INTERNATIONAL COLLABORATION

Japan Learns to Accommodate Its Global Research Partners

ITER

Catering to foreign needs. Russian physicist Yuri Gribov picks up daughter Ania at Naka's school for foreign kids.

When a team of U.S. physicists led by the University of Hawaii's Steve Olsen signed on in 1983 to build an international detector for Japan's new electron-positron accelerator, they got a traumatic culture shock. The host laboratory, the National Laboratory for High-Energy Physics (KEK), wasn't set up to accommodate them: It didn't even have a secretary to help arrange housing or show the visiting researchers how to set up a bank account, apply for a visa, or go shopping. "We had no help at all from the administration at KEK," says Kazuo Abe, a member of Olsen's team who is now head of the AMY collaboration.

Contrast that with the accommodations Japan is making for foreign researchers at Naka, 90 minutes north of Tokyo by train, where one of three international facilities for the International Thermonuclear Experimental Reactor (ITER) is located. The Japanese home team, as it's called, has built homes for married couples and rented a block of apartments for single foreign scientists, who might feel more comfortable living together. It has also provided an ombudsman to help make their stay a pleasant one.

The contrast reflects Japan's acceptance of its growing role as a global scientific power. It is a role that Japan has only recently begun to take on: The country was unable to afford world-class research laboratories until the mid-1970s, and only in the past decade or so has it begun to build up the kinds of facilities that attract large numbers of top-rate foreign scientists. But now that Japan is becoming a full-fledged member of the international scientific community, it is having to pay more attention to integrating scientists from other countries.

"The natural sciences were really created in Europe and the United States, and the center of the academic community is still in the West," says University of Tokyo physicist Yoji Totsuka, head of a large underground physics experiment known as Super Kamiokande. "By collaborating with American and European scientists, we learn how to work with the natural sciences. It's especially important for young researchers to work closely with good foreign scientists."

In spite of Japan's growing hospitality, however, the balance of trade in scientists is still heavily weighted toward the United States and Europe. To most scientists overseas, Japanese research activities are a "black hole," says Ray Tsuchiyama, head of the Tokyo office of the Massachusetts Institute of Technology (MIT). In fields where Japan excels, such as semiconductors, materials science, and mechanical engineering, Western scientists who want to keep abreast of the field can benefit from collaboration. "On the flip side," says Tsuchiyama, "in fields like medicine, chemistry, and biology, coming to Japan and learning something is going to be hard. And most of the interesting research is going on in industry labs" unwilling to share their work.

And the cultural and logistical barriers confronting foreign scientists in Japan are still formidable. In addition to the demands of learning a new language and culture, the declining strength of the dollar against the yen can make a stint in Japan uncomfortable and costly for Americans. "The biggest concerns are always for the family," says Aki Maki, director of the Washington liaison office of the Japan Society for the Promotion of Science (JSPS), who notes that foreign schools are few and cultural barriers remain high for spouses and children.

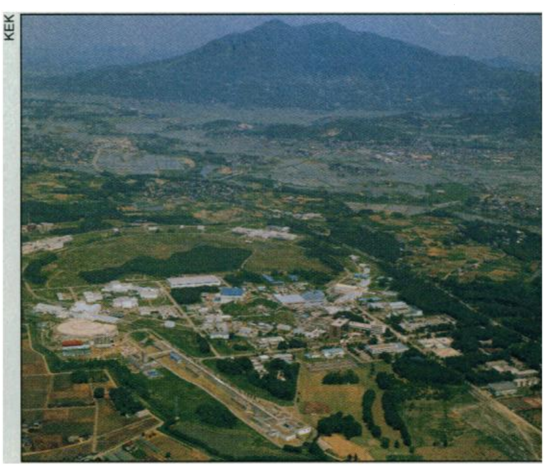
Moreover, researchers hoping to come to Japan for anything more than a short-term stay will find few opportunities to obtain semipermanent positions, says Tsuchiyama. "About 30% of the faculty of MIT, for instance, originally comes from another country," says Tsuchiyama. But "you don't see that many blue-eyed, blond people directing Japanese companies or being professors in Japanese universities," he adds. "It's a glass ceiling [for outsiders]."

Big physics shows the way. Two fields that have made the biggest strides toward becoming full international players are nuclear and high-energy physics. The disciplines share a pair of characteristics that are vital to successful international collaborations: They are too expensive for one country to pursue alone, and they offer few, if any, immediate technological payoffs that would tempt companies to hinder the free flow of information.

In high-energy physics, the first signs of change in Japan came with Tristan, an electron-positron colliding beam accelerator at the KEK laboratory in Tsukuba. "Before Tristan," says Fumihiko Takasaki, head of the physics division there, "all we had was a proton synchrotron, and it wasn't cutting-edge. So most Japanese physics students went to the U.S. or Europe, and it was really hard to get good people to come back here."

Tristan's debut in 1987 gave the Japanese a 2-year reign as the owner of the highest energy electron-positron collider in the world. "It produced many experts which we didn't have before," says Takasaki. "We didn't have accelerator physics, detector, or data analysis capability before." And it also attracted physicists from other countries who were looking to work on the frontier, says Olsen.

Tristan also marked the start of what Michael Roberts, director of international programs at the Department of Energy's (DOE's) Office of Fusion Energy, calls an attempt by Japanese laboratories to be "accommodators." Half of AMY's approximately 60 team members were American, says Abe, and "lots of U.S. dollars were spent here. But we had no infrastructure. We needed permission from MITI to import the VAXes and Crays we needed. We needed to request a tax exemption." (The import restrictions no longer apply.) Japan offered to hire foreign scientists through the JSPS fellowship program, he says, but the slots could never be guaranteed.



KEK

Making room. Foreign scientists are flocking to KEK's new b-factory in the works.

Even such a simple concept as how Japan would be reimbursed for the money spent by foreign researchers had to be worked out, says Maki, who is a former KEK physicist. In the United States and Europe, he says, university teams working at a national laboratory typically set up an account to handle their local expenses, and the host lab collects money from the home institution. "But the Japanese government organization is not allowed to operate in this way," he says. "So we had to invent a tricky way to operate this kind of practice."

Now, foreign scientists are no longer an oddity at KEK. "Things have changed quite a bit," says Abe. "The procedure to get housing, for instance, is well defined, and we have a secretary who can teach them how to go to the bank and set up an account, or go shopping. Even the procedures for getting a visa are well defined."

Similar accommodations are being made in an effort to make Japan the world center of nuclear fusion research, a field in which Japan has a long history of international collaboration. In 1978, Japan sent a team of researchers, hardware, and $70 million to San Diego to participate in a joint magnetic fusion program involving a large DOE fusion facility run by General Atomics. "As a measure of its importance to them," says Roberts, "the Japanese turned off a domestic research facility and decided it was a better investment to put their money and people into the existing facility here."

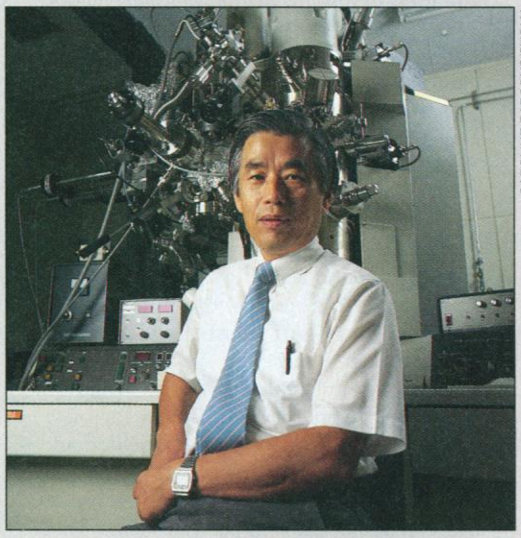
That research work has steadily grown, and Japan is now one of four partners—with the United States, Russia, and Europe—in the ITER program, which is the first big-ticket scientific project in Japan that is international by definition. ITER has three co-centers, in San Diego, Munich, and Naka, the site of Japan's major fusion research center run by the Japan Atomic Energy Research Institute (JAERI). Each co-center is staffed by researchers from the four countries, who stay from 2 to 6 years. ITER's designated design period is scheduled to end in July 1998, and at that point, if the four partners decide to build a full-scale fusion machine, a site will be chosen. JAERI officials hope that Japan wins the prize.

With that in mind, Japan has built a Western-style office building in Naka. "That means one office per person, even though they clearly don't do that in their own buildings," says MIT's Bruce Montgomery, a prin-

PROFILE

A Sense of What to Look For

TSUKUBA—The discovery of carbon-60 molecules excited scientists around the world, but Sumio Iijima hesitated even to take a look at them. Studying the soccerball-shaped fullerene molecules "is not interesting for a microscopist," says the 55-year-old Iijima. But after a method of mass-producing C-60 had been developed, he had a hunch that electron microscopy might help elucidate how the molecules form. So in the summer of 1991, while most C-60 researchers were sifting through the sooty remains of the vaporized carbon rods, Iijima focused on the electrodes that vaporized them. And what he found—a form of fullerene called carbon nanotubes—may prove to be even more important than the C-60 molecules themselves.



CAROLINE PARSONS/SYGMA

Material pleasures. NEC's Sumio Iijima explores carbon nanotubes, which he discovered in 1991.

"I emphasize that it was serendipity," says Iijima. It's not false modesty: Although Iijima, a relaxed, affable man with a mop of salt-and-pepper hair, becomes bashful when describing his accomplishments, he's quite forthright about his gifts as a scientist. "I have the best technique in microscopy," he says flatly.

But there's more to Iijima than just technique. "He has a sense of what to look for, of what will give us the most interesting and most valuable information [about a material]," says Roy Lang, director of NEC's Fundamental Research Laboratories in Tsukuba, where Iijima is a research fellow.

Even before his discovery of carbon nanotubes propelled him to worldwide fame—and two of the 10 papers currently most cited in chemistry and physics—Iijima had attracted worldwide notice. After earning a doctorate in physics from Tohoku University and doing a stint there as a research associate, Iijima went to Arizona State University in 1970 to work under John Cowley. In addition to helping Cowley's group take electron microscopy to ever finer levels of resolution, Iijima became the first microscopist to image localized atomic defects in crystals.

Iijima returned to Japan in 1982 to join one of the first projects funded under the innovative Exploratory Research for Advanced Technology (ERATO) program started by the Science and Technology Agency. As part of the Hayashi Ultra-Fine Particle Project, Iijima worked with a specially designed electron microscope equipped with a fast videotape recording system to capture moving images on an atomic scale. Among other achievements, he showed that crystalline particles of gold spontaneously change shape and that the arrangement of the atoms within the particles also changes. "That type of work had never been done by any other group," he says. His peers agreed: In 1985 he received Japan's prestigious Nishina Memorial Award in physics.

When the ERATO project ended in 1987, Iijima declined offers from several universities and joined NEC, lured with promises of a $2-million, custom-built, ultrahigh-vacuum, high-resolution transmission electron microscope. Iijima has been applying electron microscopy to the study of new materials. Ironically, he was using a standard transmission electron microscope, not his prize tool, when he found the carbon nanotubes.

Being as much a materials scientist as a microscopist, Iijima has continued to explore nanotubes since his 1991 discovery. Despite having a tiny team—one colleague, an assistant, and the occasional postdoc—Iijima has succeeded in filling the tubes with liquid lead, describing how the tubes change diameter along their length, and finding single-shell tubes instead of the more common multiple concentric tubes. He's now trying to mass-produce single-shell tubes to confirm predicted electrical and mechanical properties and to demonstrate applications, including new composite fibers and the use of nanotubes as templates to form nanometer-scale wires. Although serendipity has played a role, his superb technique and sense of what to look for should keep Iijima at the focal point of his field.

–D.N.

cipal investigator on the magnet research and development project for ITER. "Japanese work spaces tend to be one big room, without dividers, used by quite a few people." Even the housing built for married couples and families is quite generous by Japanese standards, he says. In addition, the town has opened a two-room international grade school for the children of foreign researchers. Older children, however, have no choice but to attend schools in Tokyo, 2 hours away.

These features—a mixture of amenities and necessities—are the key to hosting successful international collaborations, say Japanese officials, who want Western scientists to feel as comfortable in Naka as they do in San Diego or Munich. "JAERI and the government of Japan know very well that the infrastructure in Japan to receive foreign researchers is still very poor," says Yasuhide Tajima, who now works in the director's office of the ITER San Diego Joint Research site. "If they cannot show an ability to accept and receive Westerners, then the other countries involved won't agree to build [ITER] in Japan."

With the experience gained from ITER and Tristan, the Japanese scientific community believes that its hospitality will soon meet Western standards. And despite the rising cost of big science, it will have a chance to prove it with several new projects in the works. The successor to Tristan, a new accelerator for the study of b-mesons (*Science*, 3 June, p. 1392), will also include international collaborators. And the Super Kamiokande detector being built in a cavern in the small town of Kamioka will also attract several dozen foreign scientists.

Further down the road is the JLC, known as either the Japan Linear Collider or the Joint Linear Collider, depending on where one believes it will be built and which countries will fund it (*Science*, 3 June, p. 1397). KEK is already collaborating with scientists at the Stanford Linear Accelerator Center on joint research and development projects, but after the demise of the Superconducting Super Collider, it's difficult to imagine Japan taking another chance on a big-ticket, U.S.-based accelerator. If the JLC is built on Japanese soil, then Japan will become home for many of the best high-energy physicists in the world, and the JLC will be the mechanism for training a new generation of world-class Japanese physicists.

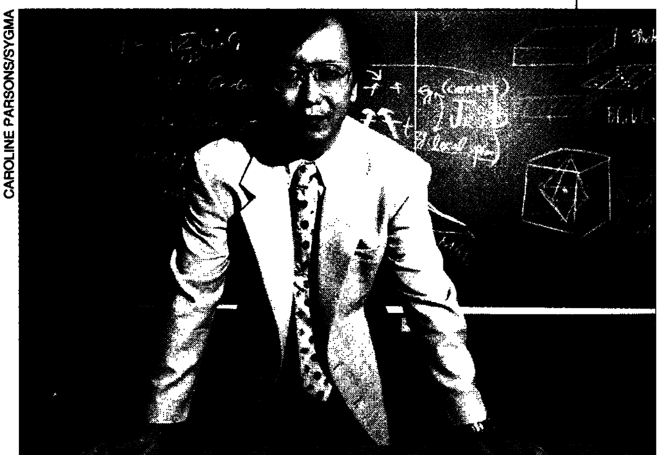
It will also require taking another step down the road to accommodating the rest of the world. "The JLC will probably be a very big collaboration of many nations," says Takahiko Kondo, the KEK physicist who led the Japanese participation in the SSC. "Somehow we'll have to come up with a completely different way of doing international collaboration."

–Gary Taubes

PROFILE

Blazing a Collaborative Trail

Solid-state physicist Yoshinori Tokura knows what it's like to go against the flow. Every Wednesday morning he leaves his wife and two sons at home in the western suburbs of Tokyo and heads east and north by train, in the opposite direction to the city's notorious rush-hour traffic, to Tsukuba science city. But it's not just the commute that sets him apart from the average University of Tokyo professor. As a group leader at the Joint Research Center for Atom Technology (JRCAT) in Tsukuba, Tokura is one of the first national university professors to be part of a major project sponsored by the Ministry of International Trade and Industry (MITI).



CAROLINE PARSONS/SYGMA

Two worlds. Yoshinori Tokura is a full professor at the University of Tokyo and a team leader at MITI's Joint Research Center for Atom Technology.

At 40, Tokura is the youngest full professor in the university's faculty of science and one of Japan's best solid-state physicists. In most countries that would be enough to secure the resources to run a high-powered academic lab. But funds are scarce, and it's difficult to assemble a large research team in a Japanese university. So for the past year Tokura has worked 2 days a week at JRCAT, where he directs six research scientists and shares in a generous 10-year research budget of $250 million to study nanotechnology and new materials. Asked to explain his professional double life, he laughs: "It's quite exceptional."

The son of a journalist, Tokura grew up near Kobe and attended the University of Tokyo, where he earned a Ph.D. in applied physics. Already well regarded as a materials scientist at home, his career took off in 1987 when he spent a year in California as a visiting scientist at IBM's Almaden research center. At Almaden he fell in with high-temperature superconductor gurus Jerry Torrance and Stuart Parkins and was stricken with what he calls "high-Tc fever." Already expert in the electronic properties of organic materials, he quickly became familiar with metal-oxide compounds and collaborated on several prominent papers in the then–red-hot field.

After returning to the University of Tokyo in 1988, Tokura soldiered on, systematically studying these compounds even though interest in the topic had cooled along with dreams of room-temperature superconductors. His work convinced him that he had uncovered "an abundant gold mine" of fascinating new properties in the materials, and JRCAT offered a more conducive atmosphere than the university to pursue this new line of inquiry. Not only does he lead a larger team, but "I don't have to care about money or other pressures" such as teaching and administrative chores, he says. "I can fully enjoy the basic research." Tokura also sees himself as a role model for other university scientists with big ideas but small grants. "There should be another path to grant money besides the Ministry of Education," he says.

At JRCAT Tokura is immersed in the hot field of magnetotransport phenomena, in which metallic oxides show changes in conductivity when subjected to low temperatures and a small magnetic field. His team, for example, has found a manganese oxide compound that shows a 10-orders-of-magnitude jump in conductivity under such conditions. Back at the university, in addition to teaching, he studies the basic physics underlying the transition of metal-oxide materials from a superconducting to an insulating state.

Making the best of such a busy life, Tokura says he uses the long commute "to read scientific papers, or I just take a siesta." And his long hours haven't made him a stranger to his family: In fact, his 12-year-old son says he wants to follow his father's footsteps into physics. The news brings wry laughter from Tokura as he thinks about what it takes to pursue a dream, including the necessity at times to go against the flow.

–A.R.