Industry Steps in to Fill the Gap in Basic Research

Even to an ivory tower academic who wouldn't normally feel at home in a company laboratory, the research center run by the giant camera and copier manufacturer Canon must look like the perfect place for basic research. Located in Atsugi, a suburb about 25 miles southwest of downtown Tokyo, the 7-year-old institute employs 250 researchers who conduct fundamental studies in fields ranging from materials science to optoelectronics to biotechnology. The building is new, the equipment all state-of-the-art, and the environment designed to enhance creativity: Scientists can relax in special meditation rooms, take in a seminar while sprawled on floor cushions in "brainstorming" rooms, trade ideas at squiggly cafeteria tables shaped to encourage "new and stimulating" interactions, and schedule their work on a flex-time plan that wouldn't seem out of place in Silicon Valley.

Even more remarkable, the institute's managers insist that anyone who comes up with a new idea for a research project can get a small pilot grant to show its promise. "If someone thinks up a new idea, the company will give him ¥1 million [about $8,000] for a budget," says general manager Takashi Nakagiri. "If it seems to be going well later, we'll put more people and a larger budget into it."

It all sounds like the lab that basic researchers dream of—but there is one surprise. Nakagiri insists that the institute's work is not basic research, an activity he considers fit only for universities. "We have a target for our research—future product technologies," he says. "Basic research, in our opinion, doesn't operate that way." In other words, Canon views its basic research facility as a logical extension of its $1.5 billion network of product development laboratories. But instead of focusing on work that will bring profits in the near term, Canon's managers are betting that an investment in the tens of millions of dollars will reap them corporate rewards much further down the road—like 10 or 15 years—in such markets as high-density computer memories or biodegradable plastics.

Welcome to the intriguing paradox of basic research in Japanese industry. Unlike the United States, where basic research flourishes in academia with federal support, Japan lacks a strong public infrastructure for fundamental research (see story, page 564). Stepping into the gap are Japan's major corporations, many of which have come to see building their own basic research as a necessary step in anticipating new technologies with commercial potential. Since 1985, just about every major electronics corporation in Japan has opened independent, and often somewhat freewheeling, facilities in the suburbs of Tokyo that are devoted to fundamental studies in materials, computing, electronics, and, oddly enough, biology.

Such a focus on fundamental studies might seem an unusual strategy for the Japanese electronics industry, given that its market is quickly saturating and its U.S. competitors are busy redirecting their own research programs toward applied work. But the managers of these laboratories are surprisingly upbeat despite the financial pressures that are bearing down on their corporate overseers. None of the lab managers contacted by *Science* reported having to cut back research operations—a fact most attributed to a consensus among top managers that company-sponsored basic R&D is the wave of the future. What's more, the investment seems to be paying off, at least in terms of the strength of the science these laboratories are producing. Not so clear is whether these investments will similarly benefit the corporate bottom line.

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Brainstorming. Seminar rooms at Canon's new basic research facility are specially designed to enhance creativity.

Open to the world?

Japanese corporations have historically held their laboratory work closely until new products were ready for release. But a quick look at the way basic R&D laboratories are run at Canon, Nippon Telegraph and Telephone (NTT), Hitachi, and NEC suggests that these companies, at least, run their new labs in a much more open manner. All four allow unrestricted publication of research results (although papers are first screened for possible patents) and frequently send their scientists to international conferences. All rate the performance of their researchers largely by assessing their scientific productivity. And all give their scientists a considerable degree of freedom in choosing their research topics within broad parameters set by company management. The end result is a research atmosphere that resembles that at U.S. universities.

Like Canon's Nakagiri, however, most managers of industrial labs don't have a lot of sympathy for such comparisons, and they especially dislike the notion that their facilities are havens for purely imaginative research. "To compare our work with the activities of universities—there's just no comparison," says Shojiro Asai, general manager of Hitachi's Advanced Research Laboratory (ARL) in Hatoyama. "We have confined our research activities around the periphery of our business activities." By letting their scientists pursue their curiosity within a broad research framework set by management, these officials say, they have tried to harness the innovative spirit of academia to their corporate goals.

Indeed, such a laboratory fusion of academic spirit and business aims—a cross between pure, curiosity-driven basic research and product-motivated applied research that some have dubbed "strategic" research—is fast becoming a necessity in high-tech industry, some company officials say. "There's a gradual change in the technological society in Japan," says Tatsuya Kimura, executive director of the NTT Basic Research Laboratories in Musashino. "Now we don't need technical improvements in manufacturing—what we need is technological innovation."

Echoing Kimura is Hiroyoshi Rangu, general manager of NEC's Tsukuba-based Fundamental Research Laboratories. "In the past, industry could do without basic research because we were innovative enough to improve products by trial and error," he says. "But now, for instance, we're pushing toward the atomic scale [in electronic devices], and to understand how electrons really behave at that level we must have a fundamental understanding of the science."

That kind of understanding, these managers argue, is best supplied by scientists working within the corporation—in effect, creat-

ing a kind of synergy between basic research and the more applied work of product development laboratories. Such ties are not now particularly close—NEC and Hitachi, for instance, set up their basic research labs as independent facilities largely in order to insulate them from the business pressures in the development laboratories. Now that the labs have begun to prove themselves, however, their managers are talking about tying their work more closely to that of the company. At Hitachi, for example, Asai says he's contemplating more joint projects with the development laboratories and talks of his researchers' "noblesse oblige" to spread the "flavor of the culture of this laboratory" by taking temporary assignments elsewhere in the company.

Industrial scientists in wonderland

The concept of "directed" basic research implies that someone must decide which fields are likely to hold the most promise for future product technologies. Company officials are a bit vague on how this is done. "First we set our management policy, then we do our research," says Canon's Nakagiri. But such "management policies" embrace work ranging from common-sense extrapolations of existing technology, like NTT's interest in optoelectronics for future use in communications and computer networks, to blue-sky research into the nervous systems of nematodes at NEC that officials hope will lead to new approaches in computational information processing. Within the laboratories, the result is a sometimes bewildering profusion of loosely related (and sometimes wholly unrelated) projects.

Many of them, of course, undeniably represent excellent science. Hitachi's ARL, for instance, is home to physicist Akira Tonomura, considered one of Japan's leading candidates for the Nobel Prize. Tonomura, who won acclaim for a 1986 experiment in which he used a coherent electron beam to verify an arcane prediction of quantum theory, has turned his attention to material studies. Having already obtained the world's first static "electron holographs" of the magnetic flux lines in superconductors (*Science*, 6 October 1989, p. 31), Tonomura now hopes to capture their dynamic behavior. If he succeeds, materials scientists would be in a much better position to introduce impurities into superconducting materials that can reliably "pin" the flux lines that disrupt superconductivity.

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Whiz kid. Hitachi's Akira Tonomura measures magnetic flux lines by electron holography.

Such potential applications are obviously of great interest to Hitachi, Tonomura admits. But he is quick to point out that his primary interest is in fundamental physics, and that Hitachi is equally generous in supporting his basic research. "In the old days, I had experienced some difficult times [obtaining approval for fundamental experiments]," he says. "Now that ARL has been established...this has become a very nice place to work. We are very active, and the company likes to support us."

Work with fewer near-term applications is also common. Take the Canon lab, which devotes some 10 to 15% of its effort to a "terabit memory project" aimed at producing computer memories sometime in the next 15 years that pack trillions of bits into a square centimeter. As one part of that effort, a team of physicists and chemists is exploring the peculiar electrical properties of an organic compound, known as "Langmuir-Blodgett" (LB) film, that can be electrically "switched" into "on" and "off" states suitable for memory storage. While the researchers have succeeded in using a scanning tunneling microscope to switch single molecules of LB film, they face some formidable obstacles in actually making high-density memory. For one thing, the films are tricky to produce and to handle; for another, there's no reliable way to use an STM to read and write memory bits over a large area. "It's very time-consuming," Canon chemist Otto Albrecht says of the STM work. "Just to test a terabit memory at a rate of one megabit per second would take us 2 weeks."

Riding the wave, or sitting on it?

Probably no one is watching the Japanese move into basic research more closely than the two U.S. electronics firms that have supported basic research for decades, but which are both now under pressure to move discoveries to the market more quickly. Surprisingly, however, at AT&T Bell Labs and IBM's Thomas J. Watson Research Center there is no clear consensus on whether Japan has caught the wave of the future.

At AT&T there is circumspect approval for Japanese efforts. "I think it's a good start, and it sends a message to U.S. industries that we need to keep up the efforts we've had," says Kumar Patel, an executive director at Bell Labs. "Any time you have your competitors start doing the kind of thing you've been doing for a while, it clearly helps reinforce your belief that you had some part of your program right."

But Frank Mayadas, an IBM vice president for research, argues that Japanese companies might be missing the point by trying to jump-start innovation by simply opening big, freestanding basic research labs. "If the Japanese are thinking about creating better links between the laboratory, product development, and product management, they're on the right track," he says. "For them simply to focus on building basic research instead of applied research is not." Mayadas argues that technological innovation doesn't really require dedicated basic research facilities, just a capability to capitalize on advances—not necessarily fundamental ones—as they arise. Those capabilities, he says, are just as readily available in applied research labs as in basic labs.

Competition in the electronics market seems likely to start settling this argument one way or the other in the next several years. Research managers with strong nerves might argue that one day Japanese companies will suddenly realize they've simply been pouring money away. But consider that over the past 15 years or so, Japanese electronics firms have demonstrated an uncanny ability to anticipate twists and turns in the market. That raises the disconcerting possibility that it will be Western companies who wake up one day and say: Why didn't we do that?

–David P. Hamilton

Major Basic Research Institutes in Japanese Electronics

Laboratory	Date Opened	Number of Researchers	Annual Budget	Fields of Research
Canon Research Center	1985	250*	N/A	Optoelectronics, advanced materials, biotechnology
Hitachi Advanced Research Laboratory	1985	114	$41m	Electron beam physics, software, molecular biology
NTT Basic Research Laboratories	1985	200	$25m	Quantum optics, computer science, materials
NEC Fundamental Research Laboratories	1989	100*	$35m*	Advanced materials, atomic manipulation, neurobiology

All budget figures calculated at $1 = ¥125.