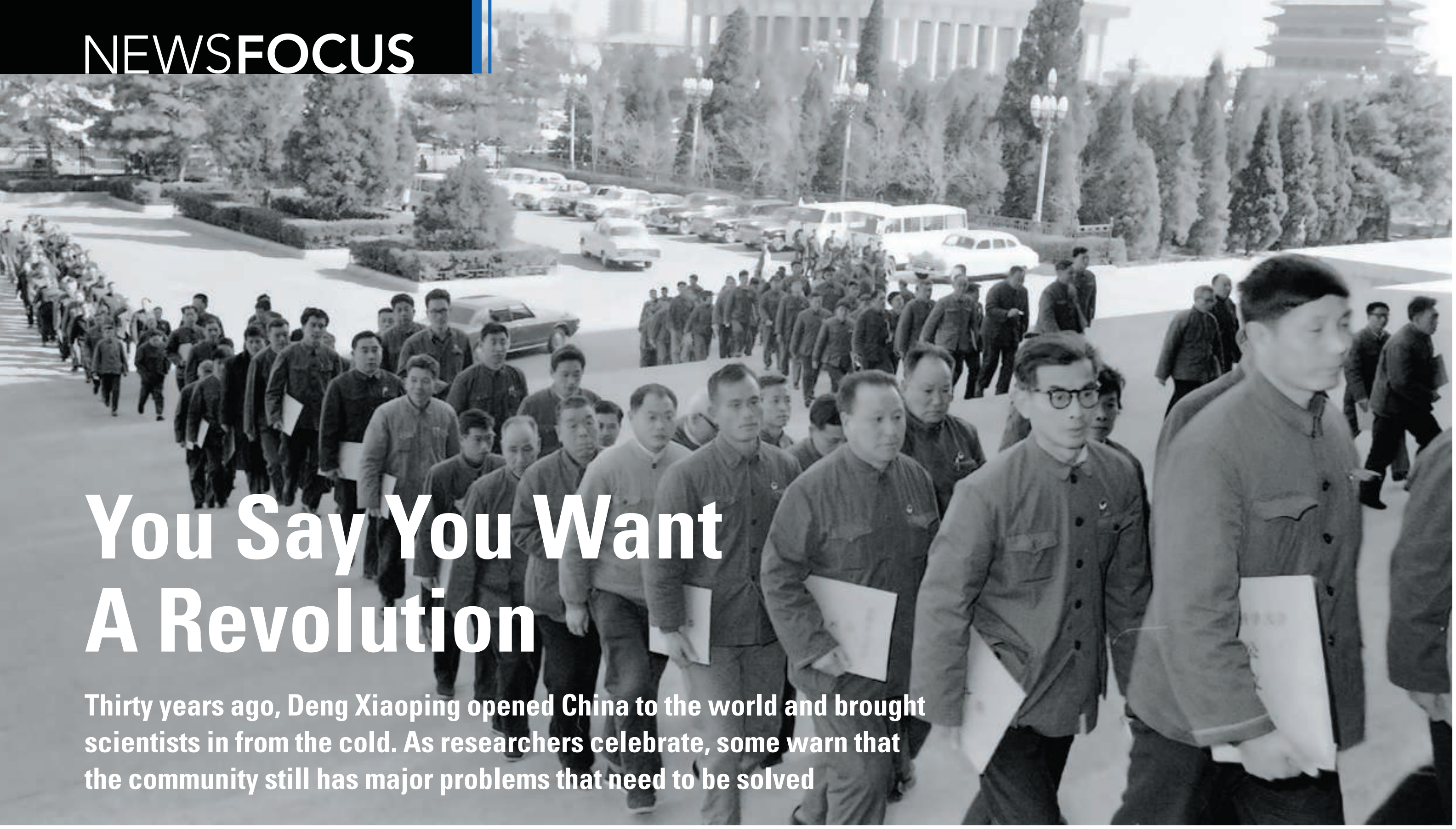

You Say You Want A Revolution

Thirty years ago, Deng Xiaoping opened China to the world and brought scientists in from the cold. As researchers celebrate, some warn that the community still has major problems that need to be solved

BEIJING—After Lu Yongxiang began a third term as president of the Chinese Academy of Sciences (CAS) last March, a TV talk show host asked the former varsity soccer player which question he would like to answer first: When can Chinese scientists win the Nobel Prize? Or when can the national men's soccer team win the World Cup?

In both cases, Lu responded, the challenges are similar. China's scientific community and its much-derided men's national soccer team must build stronger foundations. For a China-based scientist to win a Nobel Prize or the soccer team to win the World Cup, Lu said, both need more money, more talent, and an environment that encourages innovation.

In the 30 years since Deng Xiaoping and other leaders opened China to the outside world, China's science, like its economy, has grown immensely. According to the Organisation for Economic Co-Operation and Development's publication *Main Science and Technology Indicators 2008*, China's \$87 billion R&D expenditure in 2006, in purchasing power parity dollars, was higher than all countries except the United States and Japan, and only the United States has more researchers—1,387,882 compared with China's 1,223,756. Officials with China's Ministry of Science and Technology (MOST) like to point out that China is now second only to the United States in the number of publications in international journals.

But in many ways, China punches below its weight in science. "Our country has not made contributions proportionate with its overall strength," neuroscientist Rao Yi of Peking University and structural biologist Shi Yigong of Tsinghua University wrote in a recent editorial in the newspaper *Huanqiu Shibao*. They and others argue that China's rising R&D investments are being misspent on facilities and megaprojects that are driven by special interests, creating an illusion of grandeur rather than bringing China closer to the forefront of international research.

Also disturbing is that many Chinese scientists exhibit a surprising lack of curiosity, asserts Rao, who says he has endured "intellectual starvation" since returning to his homeland last year from Northwestern University's Feinberg School of Medicine in Chicago, Illinois. Although many scientists eagerly showcase their own work at conferences, Rao says, few discuss ideas informally or show up at seminars to listen to colleagues—interactions that inspire creativity in the West. "True collaborations are rare, and motivations for science are driven by temporary and relatively easy goals," he says.

Another damning assessment comes from theoretical physicist and former president of CAS Zhou Guangzhao. In China, he says, "success is often scored by quantity rather than quality." For that reason, Zhou contends, most Chinese scientists are content to follow well-trodden paths and churn out routine papers rather than strive for fundamental breakthroughs. Deference to status also makes it difficult for junior researchers to challenge academicians or science mandarins. That wasn't so in the 1950s and 1960s, when Zhou was working on China's atomic bomb project; then, he says, scientists treated one another as equals and worked collectively toward the goal of strengthening China. These days, many scientists say, there is greater freedom in society, but a market economy has made private interests the driving force of science, supplanting the idealism that inspired earlier generations of researchers.

Although public discussion about systemic problems in Chinese science runs up against censorship in state newspapers and TV—the government's voice—the blogosphere now provides a largely unfettered forum. "Blogs and the Internet as a whole are changing China's political discourse," says Cao Cong, a senior research associate at the Neil D. Levin Graduate Institute of International Relations and Commerce in New York City. Cao, a blogger on ScienceNet.cn, hopes that "positive and constructive opinions raised in the blogosphere" will receive official attention. This seems to be happening. Earlier this month, Chinese media reported that Premier Wen Jiabao, alerted by a journalist's blog about a cover-up of a disaster in Shanxi Province—where a mudslide caused by dumping mining waste killed more than 40 people in August—sent a team to

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On the march. Scientists arriving at the Great Hall of the People for the transformative "Spring of Science" conference.

investigate. Zhao Yan, editor-in-chief of ScienceNet.cn, hopes the site's 1400-plus bloggers may spark a bottom-up reform not just in matters of public safety and governance but also in science and technology, about which frank talk among peers is sorely needed.

A time of revival

China's reforms and opening up followed the decade-long turmoil known as the Great Proletarian Cultural Revolution launched by Mao Zedong in 1966. Seeking to rid the country of what he labeled as feudal, bourgeois, and foreign influences, Mao closed universities and banished professors to the countryside to work as peasants. Research was halted, except in areas that served national needs such as defense.

Careers like that of Chen Jia'er, a young physicist in the 1960s, were thrown into reverse. After 3 years as an exchange researcher in nuclear physics at the University of Oxford in the U.K., Chen returned home in 1966, hoping to build a heavy-ion research program. Instead, he was branded a "reactionary academic authority" and sent for reeducation to a village in eastern China, where he laid railroad tracks, raised pigs, and worked odd jobs for almost a decade.

Mao's death in 1976 and the subsequent purge of the coterie led by Mao's widow released China from its ideological straitjacket. One of the first reform steps Deng took was to rehabilitate scientists from a class to be "won over, reeducated, and transformed" to vital members of society whose knowledge and expertise would help modernize the country. Scientists such as Chen were brought in from the cold.

In a keynote speech at the first National Science and Technology Convention in Beijing in March 1978, Deng declared that "science and technology is a productive force." The "Spring of Science," as the founding and then–CAS president Guo Moruo poetically pronounced, had arrived. Many scientists recall that time fondly. It was "the turning point of my life," says Chen, who served as president of China's National Natural Science Foundation (NSFC) from 2000 to 2003.

Eager to learn. Some students of Peking University's first post–Cultural Revolution freshman class in 1978.

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Deng's call for modernization posed a daunting challenge. For some like Peking University biochemist Gu Xiaocheng, it meant racing to recoup lost ground. Gu had been one of the few professors permitted to remain in Beijing during the Cultural Revolution. She was part of a team that set out to synthesize insulin, a project considered in the national interest. They succeeded in 1965 and tried to determine insulin's crystal structure. But even for this elite group, "no international journals were available to us," Gu says. After the Cultural Revolution in the late 1970s, "when I saw *Science* again after so long, I thought, 'They're speaking a different language.' We really didn't know how to catch up."

Since then, China has worked to reform its R&D system, but these efforts have been top-down and often flawed, says He Zuoxiu of CAS's Institute of Theoretical Physics here. In the 1980s, then-Premier Zhao Ziyang wanted the marketplace to decide what research was needed and directed CAS to focus on applied research. The leadership "confused applied research with product development," He says, and the resulting tendency to ignore basic research has weakened the country's ability to innovate. Chinese leaders abandoned Mao's idea of self-reliance and expected the country to acquire advanced technologies from multinational companies in exchange for giving them market access. Zhao infamously told Chinese scientists in 1985 to "go up hills and pick peaches," reflecting his belief that China could simply reap the fruits of research done in other countries. But without accumulating one's own knowledge, says Chen, "it's impossible to have new ideas or really know how to apply them."

A second major reform came in the late 1990s, when "indigenous innovation" became a buzzword. Former president of China Jiang Zemin called on scientists to focus their efforts on national needs, "to do [research in some areas] and not to do [it in others]." In response, in 1998 Lu launched CAS's Knowledge Innovation Project (KIP). Under that banner, Lu reduced the number of CAS institutes from more than 100 to about 80 and its 80,000 work force to 48,000 (*Science*, 23 February 2001, p. 1477). The streamlining, Lu says, made institutes "more active and dynamic."

The innovation project achieved some positive results: "Our facilities were dilapidated before, but now many new buildings rival those at universities," says Wang Zhizhen of CAS's Institute of Biophysics here. The work force is much younger than it was a decade ago, and most researchers have studied abroad. Some institutes, especially newer ones, such as the Institute of Neuroscience established in 1999, compete at an international level, says Lu.

But for many older institutes, the drastic work-force reduction only looks good on paper. These institutes must use money allocated to a smaller payroll to support retirees and staff members not counted as KIP personnel. To accomplish this, institutes collect "head taxes" from principal investigators with grants to augment PIs' salaries, based on their productivity, and to pay junior researchers and grad students. Although basic salaries for PIs are fixed at several thousand dollars a year, productivity-based supplements can boost annual incomes to well over $30,000. For grad students, the basic stipend is about $500 a year; those lucky enough to receive supplemental pay may get an additional $3000.

Grants are golden because they provide the lion's share of productivity-based pay, even though many funders explicitly forbid using grant money this way. Institutes account for the payments as user fees, processing fees, or collaboration fees, according to several researchers who asked to remain anonymous to avoid retribution. These scientists estimate that about 10% of total grant money at well-funded institutions, and as much as 50% at poorer ones, is spent on salaries. As a result, some PIs go after grants beyond what's needed for research and outside their areas of expertise, says Zhao Zhongxian of the Institute of Physics here.

To combat this problem, Zhou says salaries should be capped and the portion

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from grants should not exceed 3 months' worth of PI pay, as many U.S. research universities stipulate. A few Chinese institutes have adopted this approach. The Institute of Physics, Zhao says, has changed its formula for productivity-based pay such that a PI's salary does not increase linearly with the amount of grant money.

Publications also contribute to a researcher's productivity-based pay. Institutes determine publication bonuses differently, but most take into account the impact factors of journals in which papers are published. CAS's Institute of Chemistry follows a typical formula in China: A paper in *Science* or *Nature* fetches \$2500 or more; a paper published in journals such as *Physical Review Letters* (*PRL*) and the *Journal of the American Chemical Society* (*JACS*) brings about \$1300; papers in journals with impact factors greater than three bring about \$500; and papers in journals with impact factors under three are awarded less than \$200. Bonuses are divvied according to the authors' contributions. Universities also pay productivity-based salaries to professors.

The Spring of Science conference was "the turning point of my life."

—CHEN JIA'ER, FORMER PRESIDENT, NSFC

A few institutes, including the Institute of Neuroscience, do not pay publication bonuses, whereas some, such as the Institute of Physics, have de-emphasized publication bonuses and only award several thousand dollars to papers published in four journals: *Science*, *Nature*, *PRL*, and *JACS*.

Quantity trumps quality

Both productivity-based pay and the way Chinese researchers are evaluated emphasize quantity over quality. This is partly because Chinese scientists are often fearful of giving offense if they critique a colleague's work truthfully, Zhao says. Instead, number-based evaluation is considered more objective and has gained popularity. To break the expectation of guaranteed employment regardless of performance—the "iron rice bowl"—Nanjing University in the early 1980s began to use the Science Citation Index (SCI) to measure the productivity of its professors. Since then, universities and research institutes have been ranked annually based on how many SCI papers they churn out. Science ministry grant applications often require PIs to state how many SCI papers they intend to publish, and researchers are promoted and occasionally demoted based on the number of their publications.

The top-performing one-third of CAS institutes has adopted a system of international review. For example, since 2003, the Institute of Genetics and Developmental Biology (IGDB) here has been using outside reviewers to evaluate PIs in its three main research areas. The institute invites a scientist from abroad to recruit a panel of reviewers for each area, says IGDB developmental biologist Zhang Jian. The panel anonymously reviews packages prepared by PIs and conducts a site visit to talk to scientists, research staff, and students. The visitors also give constructive comments to the lab under review. Reviews are conducted every 5 years; a few investigators have been forced out primarily because of the reviews, says Zhang.

Speaking out

To Xu Liangying, a retired science historian here, the root cause of the problem in China's scientific community is Deng's declaration 30 years ago of science and technology as a productive force, now an official mantra. Since then, the Chinese words for "science" and "technology" have been fused into "scitech," which in common usage solely connotes technology. In China, science is expected to contribute directly to economic development and not to the pursuit of truth and knowledge, asserts Xu.

Xu has always spoken his mind, even though it has cost him dearly. In the late 1950s, he was branded a "rightist" and banished to his ancestral village in Anhui Province. For more than 2 decades, Xu toiled in the fields during the day and translated the collected works of Einstein into Chinese during his spare time. After being allowed back into CAS in 1978, he became China's foremost Einstein scholar. He also took up the cause of human rights in China. Xu was put under house arrest for a time in 1989 after writing an open letter, and collecting signatures for it, that called on the Central Committee of the Communist Party to release political prisoners and allow freedom of speech. Last April, the American Physical Society awarded Xu the Andrei Sakharov Prize for a "lifetime's advocacy of truth, democracy, and human rights."

These days, speaking one's mind is not nearly as risky. Peking University's Rao was allowed to come back to China after he and others wrote an article in *Nature*'s China Supplement in 2004 that advocated stripping MOST of its power to administer research funds and making the ministry an advisory body. Rao says China needs an impartial science and technology board to advise the State Council on policy and funding priorities. The board, he says, should be made up of people free of institutional conflicts of interest, replacing an existing science and technology group under the premier that consists of ministers who inevitably want more money for their own ministries.

Theoretical physicist He Zuoxiu of CAS agrees and says MOST failed to curb institutional interest when it led the formulation of China's mid- to long-term science and technology plan. "The plan does not represent true national interest; it is a balancing act among interest cliques," says He. One of the plan's biggest flaws, he says, is its backing of "megaprojects" advocated by individual ministries and scientists (*Science*, 17 March 2006, p. 1548). Even though China needs to invest more heavily in renewable energy, an area critical for sustainable development, the plan hardly mentions it, He notes. Because the country's top leaders emphasize R&D for national needs, scientists often promote their own research as aligned with such needs, says Rao. Some use political clout and connections to designate their own projects or those of associates and friends as "top national priorities," he says.

Many researchers discuss such issues openly on ScienceNet.cn, a Web site that has been running for fewer than 2 years and boasts tens of thousands of readers per day. The site's bloggers do not hide behind pseudonyms, which sets it apart from most Internet forums and blog sites in China. "Scientists have no problem with using real names," says Zhao, "because they want to be responsible for what they say."

These bloggers call for systemic reforms to curb special interests in setting research priorities, to make the funding system more transparent and fair, and to liberate scientists from meaningless evaluations imposed by administrators. These cries for reform offer a glimpse of what could happen in the future, as a new generation that has prospered in Deng's reformed China pushes its way into the ranks and pressures science leaders to live up to their expectations.

–HAO XIN

With reporting by Richard Stone.

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