Japan Bids for U.S. Basic Research

The electronics giant NEC has created a Princeton research haven that may be a model for other Japanese companies investing in basic science

In a sleek corporate laboratory just 5 miles north of Princeton University, 40 select U.S. scientists study basic questions in physics and computer science in an environment many of them thought was vanishing for good. They get steady, guaranteed funds. They are free to follow their scientific instincts. And they even earn comfortable salaries. It may sound like the halcyon days at AT&T Bell Laboratories, a decade or more ago, or a physicist's dream of an ideal research university. But there's a big difference: These people are working for a Japanese company—the Nippon Electronic Corp. (NEC).

To most of the scientists at the NEC lab, its ownership is irrelevant. The generous research funds free them to do the kind of research—in materials science, chaos theory, biophysics, artificial intelligence, and other forward-looking edges of science—that many of them had struggled to pursue elsewhere. So far, they say, they've faced no restrictions in publishing and discussing their work. And best of all, they don't have to justify their projects on practical grounds—a luxury that has nearly vanished from U.S. industrial laboratories, they point out. "The Japanese are doing what we did 20 years ago," says materials researcher Robert Haushalter. "There's hardly anywhere in the country that does this kind of basic research [any more]."

One of Japan's comparative weaknesses is in basic research. *Science* recently reported that Japanese companies are stepping up their investments in basic research facilities in Japan (23 October, p. 561). In this article and the article that begins on page 1431, we examine a companion trend: increased investments by Japanese companies in basic research laboratories in the United States.

To many outside observers, though, the NEC Research Institute presents a more complex conundrum. Some, including Harvard physicist and technology policy analyst Lewis Branscomb, call NEC's $16 million-a-year investment in the lab a gesture of scientific good citizenship. They applaud the example of a Japanese company doing its fair share to support the worldwide scientific enterprise. Others worry, however, about the impact of investments like these on U.S. competitiveness: Even if the parent company isn't reaping short-term gains, they say, it may gain a long-term edge that will ultimately benefit its manufacturing operations back home. "They aren't doing this out of the goodness of their hearts," says former National Science Foundation (NSF) director Erich Bloch. "If NEC wouldn't get anything out of it they wouldn't do it." To still other observers, the sharpest lesson from the Princeton laboratory is the contrast between NEC's commitment to basic research and many U.S. companies' retreat from it. "The question is, Why aren't American companies doing this?" says University of California, Berkeley, computer scientist Michael Harrison. "U.S. companies are backpedaling from basic research—becoming product-oriented."

Meanwhile, Japanese companies are moving forward—and into the United States. Some are supporting research in U.S. universities; others have opened industrial research

Taking the Long View of Computing's Future

Down the road from AT&T Bell Laboratories, the kind of forward-looking industrial research it used to specialize in has found a new, albeit smaller, home, at the NEC Research Institute in Princeton. Some outsiders are unnerved that this 4-year-old laboratory comes courtesy of a Japanese electronics giant, the Nippon Electronic Corp. (NEC); they fear that the U.S. research talent NEC is attracting will end up enriching it at the expense of U.S. companies. Others argue that the work, which the scientists freely publish, benefits those on both sides of the Pacific (see main text). But whoever gets the benefits, they won't come anytime soon, say other researchers. Remarks University of California, Berkeley, computer scientist Michael Harrison, "NEC is gambling on stuff that may never pay off."

What will the computer chip of the next century look like? A three-dimensional structure relaying and processing information in beams of light? Or a device modeled on the neurons in the human brain? And what will it take to realize computer scientists' dreams of artificial intelligence? Those are among the questions animating the NEC lab—and they have brought together an entire menagerie of research, ranging from materials science to linguistics and biophysics to fields whose link—if any—with computer science will emerge only after years of research.

- Physicist Richard Linke, for example, says he would like to do away with the "rats' nests" of wires that fill today's computers. "The dream is to have optics enter computers and do what it did with communications," now that information zips across the globe through a web of optical fibers. But it was a little naive to think it would happen any time soon, he says. "You can't just pull out the wires and put in optics. It's a totally different concept." For now, he's working on an intermediate step: optoelectronic devices that combine light and electricity, such as "microcavity lasers" that transform electric current to light.
- Physicist Ned Wingreen is getting ready for the day when circuits get so small they will enter the realm of quantum mechanics. To do so, he's studying the behavior of bits of material so small you could count the atoms. Existing somewhere between the solid world of bulk materials and the quantum-mechanical realm of the atom, these "quantum dots" hold just a few electrons at a time, yet they can support a miniature electric current as electrons "tunnel" through by the magic of quantum mechanics. Wingreen's studies of how the current varies with changes in the voltage across the device may be at the level of basic physics, he says, but not for long. "Whether we

labs. Along the high-technology corridors of Princeton, Palo Alto, and elsewhere, Japanese electronics companies have opened scores of research centers, most of them small, specializing in research in semiconductors, lasers, and other technologies. NEC's Princeton laboratory is one of the largest. And its far-sighted thrust, says Martha Harris of the National Research Council (NRC), who just compiled a catalogue of foreign labs in the United States, makes it "something of an exception."

At least for the moment. The NEC Research Institute may represent a vanguard, says Richard Samuels of the Massachusetts Institute of Technology's (MIT) Japan program. "It may be a short-term trend, but the Japanese are investing heavily in basic research in the United States." With their focus on the long term and their belief that U.S. scientists represent a pool of basic research talent ready for tapping, he says, many more Japanese companies may soon be stepping in to fill the role vacated by their U.S. counterparts.

A baby Bell

The inspiration for NEC's effort came from that most famous of U.S. industrial research labs, Bell Labs. And the prime mover was not an NEC corporate official but a U.S. physicist: Dawon Kahng, who worked for most of his career at Bell Labs.

Until the changes in research strategy precipitated by the breakup of the parent company (*Science*, 14 June 1991, p. 1480), Bell Labs researchers were free to roam through basic physics—an approach that paid off when early work on semiconductor physics and optical spectroscopy led to the integrated circuit and the laser. Kahng thought computer science might benefit from a similar attention to basics. Explains laboratory vice president Joseph Giordmaine, "Kahng made an educated guess that the future of computer science will involve a new understanding of physics."

Kahng shared his vision with fellow Bell Labs researcher Michiyki Uenohara, who had since gone to NEC in Japan. Their vision resonated with the NEC management, which had set its sights on such long-term goals as artificial intelligence and language translation by machine. Because of its traditional strength in basic research, the United States seemed the right setting to pursue those goals, according to lab physicist Richard Linke, who often visits the parent company in Tsukuba Science City. "They really have an interest in U.S. research institutes," says Linke. So when Kahng and Uenohara proposed a Princeton lab to NEC, the suggestion fell on fertile ground. Kahng started up the New Jersey facility in 1989 with eight physicists.

Kahng died last year, but researchers say his vision still reigns at the lab. The offices of computer scientists and physicists alternate down the halls, in an attempt to stimulate mixing of ideas. And the research is still resolutely basic, with any applications lying well over the horizon. Computer scientist William Gear, who recently replaced Kahng as president, says the lab selects people on the basis of their ideas and goals in key areas, then sets them free. "We hire them because of the areas they are interested in but we don't tell them what to do."

That hands-off style has proven a powerful lure to the lab's recruits—as has the guaranteed research funding, which is awarded to each scientist in an annual chunk depending on his or her official rank. Take physicist Ned Wingreen, one of the more recent arrivals, who came directly from a postdoc at Cornell, where he earned subsistence wages and sweated about grants. Now he gets a comfortable salary and $30,000 in research money each year to study the way electrons traverse atomic-scale structures known as "quantum dots." For Linke, a more senior recruit who came from AT&T 3 years ago, freedom was the major lure. At AT&T, he says, he had just been promoted. "I hated it," he says. His new management duties sucked up all his time, leaving little for doing science. When interviewing for the job at NEC, he says, his prospective employers told him

end up using silicon chips or biological materials, you will see electrons confined to small spaces and tunneling effects. The physics of small systems is essential to understand," he says.

■ Computer scientist Eric Baum is trying to sharpen the wits of future computers by teaching them to play games. Today's chess-playing computers don't have to think because they can win by brute force: evaluating every possible move. The Japanese game Go is another matter, says Baum. In Go, players cover a board with black and white stones, each player trying to surround the other, and the astronomical number of possible moves can boggle the computer. Playing well takes the kind of educated guesswork we call reasoning and judgment. "What I'd like to do is figure out how people reason," Baum says, and apply it to computers. As a first step, he's teaching a computer to ignore obviously bad moves—to construct a streamlined, smarter "tree" of possible moves. So far the strategy has improved the computer's Go game, but the machine still lacks the finesse of a human opponent.

■ Computer scientist Sandiway Fong is working on a universal grammar to allow computers to become translators. Sentences like "Which report did you file without reading?" are the downfall of current computer translation programs because different languages put those words in different order. To get around this, Fong has been drawing on the linguistic theory of Massachusetts Institute of Technology linguist Noam Chomsky, who proposed that one common grammar can link all the different languages of the world. If Chomsky is right, says Fong, computer scientists may be able to develop a set of rules by which a computer can analyze sentences. "It's not clear this would ever become a product, but some of the techniques might filter down," Fong says.

■ Physicist Albert Libchaber, known for previous work in turbulence and chaos theory, is now moving in a different direction—toward living things. By looking at the underlying organizing forces that turn biomolecules into parts of plants and animals, he hopes to catch a glimpse of processes that might someday point the way to self-assembling microscopic devices. In biological systems, everything happens by statistics, he says. The proteins link up and break apart over and over, until they achieve a stable kind of filament. "All the time [these filaments] are growing fast and shrinking," he says. "That's what's fascinating." This frantic trial-and-error, says Libchaber, generates many of the patterns of nature—the anatomy of leaves, the patterns of clouds, the web of blood vessels in our body.

That's a stew of research rich enough to nourish everyone, not just the parent company, insists NEC Research Institute vice president Joseph Giordmaine. "Basic research is capable of producing benefits that change whole industries," he says, "not individual companies."

–F.F.

flatly: "We're going to expect even the senior level people to do their own research." Now he is working on something that interests him: substituting light for electrons as the life blood of integrated circuits.

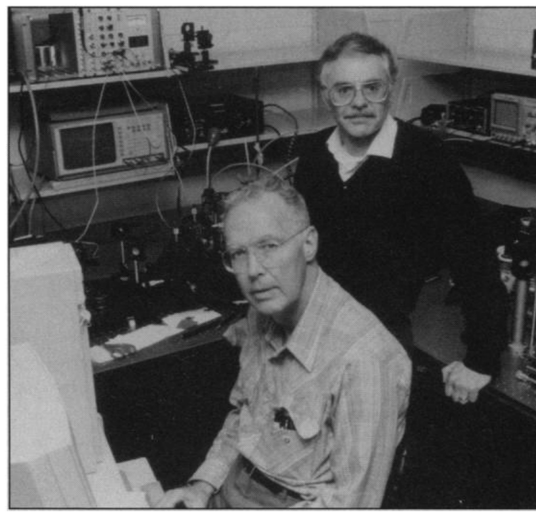
All of which has fostered a sense of good fortune at the Princeton institute. Says computer scientist Eric Baum: "I don't have to worry about anything—no grants, no teaching!" Agrees Haushalter, "For a scientist I couldn't have it better."

Some of the New Jersey scientists say they are a little mystified about what the parent company expects in return for all this. Officially, the goal of the lab is to do research that advances both computing and communications. "We call it C&C," says vice president Giordmaine. But although NEC does have patent rights to the work of its scientists, says Linke, only a handful of patents have been filed, including one on a technique he developed for transmitting information among computer elements using light instead of electricity. Nor does the company have a stringent policy of prepublication review to screen work for patentable developments. So far, NEC researchers say, management has never interfered with publication or prevented researchers from collaborating with outsiders. Insists physicist Albert Libchaber, an expert on turbulence who now studies biophysics, "There's no secrecy here."

A fair exchange?

That policy might sound self-defeating for NEC. But technology policy expert Branscomb thinks the parent company isn't expecting its payoff to come from patents; instead, insights from the basic research in Princeton will help guide its technology strategy back home. "If you do basic research looking into the future, you get a depth of understanding that will help you make technology decisions in the shorter term," says Branscomb. When will we hit the limits of silicon chips? What will we use as a substitute? How will it be used? "These are billion dollar decisions," he says. And a company with strong basic research will know how to make them.

As Branscomb sees it, NEC's gain isn't necessarily a loss for the United States. The basic research coming out of the NEC lab could, properly applied, strengthen the competitive positions of U.S. companies as well. And that, he says, would be a welcome turnaround from past years, when U.S.-funded basic research fed into Japanese product development. "We need the Japanese to do their fair share of funding of the production of basic knowledge," Branscomb says. The mistake the United States is making, he says, is not in letting NEC set up a lab, but in scaling back similar research in our own labs, such as those run by Bellcore and IBM.



NEC

Back to basics. Richard Linke *(standing)* and George Devlin collaborate on microcavity lasers at NEC's lab.

Former NSF director Bloch is less sanguine. He's convinced that the company is tapping into the fruits of the researchers' labors in a way that the outside scientific community can't. Sure everyone can read their publications, he says, but those don't contain every detail of the research. Meanwhile, those researchers are forestalled from contributing to U.S. academic or industrial strength. "[NEC is] just skimming off our top level scientists," he says. In a truly fair deal, Bloch insists, NEC would bring to the United States some of the manufacturing jobs that he thinks will ultimately emerge from the Princeton lab's fundamental research. Bloch says he'd like to see such an exchange become a legal requirement for foreign companies tapping into U.S. research.

MIT's Samuels agrees that we need more quid pro quo, but his solution is to exploit Japan's strengths. "They have a weakness in basic research, so they buy into ours. If we have a weakness in manufacturing, we should be going there and hiring the best and brightest manufacturing engineers," he says. "We've got to switch the button from transmit to receive."

New direction or dead end?

All these issues will become more pressing if the NEC model catches on. For now, most of the other U.S. labs supported by Japanese electronics companies look more like the Matsushita lab just 5 minutes down the road from NEC. It has only eight scientists and the research is highly applied, focusing on computer systems, says vice president Hank Korth. Matsushita runs other small labs specializing in speech technology and high-definition television; NEC, Canon, and Hitachi also have engineering laboratories scattered across the country. Such laboratories, though they raise some of the same questions about competitiveness and quid pro quo as the NEC lab, don't exploit America's undisputed strength in basic research.

Canon, however, is tentatively following in NEC's footsteps in the laboratory it recently opened in Palo Alto, near Stanford University, where it supports 25 scientists devoted to basic research. For now, their work is "closer to the marketplace" than NEC's, says vice president Harry Garland. Canon makes copiers and fax machines, and the researchers in Palo Alto study things closely related to those technologies—new ways of processing and compressing data and images, for example.

It's too soon to tell whether such ventures will help or harm the U.S. competitive position, says NRC's Harris. And it's even too early to know whether these laboratories will live up to the hopes of the companies funding them. Biophysics researcher Libchaber points out that Japanese companies, long focused on applied research, are just getting started in the world of basic science. "It's a new adventure for them," he says—and in the case of the NEC lab, the uncertainty is compounded by the lab's distance from the home office and its independence. "This place is an experiment," he says. "Whether it is successful or not—there hasn't been time to tell."

–Faye Flam

Biggest Japanese-owned Electronics Research Labs in the U.S.

Company	Location	# Employees	Type of research
Fujitsu Network Systems	Raleigh, NC	150	Telephone Switching Equip.
Toshiba Information Systems	Irvine, CA	150	Cellular Systems, FAX
NEC Research Institute	Princeton, NJ	85	Computers & Communications
Hoya Electronics	San Jose, CA	48	Opteoelectronics
Sony Microsystems	San Jose, CA	50	Software & Computers

SOURCE: Donald H. Dalton, U.S. Department of Commerce