that places our organization at the forefront of global science and technology.

"Doing research in RIKEN has given me a unique opportunity to work in a multidisciplinary environment with access to numerous resources unparalleled in many research centers in the world," says **Juan G. Betancur**, from **Colombia**, who is doing his postdoctoral research in the Laboratory for Developmental Genetics. "In addition, administrative and personal support is available whenever necessary, which

helps me to focus on my research. I am currently using my own expertise in RNA biology, along with the strength of my current laboratory in mouse genetics and epigenetics, to understand the role of RNAs in the recruitment and function of epigenetic modifying factors."

Qualified candidates of all nationalities are welcome to apply.



## International Program Associates Program

*RIKEN offers non-Japanese PhD candidates at participating universities the chance to undertake their doctoral studies in Japan under the supervision of a senior RIKEN scientist. Each year RIKEN accepts about 100 students as International program Associates (IPAs). Students enrolled, or about to enroll, in a PhD at one of the many Japanese and overseas universities participating in RIKEN's Joint Graduate School program are eligible to apply.*



trip airfare, as well as the benefit of international collaboration in their research and the chance to experience a new culture.

"Joining RIKEN as an IPA has been a golden opportunity to enhance my skills and broaden my knowledge," says **Kruthi Suvarna** from **India**. "Thanks to the excellent work environment, advanced technology and support from the administration, I am able to work without stress.

As of October 2015, we had IPAs from 51 universities in Asia and Europe studying at RIKEN. They included students from Peking University in China, Seoul University in South Korea, USM in Malaysia, Liverpool University in the United Kingdom, and ETH Zurich in Switzerland.

Associates receive living expenses, a housing allowance and round-

"RIKEN also provides an excellent platform for presenting our ideas, including through various events that bring together scientists from different fields and multidisciplinary areas. The atmosphere stimulates creativity and allows the mixing of ideas. It has provided me the opportunity to use a skillfully developed chemical library against carcinoma-associated fibroblasts."

## Schools/visiting scholars

*In addition to the Special Postdoctoral Researcher and International Program Associates programs for young researchers, RIKEN operates a number of summer schools that give junior scientists and students the opportunity to learn from eminent researchers.*



### Brain Science Institute Summer Program

The BSI Summer Program is a stimulating opportunity for young researchers to study brain science in Japan. Graduate neuroscience students from all over the world can participate in either a two-month laboratory internship at a BSI laboratory, or an intensive one-week lecture course given by distinguished international scientists.

### Nishina School

The Nishina School offers select students from Peking University, Seoul National University, and several Japanese universities, the opportunity to acquire hands-on experience in theoretical and experimental nuclear physics in a two-week summer school at the Nishina Center.

### Center for Integrative Medical Sciences International Summer Program

The RIKEN IMS International Summer Program (RISP) aims to provide PhD students and young postdoctoral researchers from around the world with the opportunity to learn about cutting-edge research in immunology and genomic medicine. It takes place over one week at the IMS facility in Yokohama and includes presentations from internationally distinguished scientists and each participant.

### Cheiron School

With the help of the Asia-Oceania Forum for Synchrotron Radiation Research (AOFSSRR),

BSI summer  
[www.brain.riken.jp/en/summer](http://www.brain.riken.jp/en/summer)

IMS summer  
[www.ims.riken.jp/english/jobs/summer\\_program.php](http://www.ims.riken.jp/english/jobs/summer_program.php)

Cheiron  
[www.spring8.or.jp/en/students#cheiron](http://www.spring8.or.jp/en/students#cheiron)

RIKEN has offered the Cheiron School to students, young scientists, and engineers from forum member countries. The School is currently being remodeled in line with the strategic plan of the facility.



## Facilities

### Radioactive Isotope Beam Factory

The Radioactive Isotope Beam Factory (RIBF) at RNC in Wako is RIKEN's next-generation heavy-ion research facility. It provides researchers with the most intense ion beams in the world. At its heart lies a superconducting ring cyclotron—the world's largest—measuring 18 meters in diameter and weighing 8,300 tons, nearly as much as the Eiffel Tower. Recent upgrades to the facility allow for the generation of intense beams containing about 4,000 unstable nuclei, which range from hydrogen to uranium, making it possible to probe beyond the limits of the known nuclei. The facility is also used

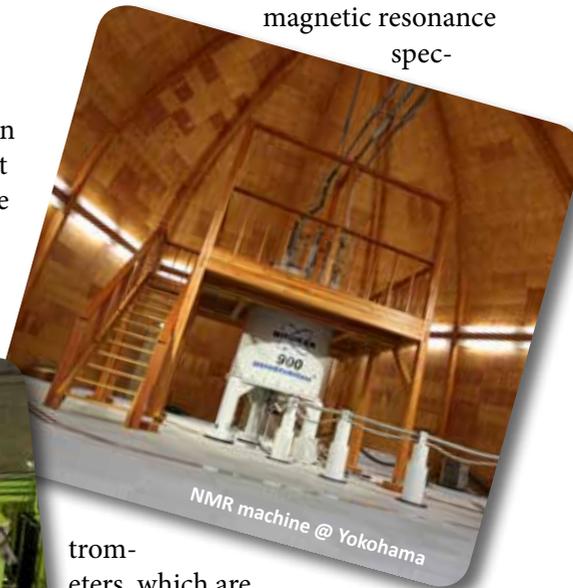


RIBF @ Wako

for heavy-ion breeding, allowing the efficient creation of new plant varieties.

### Life Science Technology Platform

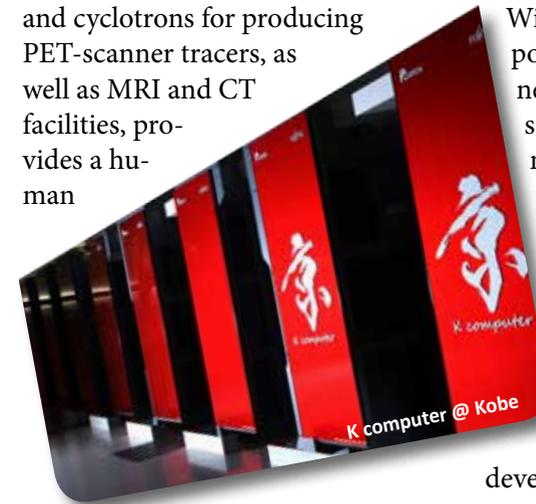
RIKEN has a rich set of advanced facilities used for research in medicine and other areas of life sciences. The NMR facility at CLST in Yokohama—one of the world's largest—operates ten nuclear magnetic resonance spectrom-



NMR machine @ Yokohama

trometers, which are used for three-dimensional structural analysis of proteins and other molecules. In addition to medicine, these tools are being used to promote technological innovation. The Genome Network Analysis Service, also in

Yokohama, offers gene expression analysis and genomic sequencing using high-throughput next-generation sequencers. Additionally, the molecular imaging facility in Kobe, equipped with microPET scanners and cyclotrons for producing PET-scanner tracers, as well as MRI and CT facilities, provides a human



K computer @ Kobe

resource development program for analyzing the dynamics of various molecules in the body.

### K computer

The K computer located at AICS in Kobe is a national project funded by the Japanese government with RIKEN serving as the operating partner. In 2011, it became the first supercomputer in the world to achieve a LINPACK performance rating of 10 petaflops. Since its opening to outside users

in the second half of 2012, the K computer has been used as a platform not only for basic research but also for commercial applications, thus contributing to the solution of problems confronting humanity. With its blistering speed, it makes possible simulations on a scale never attained before. Areas of research using the K include drug manufacture, new materials and energy, disaster prevention, manufacturing technology, and exploring the origin of matter and the universe. It is also made available to industrial partners for projects requiring its power. RIKEN is currently engaged in the development of a new post K super-computer.

### SPring-8 and SACLA

The RIKEN SPring-8 Center in Harima is a unique facility, the only research entity in the world offering both an x-ray free electron laser (SACLA) and a synchrotron radiation (SPring-8), at the same location. These two powerful tools are offered to researchers from both academia and industry, in Japan and from around the world, to conduct advanced research in materials science, spectroscopic analysis, earth

and planetary science, life science, environmental science and industrial applications. SACLA, which produces laser with very short wavelengths of light a billion times brighter and with a pulse width a thousand times shorter than the light available from SPring-8, is an ideal instrument for observing extremely fast phenomena

and small molecular structures, and has become a powerful tool for protein analysis.

## BioResource Center

The BioResource Center in Tsukuba, established in 2001, has quickly developed into one of the world's most important repositories and distribution centers of biological resources for life science research. The center's reputation derives from its capacity to handle a wide range of living strains of experimental animals and plants, cell lines of human and animal origins, genetic materials, microorganisms and the associated bioinformatics. The center is particularly notable for providing human induced pluripotent

stem (iPS) cells to researchers. Visit their website to find if there are resources that will be valuable in your research.

## Advanced Center for Computing and Communication

ACC is both a research organization and the group that manages RIKEN's high performance computing and communications infrastructure. In addition, the Center develops novel methods and software to integrate sequencing data and understand complex biological phenomena.

As infrastructure manager, the Center ensures the efficient organization and storage of the enormous amounts of data generated daily by scientific experiments at RIKEN. It

provides RIKEN staff with user support and services such as email, data storage and research databases as well as providing technical and R&D support to the supercomputer and bioinformatics programs.

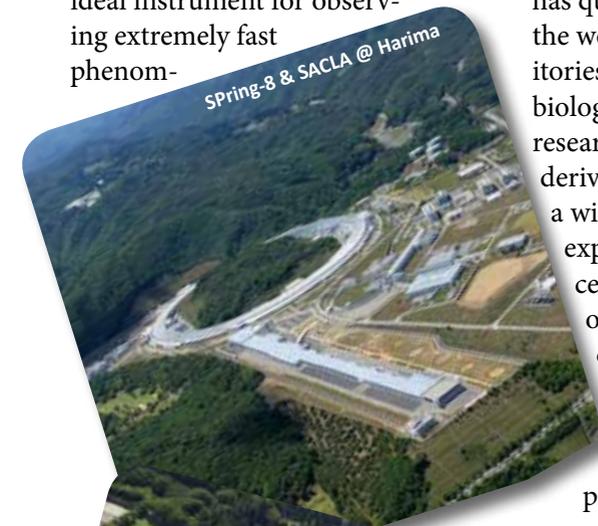
## Crossing boundaries

*What makes RIKEN a really unique place is the way that scientists are encouraged to interact beyond disciplinary boundaries and to pioneer to new fields*

When President Hiroshi Matsumoto took the reins at RIKEN in April 2015, one of the things that he said surprised him was how low the barriers are between laboratories and disciplines compared to the situation in universities. Indeed, interdisciplinary collaboration—coupled with a strategy to use such collaboration to pioneer new fields—has always been part of RIKEN's DNA.

## Institute laboratories

RIKEN has a large number of laboratories, run by scientists known as Chief Scientists, who run independent laboratories and



**i** Did you know ...

The popular sports drink VAAM was developed by RIKEN Special Chief Scientist Takashi Abe, and was inspired by his studies of hornet venom at RIKEN. He discovered that a unique combination of amino acids in hornet larvae saliva allow them to fly 80 km a day, non-stop. The mixture works similarly in humans, and is the basis for the longer endurance afforded by drinking VAAM.

serve to coordinate research among the different research centers. The Chief Scientists play a key role in RIKEN by serving as members of the RIKEN Science Council, which provides advice to the President on a wide range of matters involving research strategy. Another body—the Core PIs—which is formed by Chief Scientists and directors of the research centers, as well as key researchers from research centers, provides overall direction for RIKEN as an organization. Through these mech-

anisms, scientists from a broad range of fields can come together to understand how their research is connected and how they can make use of synergies to open up new fields.

### Research Groups

Several of RIKEN's current strategic research centers have been deliberately organized with a multidisciplinary mission. CSRS brings together chemists and biologists—specifically plant scientists—to collaborate on projects to deal more effectively with carbon dioxide, improve the production efficiency of fertilizers based on nitrogen, and make efficient recovery and reuse of metals. At CEMS, specialists in physics, chemistry, and electronics are collaborating to create a new generation of highly energy efficient devices and to contribute to the birth of quantum computing.

Further, in the Interdisciplinary Theoretical Science (iTHES) Research Group, scientists from physics, chemistry, and life scientists are working together to discover new theoretical principles that apply to different hierarchies of science, across all branches. Recently, scientists encouraged by this launched a new organization, iTHEMS—Inter-

disciplinary Theoretical and Mathematical Sciences—which seeks to find applications in science for new mathematical models. This is a milestone, as it has brought the study of mathematics back to RIKEN following a hiatus of just about a hundred years, following the death of RIKEN's first president, Dairoku Kikuchi—a mathematician.

Based on this multidisciplinary structure, a number of events are held each year in which scientists from different fields, nationalities, and positions can come together to share their results and discuss how they can collaborate to help answer the scientific questions and social needs in line with RIKEN's mission. These events include the Interdisciplinary Exchange Evening, held a few times each year, and Discovery Evening, a venue for young scientists, as well as the Summer School for junior scientists and the reporting session for researchers working on grants awarded under RIKEN's competitive interdisciplinary program.

## Working with industry

*RIKEN collaborates with industry in many different ways and we are always open to inquiries about potential collaborations*

Joint and sponsored laboratories, commissioned research, trainee internships to develop skills, shared facilities—RIKEN's profound commitment to working with industry is realized in many ways. It is most directly exemplified in our "Baton Zone" of innovative programs in which science and industry work together.

As the name suggests, the program involves a handing on of knowledge from one partner to another. That process is managed by a dedicated group, the RIKEN Innovation Center (RInC), whose job is to support the transfer of RIKEN's scientific achievements into commercial products through partnerships with private companies.

The Baton Zone includes the Integrated Collaborative

A still from the award-winning video created using the K computer, based on data from the UT-Heart simulator.



© Meiji Co., Ltd.

Research Program with Industry, under which joint research teams headed by company personnel are established for a limited time. But there are many other ways in which industry can become involved with RIKEN, including licensing its patents. In 2014, RIKEN held 652 domestic and 681 patents outside Japan for technologies ranging from physics to medicine.

Another important part of RIKEN's collaborations is the RIKEN Venture System. Under this, we contribute to industrial technology and people's everyday lives by using the new knowledge and new tech-



RIKEN VENTURE certification mark

nologies that arise in the course of research at RIKEN on basic natural science.

Among these companies are Healios, which is working in the field of regenerative medicine using iPS cells, and NanoMembrane

Technologies, which is conducting research and development on fuel cell component and membrane products. In 2015, Healios gained a listing on the Tokyo Stock Exchange's Mothers market.

## Technology transfer

*RIKEN works closely with industry, applying our expertise and technology towards developing innovative and useful products.*

**N**ew drugs, green technology, simple and efficient medical diagnoses, improved decorative and crop plants—these are examples of the kinds of products developed in RIKEN's Innovation units, mainly in the RIKEN Cluster for Industry Partnerships (CIP). The laboratories in CIP work closely with industry to ensure their research satisfies industry requirements and can be translated quickly into useful products.

CIP includes two research programs for industry and society: the Drug Discovery program and the Preventive Medicine and Diagnosis program, which contribute to health research. These work in collaboration with the RInC, which administers RIKEN's collaborations with

industry.

In addition to a Business Development Office, RInC operates several joint laboratories—such as the Ultra-Sensitive Biomolecule Detection Laboratory in conjunction with Olympus Corporation. There are also industry-sponsored laboratories in areas ranging from the role of gut bacteria in digestion to the development of flexible electronics using organic semi-conductors. Other groups are working on efficient ways for generating electricity using solar and radiant energy and developing new crop plant strains incorporating mutations generated using beams of charged particles.

### Drug discovery

**T**he RIKEN Program for Drug Discovery and Medical Technology Platforms (DMP) assists the identification of new treatments for cancer and other diseases by promoting collaboration within RIKEN on the development of innovative pharmaceuticals and medical technologies. The Program is involved in all phases of development from the discovery of promising drug targets to the identification of potential lead compounds such as small molecules and antibodies. It supports the acquisition of intellectual property

rights to drugs and technologies that can then be brought to the development phase. The program also provides support for translational research and the transfer of potential drug candidates to preclinical and clinical phases of drug development.

### Preventive medicine

**D**isease prevention is more effective when any signs or symptoms of disease are detected early. Research groups in the RIKEN Preventive Medicine and Diagnosis Innovation Program (PMI) deploy a broad range of research resources in physics, chemistry, engineering, biology and medical science to develop and establish more efficient detection technologies. They are working on the discovery of new biomarkers, the development of detection technology for clinical practice, and the development of diagnostic kits.

The Program interfaces between the scientific advances made at RIKEN and colleagues in medical institutions, companies and research organizations, ensuring that scientific breakthroughs are effectively translated into clinical practice.

## Work force

Thanks to our global recruitment programs, RIKEN is an international organization with an increasingly diverse staff.



RIKEN employed 3,462 individuals in 2016, a figure that has remained relatively constant over recent years. Nevertheless, the number of international researchers has risen significantly in the past ten years, and now about 18 percent of RIKEN's nearly 2,000 researchers come from outside Japan. Most are from nearby countries, including China and Korea, but a significant number have come from Europe, North America, and other countries in the Asia-Pacific.

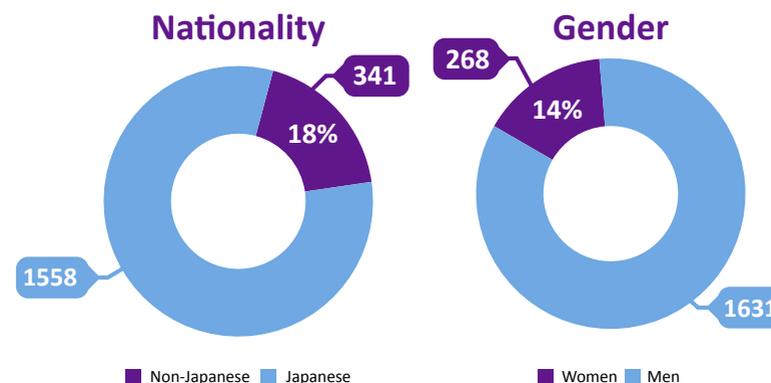
Through a focus on international

recruitment, RIKEN has become a leader among Japanese research organizations in employing non-Japanese staff. We aim to increase the proportion of foreign research staff to 20 percent by 2018.

We are also making strong efforts to increase the number of women at RIKEN. In Japan, women are generally underrepresented in the science and technology world, but RIKEN has shown leadership in this area by implementing a variety of programs to encourage the recruitment and retention of female staff.

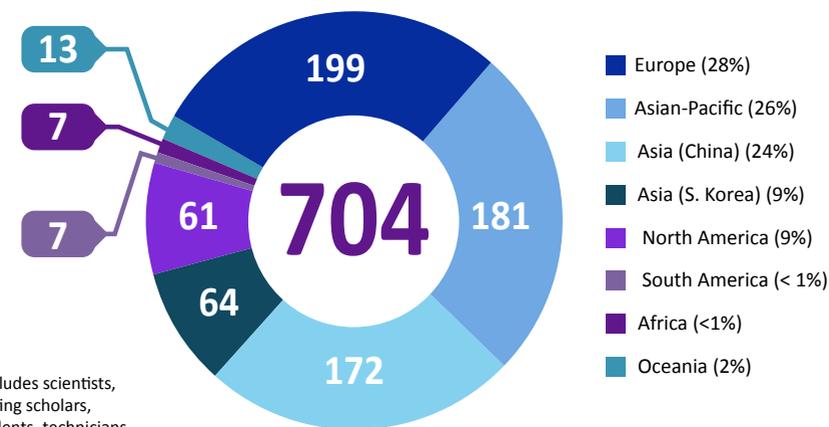
## DEMOGRAPHICS

### Diversity of RIKEN Scientists\*



\* includes all scientists directly employed by RIKEN

### International Faculty & Staff\*

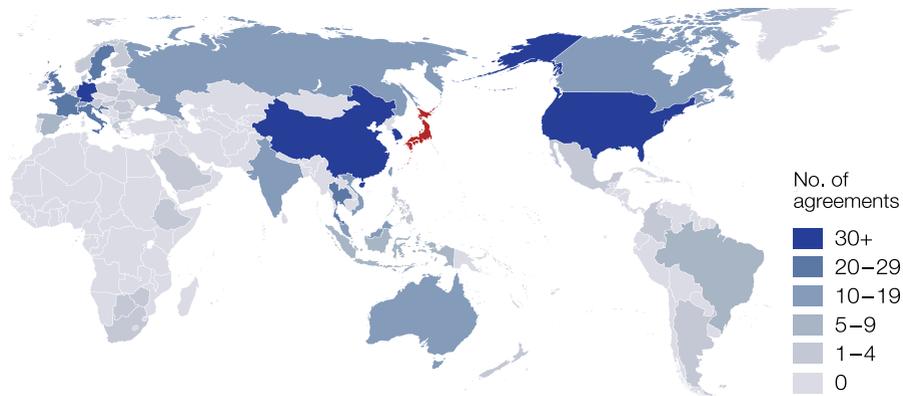


\* includes scientists, visiting scholars, students, technicians, and administrative staff

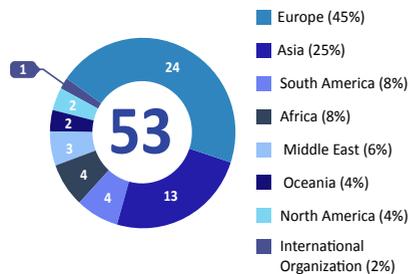
as of Oct. 1, 2015

## International research partners

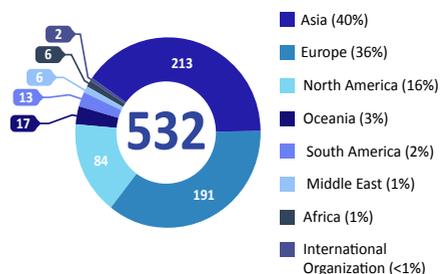
As RIKEN continues to grow, so does its network of collaborators at research institutions around the world. RIKEN actively supports research collaborations and the exchange of researchers, students and staff with universities and institutions all across the globe. The map below outlines the distribution of these reciprocal research arrangements, including the major institutions and universities that have a General Collaborative Agreement or Memorandum of Understanding (MoU) with RIKEN.



Number of Partner Countries

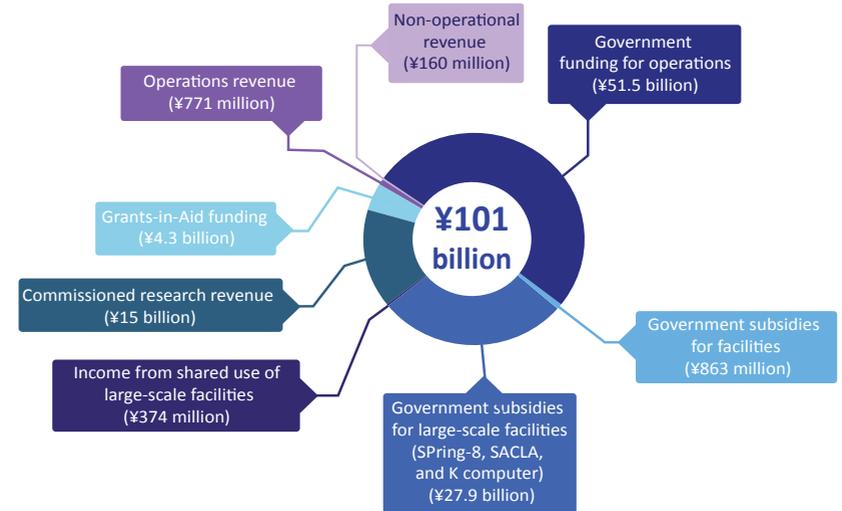


Number of Collaboration Agreements

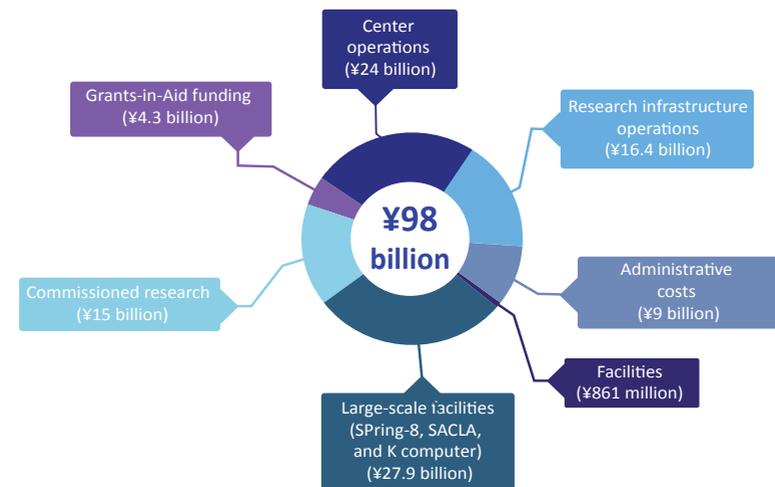


as of Mar. 31, 2016

## FY 2015 Year-end revenue



## FY 2015 Year-end expenditures



\*revenues and expenditures do not match due to carryover and returned funds

\* ¥1 billion ≈ US \$8.8 million

## Research output and patents

Each year RIKEN scientists publish between 2,000 and 3,000 papers covering all areas of the natural sciences, many in top-rated international journals such as Nature and Science. Our breakthroughs translate into much more than journal papers, however. We also actively encourage our researchers to patent their discoveries and protect our intellectual property portfolio to ensure that industry can use it to improve people's lives. Some of our recently licensed technologies include a high-tech blood pressure monitor, new varieties of Japanese cherry blossom trees, and a safe and environmentally friendly line of pesticides.



Safe and environmentally friendly pesticides developed @ RinC

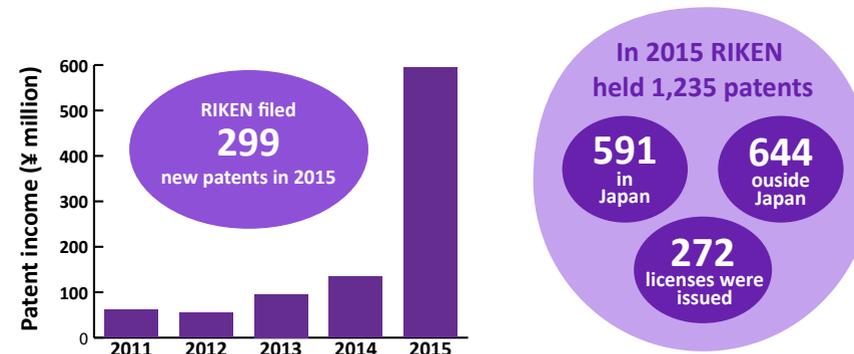


Plants developed using heavy ion beams to generate advantageous mutations @ RIBF



Nishina Homare sake is made with yeast that was modified using the RIBF

RIKEN earned **594** million yen\* from patents in 2015



\*about US \$5.2 million

RIKEN researchers published **2591** papers in 2015

By citation based on all papers published worldwide in 2014

28% ranked in the top 10%

6% ranked in the top 1%

Source: Clarivate Analytics's Web of Science, Science Citation Index Expanded, Jun. 8, 2016

## RIKEN centers

### Center for Developmental Biology (CDB) pp. 8, 9, 11

Research at CDB focuses on gaining insights into how the complex animal body develops from a fertilized egg—a single cell—and applying that knowledge to better understand the pathogenesis of a variety of human diseases, and to contribute to the advancement of medicine such as stem-cell based regenerative medicine. Since its establishment, CDB has become a leading institute with a strong record in high-impact publications and international engagement. Its most recent generation of labs is focusing on new questions and avenues in the study of development, with special focus on organogenesis and the use of quantitative approaches.



### Brain Science Institute (BSI) pp. 9, 10, 13, 22, 30, 31



BSI is a global center of excellence in comprehensive research on the brain in both health and disease. The Institute is exploring the fundamental capacity of the human mind for adaptive intelligence and social interaction—the foundations of society. Investigators study how the brain's myriad neural circuits control perception, cognition, and action; and how they go awry in diseases like Alzheimer's, depression, schizophrenia, and autism. The Institute features an interdisciplinary research system encompassing biology, medical science, biophysics, informatics, mathematical science, psychology, and linguistics. This integrative approach also underlies BSI's development of novel technologies and model systems for brain research. The Institute fosters international collaboration, policy discussions, and scientific communication.

### Center for Life Science Technologies (CLST) pp. 12, 13, 32



Next-generation life sciences and its applications are key to a healthy future for the world's population. Research at CLST focuses on designing molecular structures at the atomic level, manipulating molecular function the cellular level, and tracing molecular dynamics at the whole-body level. The Center aims to collaborate with the global life science community in developing key technologies to translate next-generation life science research into medical and pharmaceutical applications. It comprises the Division of Structural and Synthetic Biology, the Division of Genomic Technologies, and the Division of Bio-Function Dynamics Imaging.

### Center for Sustainable Resource Science (CSRS) pp. 17-21, 36

CSRS contributes to the development of sustainable production of energy, chemicals, and biomaterials by conducting integrated biological and chemical studies. Interdisciplinary projects are underway in four key areas of research. (1) *Carbon utilization* – investigating ways to enhance photosynthesis in plants and developing catalysts for efficient use of carbon dioxide. (2) *Nitrogen utilization* – developing new methods for resilient agriculture and efficient production of fertilizer from nitrogen. (3) *Metallic element utilization* – using universal metals to create highly active catalysts and using plants and microbes to recover rare metals from waste. (4) *Research platforms* – using state-of-the-art infrastructure to provide metabolomics and chemical biology platforms to institutes in Japan and abroad.



### Quantitative Biology Center (QBiC) p. 11, 12, 18

QBiC's aim is to achieve "whole cell modeling", which would give scientists an unprecedented understanding of dynamic living systems. In cells, molecules communicate in elaborate, complex networks that regulate an extraordinary number of functions. By combining techniques that can measure molecular dynamics, model cellular environments, and simulate molecular and genetic networks, scientists aim to predict and control a cell's behavior. Such control would revolutionize the life sciences and their applications, including fields like regenerative medicine and predictive diagnostics.



### Center for Integrative Medical Sciences (IMS) pp. 11, 12, 31

IMS in Yokohama is contributing to the creation of new medical sciences for the future of human health. The new medical sciences combine the research of homeostasis that underpins our bodies and how its breakdown leads to diseases with comprehensive analysis of the genomic diversity in individuals and identification of the genetic causes of disease and drug responsiveness. Its efforts are contributing to the advancement of personalized and preventive medicine for predicting individual diseases and the development of preventive methods and treatments tailored to the individual.



## Center for Emergent Matter Science (CEMS) pp. 16, 17, 19, 36

 Scientists at CEMS are developing more efficient technologies to reduce energy consumption and the environmental burden of energy production in order to provide for humanity's energy needs and build a sustainable society. They are using physics, molecular chemistry and quantum electronics to generate novel materials and processors. New properties emerge in materials or molecules fabricated from interactions of large numbers of component electrons, atoms or molecules at the nanoscale. These new materials and processes can be used for technologies such as highly efficient energy-conversion devices and low-consumption electronics.

## BioResource Center (BRC) pp. 11

 BRC in Tsukuba collects, preserves and distributes an extensive range of biological resources required for academic and industrial research. These include experimental mice, experimental plants, human and animal cellular materials (including induced pluripotent stem cells; iPS cells), genetic material and microorganisms. These resources are used in studies ranging from basic research to the treatment of disease, health promotion, regenerative medicine, food production and even environmental conservation. The Center has been distributing these materials to researchers inside and outside Japan since 2001, and has been providing extensive information about them, including training courses.

## SPring-8 Center (RSC) pp. 16, 22, 31, 33, 34

 Observing microstructures at the atomic and molecular level gives scientists new insight into physical and biological phenomena. This can be achieved using x-rays, which have a much shorter wavelength than visible light. The RSC, established at Harima in 2005, is unique in offering researchers both a synchrotron radiation facility, SPring-8, and an x-ray free-electron laser (XFEL) facility, SACLA, at one site. In addition to medical applications, they can be used to examine microstructures at the atomic and molecular level. When SACLA opened in March 2012, RSC became only the second institution in the world to offer x-ray free-electron lasers for research.

## Nishina Center for Accelerator-Based Science (RNC)

pp. 14, 15, 18, 20, 21, 30, 32, 44

 RNC on the Wako campus is a world-leading accelerator facility for theoretical and experimental nuclear physics research. It is named after Yoshio Nishina who constructed Japan's first (and the world's second) cyclotron at RIKEN in 1937. The Nishina Center was established in 2006 to promote research into the origin of matter by investigating the nature of nuclei and their constituents, elementary particles. That year, the Radioactive Isotope Beam Factory (RIBF), with its world's first superconducting ring cyclotron and superconducting radioactive isotope beam separator started full-scale operation. The Nishina Center collaborates with researchers around the world.

## Center for Advanced Photonics (RAP) pp. 16, 21, 22, 23

 RAP is working to make the previously invisible visible by pushing the possibilities of light to the limit. Projects include: working with lasers that generate pulses as short as one attosecond ( $10^{-18}$  seconds), which makes visible the motion of individual electrons; developing near-field optics to overcome the diffraction limit of visible light, thus making the nano-world visible; using meta-materials to manipulate the spectrum; and developing terahertz wave sources and detectors to open up new imaging, sensing and other technologies. Research at the Center focuses on making discoveries that will contribute to society through practical applications.

## Advanced Institute for Computational Science (AICS) pp. 23, 33

 With their high computational speed and exceptional precision in simulations, supercomputers have become indispensable to research and development in many fields. AICS was established in Kobe in 2010 to operate Japan's flagship supercomputer, the K computer. The main objective of AICS is to develop and establish the science of forecasting based on computer simulation. This also involves undertaking groundbreaking research linking computer and computational science. AICS researchers have played a leading role, for instance, in generating software applications and making them available to other researchers worldwide as open source.

## Subluminal outreach

You can find out more about RIKEN's centers, laboratories, and researchers, as well as the newest breakthroughs through our main website, social media outlets, and RIKEN Research magazine.

### Our homepage

From the RIKEN English homepage you can find detailed information about each center, program, and laboratory. Additionally, you will find a directory with contact information for RIKEN's lab heads.

You can also find details regarding RIKEN's worldwide educational and research partnerships, shared resources, and collaborations with industry.

### Hot off the press!!

Keep up to date on the latest breakthroughs at RIKEN by following us on Facebook ([RIKEN.english](#)). We regularly post links describing our newest and best research, so you will know what we're accomplishing as soon as it has been published.

If Facebook isn't your thing, we

also have a popular Twitter feed ([riken\\_en](#)), and a Youtube channel ([rikenchannel](#)) that includes videos in both English and Japanese.



### Blogging & beyond

Our Global Communications team has recently started a blog called *It Ain't Magic* as a way to give a lighter background to what



we are doing, explain some of the science behind our discoveries, and have more interaction with those of you who are interested in science and RIKEN. Comments are welcome!!

### RIKEN Research

We also publish RIKEN Research, a free quarterly magazine that includes our best research, interviews with top scientists, and ideas about how RIKEN's research can benefit society. **RIKEN Research Highlights** are also available weekly online.



## Where is RIKEN?

### Wako (RIKEN Headquarters)

- Chief Scientist Laboratories
- Associate Chief Scientist Laboratories
- Distinguished Senior Scientist Laboratories
- Initiative Research Units
- Special Research Units
- Research Groups
- Global Research Cluster
- Center for Emergent Matter Science (CEMS)
- Center for Advanced Photonics (RAP)
- Center for Sustainable Resource Science (CSRS)
- Brain Science Institute (BSI)
- Nishina Center for Accelerator-Based Science (RNC)
- Advanced Center for Computing and Communication (ACCC)
- Cluster for Industry Partnerships (CIP)
- Interdisciplinary Theoretical and Mathematical Sciences Program (ITHEMS)

### Kobe

- Center for Developmental Biology (CDB)
- Center for Life Science Technologies (CLST)
- Advanced Institute for Computational Science (AICS)
- Quantitative Biology Center (QBIC)

### Harima

- Spring-8 Center (RSC)

### Asia

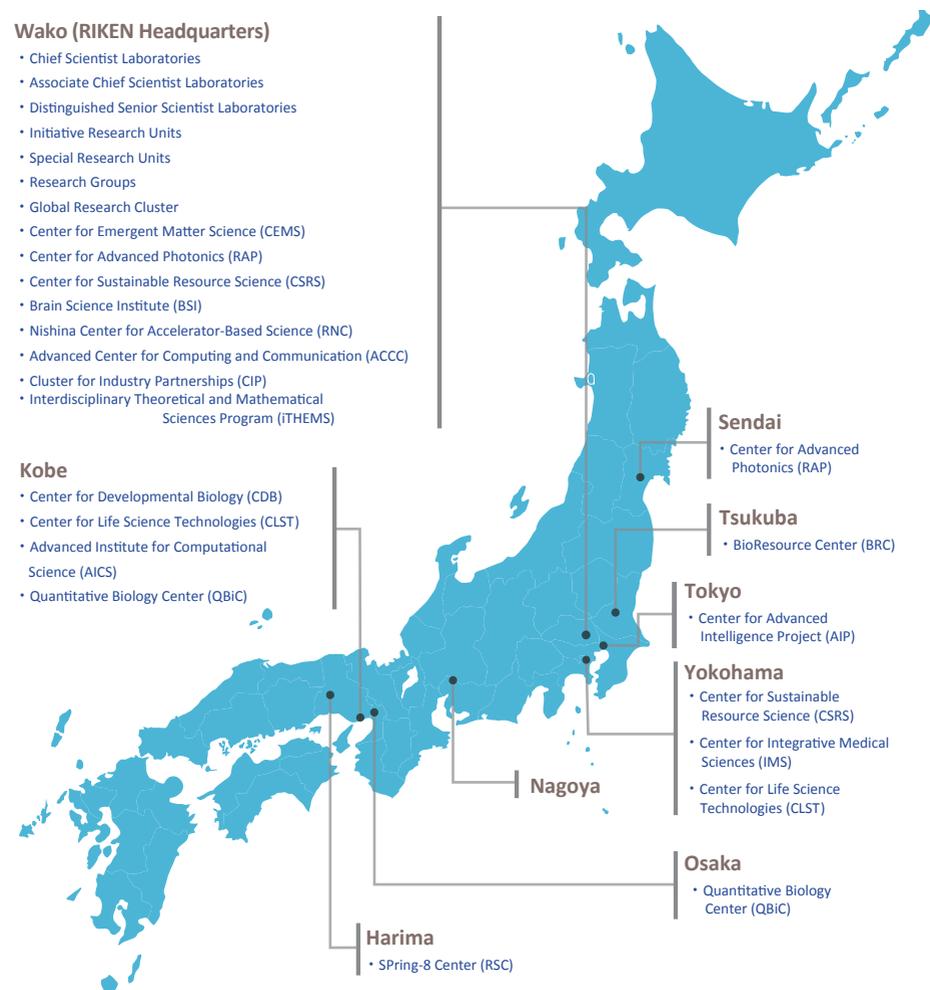
- RIKEN Tsinghua Research Groups (China)
- RIKEN-XJTU Joint Research Center (China)
- RIKEN-SJTU Joint Research Center (China)
- RIKEN-SIOM Joint Research Laboratory (China)
- NCTU-RIKEN Joint Research Laboratory (Taiwan)
- RIKEN-KRIBB Joint Research Center (S. Korea)
- USM-RIKEN International Center for Aging Science (Malaysia)
- RIKEN-NCBS Joint Research Center (India)
- RIKEN-JNCASR-IISc Joint Research Center (India)
- RIKEN Beijing Representative Office
- RIKEN Singapore Representative Office

### North America

- RIKEN-MIT Center for Neural Circuit Genetics (USA)
- RIKEN BNL Research Center (USA)

### Europe

- RIKEN-Max Planck Joint Research Center (Germany)
- RIKEN-KFU Joint Research Labs (Russia)
- RIKEN Facility Office at RAL (UK)





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