training current staff—to handle the increased student load, as well as acclimating staff to a younger batch of students. Conversely, there's also the problem of how to cope with a temporary surplus of biology teachers, including some not certified to teach other subjects, as biology becomes an upper level course. "Professional development is the key, both for current and future teachers," says Rodger Bybee, head of the Center for Science and Math Education at the National Academy of Sciences and an adviser to ARISE. "And that costs money." Then there's the issue of elitism. Lederman remembers the reaction of 60 physics teachers during a workshop in which he outlined his proposal. "They gave me an ice-cold stare, as if to say, 'We don't do freshmen.' "

Instead of simply restacking the layers in the science cake, the SS&C project—spearheaded by former National Science Teachers Association (NSTA) executive director Bill Aldridge and separated into middle school and high school projects—set out to teach each of the disciplines every year with materials prepared ahead of time by the teachers themselves. But its fate illustrates the difficulties such reform efforts face. In 1996, officials at the National Science Foundation (NSF) pulled the plug on the high school portion of SS&C, which operated at 13 sites, after expressing concern about the quality of the materials. The project was halfway through its expected 4-year life. (Existing units are available online at no charge from NSTA at www.gsh.org/nsta/default.htm)

"What's so good about SS&C, in theory, is that it tried to break away from labels and create a genuine, spiraled approach," says NSTA's current executive director, Gerald Wheeler. "As a teacher, it meant I don't have to wait a whole year, while I'm doing physics, to bring up a concept in chemistry. That's closer to the real world." But Wheeler admits that SS&C failed to overcome enormous "logistical hurdles," from developing the material on time to retraining the staff to preparing students for year-end achievement tests. "You needed teachers certified in all four areas, which we didn't have at Fox Lane," says Eisenkraft. Although some schools used a rotating team of teachers to compensate for that lack of individual expertise, others say this approach disrupted the usual ties between students and teachers. And several schools have avoided integrating courses because of the risk that some students may not be adequately prepared for discipline-based tests.

Regardless of the content, any reform effort also must overcome the problem of assessing its impact on a complex and dynamic environment—what some evaluators compare to "changing the tires on a car as you're driving down the road." Aldridge has complained bitterly that NSF demanded a finished product after too short a time, and NSF program manager Wayne Sukow, who was closely involved in SS&C, admits that the impact of any major reforms is hard to gauge, at least in the short term. "You really need at least a generation of students—12 to 15 years—to study the impact of curriculum reform," says Sukow. "But it's tough to sustain interest for that long." Frances Lawrenz of the University of Minnesota, Minneapolis, concluded after a $400,000 evaluation of the SS&C's first 2 years that "it is certainly no worse than traditional science teaching." But she found "little evidence" that students had learned more or changed their attitude about science.

Old hands of school reform know how hard it is to bring about change. Shirley Malcom, head of education programs at the American Association for the Advancement of Science (which publishes *Science*) and an adviser to ARISE, thinks the project is promising "not because it's the truth and the light ... but because Leon's questioning the canon, and that's always healthy. I wish him luck, because he'll surely need all the help he can get."

—**JEFFREY MERVIS**

KOREA

Major Reforms Proposed to Improve Science Payoffs

Korea's current economic crisis highlights the need for changes to boost the return on its large investment in research

SEOUL, SOUTH KOREA—The new government of President Kim Dae Jung has begun a comprehensive reform of science and technology (S&T) policy aimed at creating what officials call a "technology-based advanced economy." The reforms are an effort to repair a system that, both scientists and government officials agree, suffers from bureaucratic infighting, a lack of incentives for quality research, and poor links between the academic and industrial sectors. "There are serious weaknesses" in the present policy, admits Kang Chang-Hee, a legislator who was appointed this spring as minister of science and technology.


KIST

Looking ahead. President Kim Dae Jung (right foreground) visits Korea's flagship Institute for Science and Technology.

The new policies are part of a broader effort by an opposition party that has finally taken power to restructure Korea's inefficient economy. The S&T changes include a new top-level body to coordinate R&D policy, a reorganization and possible streamlining of the government's 34 research institutes, a plan to create 10 or more science and technology universities, and a decision to extend dual citizenship to scientists and engineers as an inducement to return home after studying and working abroad. Efforts are also under way to reform hiring and promotion practices within institutes and to foster innovation with large grants for high-risk, high-payoff research.

The reforms are aimed at correcting a situation in which a heavy investment in R&D—sixth largest in the world in 1995—has yielded relatively low dividends. A recent international survey combining data and the responses of global business executives, for example, places Korea 28th in terms of S&T competitiveness. The previous government aggravated the problem by a continual churning of top officials, including five science ministers in 5 years.

The new government has promised to remedy this situation, preaching efficiency. In line with that approach, planners at the Ministry of Science and Technology (MOST), which Kang oversees, want to divide South Korea's 34 publicly funded research institutes and related projects into three categories, representing basic, applied, and social science research. (MOST currently operates 20 of the institutes, which range from the Korea Institute for Science and Technology, founded in 1965, to the 2-year-old Korea Institute for Advanced Study.) A proposal to replace each institute's board of directors and president with one board for each category is under "heated discussion," says Joon Eui-Jin, director-general of the ministry's Science and Technology cooperation bureau. Some see the reorganization as the first step in a weeding-out process.

MOST controls just 35% of the government's $2.5 billion R&D budget. (Industry funds the major part of the country's R&D.) The rest of the publicly funded research is divided among the other 15 ministries, which are forever squabbling about jurisdiction. The ministries of information and trade, for example, each want to control research on high-capacity computers. MOST vies with the defense ministry to control research on spy satellites. Another ministry spars with MOST over aeronautics. "Somebody should have an overall responsibility," says Joon.

That somebody will be President Kim, who will chair a new National Science and Technology Council to be created after the National Assembly opens in September. The council is seen as a forum for debate on overall science and technology policy, with the president as arbiter and MOST as administrator.

However, many observers are skeptical. "They're always rediscovering the wheel," says Han Moo Young, editor of the Internet-based Korean-American Science and Technology News (www.phy.duke.edu/~myhan/B_KASTN.html) and a physicist at Duke University. But "everything turns to dust" when it comes to implementation, he adds.

Internally, the institutes also need overhauling. Bad researchers aren't fired and good ones aren't rewarded, say Korean and Korean-American scientists who requested anonymity. Cronies are often chosen over qualified candidates for top positions, they add, and research proposals are sometimes judged by scientists from other fields. "Koreans never say 'I don't know.' You're supposed to know everything," says one scientist. The Science and Technology Policy Institute, a government-supported think tank, has recently adopted changes in hiring and promotion practices that are seen as a possible model for the country.

In the meantime, efforts are under way to strengthen the scientific infrastructure. Last year, for example, Korea began a $25 million Creative Research Initiative with large grants for what the government calls "very imaginative but highly uncertain" projects in fields ranging from genetics to nanofabrication.

To complement this investment in basic research, officials are considering a proposal to establish 10 to 15 new S&T universities. The 4-year programs would emulate Germany's dual system of awarding academic and professional degrees and England's "sandwich system" by allowing students to spend their sophomore year getting credit while working in industry. "The problem is the quality, not the quantity, of our graduates," says Kang. "It's very important to shorten the [skills] gap between what universities produce and what industry needs."

The government also plans to offer dual citizenship to ethnic Korean scientists now holding foreign citizenship. Lack of citizenship is a barrier for those seeking top positions at national institutes and universities. Kang hopes the new rules also will be a signal to domestic students planning to go overseas that they are always welcome to return.

Ironically, the economic crisis itself may be the biggest harbinger of reform. Although the government is increasing R&D spending relative to other programs, this year's overall budget was cut by about 13%, and industrial R&D is expected to drop by 16%. Even bigger cuts are in store if the banks need a massive recapitalization. If that happens, greater efficiency—the reformers' rallying cry—could also become the most important measure of success in trying to remake Korean science.

–MICHAEL BAKER

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STRUCTURAL BIOLOGY

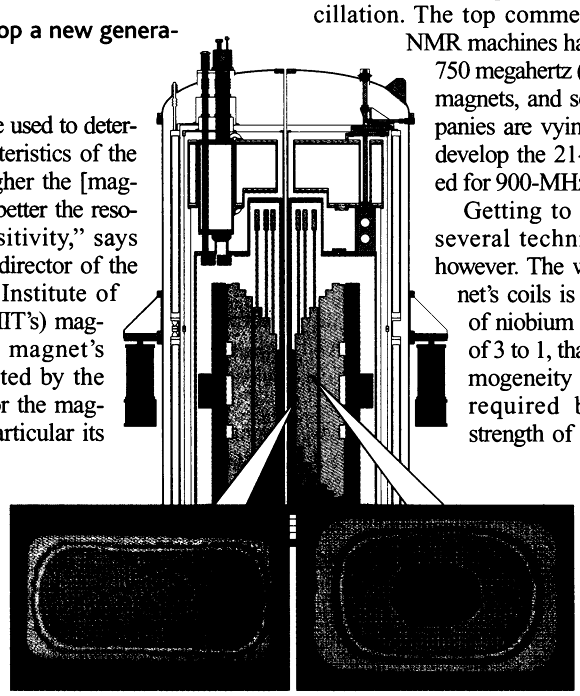
Race for Stronger Magnets Turns Into Marathon

Researchers are pushing magnet technology to develop a new generation of nuclear magnetic resonance (NMR) machines

TOKYO—U.S. spectroscopist Paul Ellis has developed a strong attachment to magnets. In 1994 his group at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington, ordered a superconducting magnet from Oxford Instruments in Britain for what will be the most powerful NMR spectrometer ever built. This superconducting magnet will generate a field of 21 tesla (T), more than 400,000 times stronger than the magnetic field of Earth and 20% more powerful than in the best commercially available NMR machines. The machine is now more than a year overdue, however, and won't be delivered for several more months. The delay reflects the challenges facing magnetmakers as scientists demand ever more powerful tools to explore molecular structures in unprecedented detail.

Magnets are the key element behind NMR spectroscopy, which makes use of the fact that a magnetic field can set some atomic nuclei wobbling like a spinning top. Changes in the wobbles caused by a second oscillating magnetic field can be used to determine the characteristics of the nuclei. "The higher the [magnetic] field, the better the resolution and sensitivity," says Robert Griffin, director of the Massachusetts Institute of Technology's (MIT's) magnet lab. But a magnet's strength is limited by the material used for the magnet's coils, in particular its current-carrying capacity and its ability to withstand the electromagnetic forces being generated.

Ellis's group, which studies the molecular structure of proteins produced by chemically damaged DNA, knew that their demands would require "a new level of magnet." But they also knew that the quest for greater resolution has fostered a steady upward march in magnet strength and field oscillation. The top commercially available NMR machines have frequencies of 750 megahertz (MHz) and 17.6-T magnets, and several other companies are vying with Oxford to develop the 21-T magnets needed for 900-MHz machines.



Core issues. New magnets being developed in Japan will rely on inner coils of niobium-aluminum or bismuth oxide *(left)* with outer coils of a niobium-tin alloy with tantalum core *(right)*.

NRIM, JAPAN

Getting to 900 MHz poses several technical challenges, however. The wire for the magnet's coils is made of an alloy of niobium and tin, in a ratio of 3 to 1, that provides the homogeneity and stable fields required by NMRs. The strength of the field depends on the current carried by the wires and the size of the coils. But the current-carrying capacity of a given material can itself be degraded by high magnetic fields. Although wire-