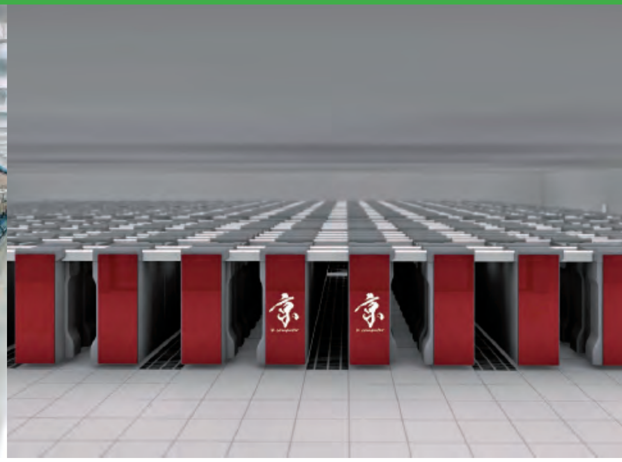




RIKEN

KEEPING JAPAN AT THE FOREFRONT

When Japan's SPring-8 Angstrom Compact Free Electron Laser (SACLA) produced a high-intensity light at 1.2 Angstroms in June 2011, scientists moved a step closer to having a highly powerful x-ray free electron laser (XFEL) to image miniature structures at scales not possible with other devices. Because of its advantages, i.e. the short wavelengths and short pulses, XFEL make it possible, for example, to visualize the movement of microstructures in biological cells and electron dynamics in materials. Based at the RIKEN Harima Institute, SACLA will be opened in March 2012 to scientists from Japan and abroad. Applications resulting from work at SACLA could range from drug development to new materials used to create renewable energy.

SACLA is just one example of the investments that RIKEN has made to remain at the forefront of international scientific developments. Established in 1917 as a physics and chemistry research institute, RIKEN subsequently expanded into biological and other sciences. The 19 research institutes, centers and programs located at RIKEN's 7 institutes now form a major core of Japan's vigorous research community.

Take, for instance, the 'K computer', the renowned fruit of a collaboration between Fujitsu Limited and RIKEN Advanced Institute for Computational Science (AICS) in Kobe. Expected to be completed in the fall 2012, it is the first computer to reach computation speed of 10 petaflops. In June 2011, this computer was crowned the world's fastest, and even in the rapidly changing world of supercomputers, it retained that top rank in November 2011 by an easy margin — it is more powerful than the next seven supercomputers on the TOP500 list combined.

Pioneers pushing the boundaries

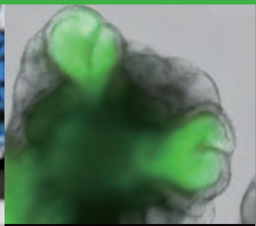
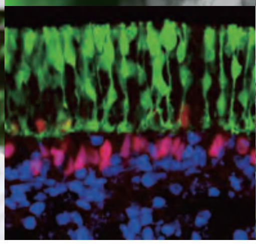
RIKEN's human resources, however, make it a true powerhouse. Some 400 principal investigators, all leaders in their respective fields, earnestly carry the weight of responsibility for keeping Japan at the cutting edge.

A leading example is Yoshiki Sasai, the principal investigator of the Laboratory for Organogenesis and Neurogenesis at RIKEN's Center for Developmental Biology (CDB) in the RIKEN Kobe Institute. Sasai's group surprised stem cell and developmental biologists around the world last year when it created an optic cup *in vitro*. As reported in the journal *Nature*, the researchers started with mouse embryonic stem cells and coaxed them to form all seven retinal cell types of a cup-shaped organ. To Sasai's surprise, the cells aligned with the right symmetry and size and even formed synapses. Startlingly, the cells also folded over to form the three-dimensional cup[1]. "It was very similar to what you see in the embryo. It was recapitulating development," says Sasai.

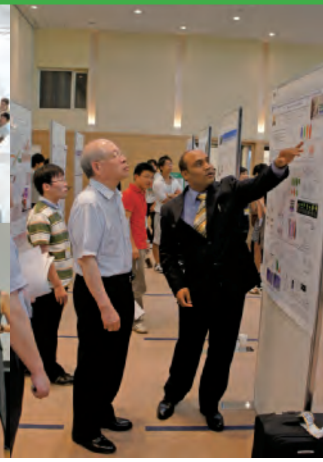
In the long term, various retinal diseases could be treated by transplanting artificial tissue. Shorter term, artificial eyes developed from cells of patients with eye-related genetic diseases could be used to study such diseases and test candidate drugs for their treatment.

For scientists, the achievement also provided evidence to settle an age-old debate. During development, do cells such as retinal precursor cells drive themselves toward tissue creation or do they depend on signals from neighboring tissues? This experiment suggests that "cells know what to make, and they know it at a very high level," says Sasai. This clearly has implications for other tissues and a wide body of researchers across the globe.

Being at RIKEN stimulated Sasai's work. Discussions with experts in fetal development allowed him to merge "cutting-edge technology of embryology and stem cell biology." He looked even further afield within RIKEN for help in understanding the complex physics of the incredible phenomenon he was observing. Taiji Adachi,



a former head of RIKEN's Computational Cell Biomechanics Team at the RIKEN Wako Institute in Saitama and currently a professor at Kyoto University, offered mathematical modeling. "The combination of different expertise and environment gave us a lot of stimulation and clues for doing this kind of work," says Sasai.

Sasai is now sought globally for technical consultation with industry, research guidance, and collaborations. He looks forward to working with CDB's Masayo Takahashi, who has long focused on retinal regeneration, for application to humans. With other achievements under his belt — including creating an artificial cerebral cortex and pituitary gland — his influence is set to grow.

Franco Nori, who came from the University of Michigan to head the Digital Materials Team at RIKEN Advanced Science Institute (ASI) in the RIKEN Wako Institute in 2002, has likewise found fertile, interdisciplinary ground in RIKEN's "outstanding research environment." To carry out his seminal research in quantum circuitry, atomic physics, and energy-related fields such as solar cells, light-to-electricity conversion, and proton pumps, he motivated researchers from different backgrounds and sub-fields to work together in new and interdisciplinary areas.

Most recently, the group's research featured in the discovery that something can come from nothing. All space, including the vacuum, has long been known to teem with the activity of evanescent "virtual" particles — a creation of quantum fluctuations that flip in and out of existence. "These fluctuations, however fleeting, are the origin of some of the most important physical processes in the universe," says Nori. But researchers had failed to observe directly the quantum properties of this vacuum state.

Nori's team succeeded using superconducting circuit devices, which could modulate the boundary conditions of the electromagnetic field with velocities near the speed of light — fast enough to achieve the "dynamical Casimir effect," by which virtual photons are converted into real light[2].

As formulated originally, achieving the dynamical Casimir effect would require a mirror moving near the speed of light. Nori's team used a different method, based on a new and rapidly advancing field of physics in which certain circuits on chips behave like artificial atoms. According to Nori, these artificial atoms can be designed to have specific properties not found in natural atoms, and can be used to study atomic and quantum phenomena.

Nori says that showing the dynamical Casimir effect is just one indication of the potentially far-reaching applications of these artificial atoms[3]. "This effect is like attaching voltmeters, wires, and current generators to giant atoms," he says.

The work has earned international recognition. Not only was it published in *Nature*, it saw quantum physics claim front-page space in major international newspapers. The study also ranked in the top five "breakthroughs of the year" in Physics World, and became the "most read news story of 2011" on Nature News. Nori says the team had to work hard —"more perspiration than inspiration, unfortunately." Still, many of his most successful prodigies keep returning to RIKEN for inspiration, he says.

With such infrastructure and inspiration, RIKEN continues to build the foundation of Japan's scientific future. ■

1. M. Eiraku, *et al. Nature* **472**, 51–56 (2011)
2. C.M. Wilson, *et al. Nature* **479**, 376–379 (2011)
3. J.Q. You & F. Nori, *Nature* **474**, 589–597 (2011)