Research Report

China's New Scientific Elite: Distinguished Young Scientists, the Research Environment and Hopes for Chinese Science*

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The health of the scientific research enterprise in any country is critically dependent upon young scientists. In most fields, the period of greatest creativity and productivity comes early in a career. Young scientists hold together the generational structure of a country's scientific community by linking the established scientific elite with a rising generation of graduate students. They also play a critical role in maintaining the community's normative structure.

The generational structure of the scientific community in China is characterized by a major discontinuity. The years of the Cultural Revolution, from 1966 to 1976, seriously disrupted university education and postgraduate training. Thus, just as the new Deng Xiaoping-led regime began stressing the importance of scientific and technological development for China's modernization, China entered the post-Mao era in the late 1970s with a missing cohort of rising young scientists.

Recognizing the generational gap in the technical community, China's leaders set about re-establishing and reforming the system of higher education, and began to send large numbers of students and scholars abroad for advanced training and graduate education. Although only about one-third of the 380,000 who went abroad over the past 20 years have gone back to China,[1] those who have returned have come to play important roles in implementing the ambitious policies for scientific research and high technology development which have unfolded in the post-Mao period. Many of those who have stayed abroad have maintained, or re-established, ties with their home institutions in China as well. In addition, China's own reformed and revitalized system of higher education is now producing productive young scientists who are making contributions to the world's store of scientific knowledge. From these developments can be identified a new scientific elite, the members of which have leading roles in research, are playing a critical role in the training of new graduate students, and are beginning to lead scientific and educational institutions. In many ways, they embody the hopes China has for international greatness in science in the 21st century. But the realization of those hopes depends not only on this extraordinary pool of talent, but also on the conditions necessary for that talent to flourish. Of

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1. http://www.chinanews.com.cn/2001-08-20.

particular interest is how the norms and best practices of the world's leading centres of research, to which most members of the rising elite have been exposed, get transplanted to a research environment with values, practices and material conditions far removed from those centres.

This article examines the backgrounds, experiences and attitudes of China's rising scientific elite and explores how this new generation thinks about the conditions necessary for scientific distinction. It focuses on scientists who have received the Distinguished Young Scientist (DYS) award from the National Natural Science Foundation of China (NSFC), the country's main funding source for basic and "oriented-basic" (*ying-yong jichu*) research. Because NSFC is independent of the institutions of the awardees, the evaluation process for DYS recipients is freer from personal connections (*guanxi*), and is more robust and fairer than are institution-initiated programmes. This year, a one-month period was set for public challenges – on scientific merit – to a candidacy for an award.[2] The results of this national programme have been impressive; the DYS award is highly acclaimed and the awardees can thus be thought of as representing the best of China's young scientists and the core of the new scientific elite.[3]

The Establishment of the Distinguished Young Scientist Programme

Throughout the reform era, China has seen the ageing of a large percentage of its scientists and a serious brain drain among younger researchers. While special programmes exist to attract young scientists who are already abroad, those who are just receiving their degrees in China are faced with a lack of housing and adequate funding, and problems of keeping families united. They thus find the prospect of going abroad attractive if for no other reason than to qualify for the respect, housing subsidies, special research funds and salary increases which are available to young Chinese researchers who return (informants no. 35 and 39). Multinational companies, joint ventures and high-tech start-ups have also attracted young talent with lucrative pay and a promise of a bright professional future. It is against this background that the National Science Fund for Distinguished Young Scientists was set up in 1994 by NSFC to provide support for especially promising scientists under the age of 45.[4]

2. http://www.nsfc.gov.cn.

3. The paper is based on interviews with 52 DYS awardees conducted between October and December 1998 and May and August 1999 in Beijing, Shanghai, Hangzhou and Changsha. Several scientists from Wuhan, Guangzhou, Chengdu and Changsha were interviewed in Beijing. The interviews covered such questions as education background, mobility, foreign study, research and work experience, publications, academic exchange and communication, quality control in scientific research, and opinions toward various issues facing the Chinese scientific community.

4. In 1994, the first round of awards were made to 49 researchers from an appropriation of 35 million *yuan* ($4 million). Awards were made for a three-year period, with awardees in experimental and technological sciences getting 600,000 *yuan* ($72,000), with half that amount going to those engaged in theoretical research. On the occasion of the fund's fifth

Since its inception, the DYS programme has made awards to 710 young scientists out of some 3,000 applications received.[5] Award recipients have come from various Chinese regions, but those from Beijing, Shanghai, Jiangsu, Hubei, Guangdong, Shaanxi and Liaoning together account for more than three-quarters. They are affiliated with institutes of the Chinese Academy of Sciences (CAS), universities, research institutes under ministerial jurisdictions and military institutions. Between 1994 and 1998, only 22 of the 426 awards have gone to women.

DYS recipients have already distinguished themselves in a variety of ways. Life scientists Chen Zhu, Wang Zhixin, Pei Gang and Zhang Qifa, and chemists Bai Chunli and Li Jinghai have been elected CAS members (*yuanshi*, or academicians), while biochemist Liu Depei has become a member of the Chinese Academy of Engineering (CAE). Of the 287 Cheung Kong Scholars appointed by the Ministry of Education (MOE), 144 are DYS awardees; biochemist Chen Zhu won first prize in the Cheung Kong Scholar Achievement competition. Four of the first 15 projects of the State Key Basic Research and Development Programme administered by the Ministry of Science and Technology (MOST) have been led by DYS awardees (Chen Zhu for a study of the genetic basis of disease, Zhang Qifa for crop germplasm, Yan Chunhua for rare-earth materials, and Gao Xiaoshan for theory and software in information technology), and additional DYS awardees have become chief scientists of other projects in this national science programme.

Education and Career Mobility of DYS Recipients

Award recipients range from 29 to 45 years in age.[6] Those interviewed had an average age of 38, with the youngest being 32, and had worked in their respective fields for seven years (14 years after graduating from college).

Educational experience. Nine of the 52 interviewees were "worker-peasant-soldier students" (*gongnongbing xueyuan*), the group of college students who were admitted to university between 1972 and 1977 based mainly on recommendations from their work units, or *danwei*, and who usually studied for only three years. Among these, one went to graduate school before completing undergraduate study and eventually received his Ph.D. from the Massachusetts Institute of Technology (MIT). Most of

footnote continued

anniversary, and in recognition of its achievements, Premier Zhu Rongji approved a significant increase in the DYS budget, from 70 million *yuan* ($8.4 million) in 1998 to 180 million *yuan* ($21.7 million) starting from 1999. The grant tenure has also been extended to four years, with funding for experimental and theoretical research increased to 800,000 *yuan* ($96,000) and 550,000 *yuan* ($66,000) respectively. Interview with an NSFC official (Beijing, 16 July 1999); *Renmin ribao* (*People's Daily*) (Overseas edition), 4 December 1999, p. 1.

5. Because of the lack of information on the 1999 and 2000 cohorts, the paper will focus on the 426 young scientists who received awards between 1994 and 1998.

6. *Guojia ziran kexue jijin weiyuanhui jianbao* (*Brief Report of the National Natural Science Foundation of China*), Nos. 5 and 6 (Beijing: NSFC Office, 22 June 1999).

the other interviewees had regular undergraduate education, but two did not: one was admitted into graduate school after studying for an associate degree and the other attended television university.[7] Four of the *gongnongbing xueyuan* interviewed who did not have doctoral degrees earned masters degrees from Chinese medical schools and then spent several years abroad on post-doctoral fellowships (two at the National Institutes of Health (NIH), one at the International Cancer Research Centre of the World Health Organization in France and later at the National Toxicology Center at Little Rock, Arkansas, and one in various research settings, including New York University and NIH).

Of the 48 interviewees with doctorates, the largest number had received them in China (30), followed by the United States (6), England (5), Japan, Germany and France (2 each) and Sweden (1). As a whole, 399 DYS awardees (93.7 per cent) have doctoral degrees, of whom 242 (60.7 per cent) obtained the degrees in China.[8]

International exposure. The awardees are not strangers to the world outside China. As one interviewee pointed out, it is not easy for someone who has never been abroad "… to go this far" (informant no. 14), although 12 interviewees had no foreign experience other than short visits and professional conferences. In addition to those who studied abroad for their doctorates, awardees with Chinese doctorates were likely to have gone abroad as post-doctoral fellows.[9] On average, the interviewees had 4.7 years of foreign study, research, and work experience; seven spent 10 years or more abroad, and five less than one year. The United States, Germany and England were the top three destinations for young scientists, followed by Japan, France and Canada.

Respondents indicated that through studying and working abroad, they gained useful perspectives on research which affect what they bring to their work in China, including an appreciation of what is involved in doing research at the frontiers of science, and the importance of networking with foreign scientists. Going abroad was also seen as advantageous for offsetting some of the drawbacks of academic inbreeding, for having new and different life experiences, improving foreign languages, making money and, as noted above, getting the attention and resources to have such problems as housing solved upon returning (informants no. 12, 32, 35 and 45). Interviewees therefore encourage and help their students to obtain such an experience. Recognizing the benefits from learning and doing science abroad, CAS intends to start an overseas sabbatical system for rising academic leaders around the age of 40 (informant no. 22).

7. The average age of the *gongnongbing xueyuan* at graduation was just slightly higher than that of other interviewees (24.13 verses 23.38 years old) as a result of the fact that *gongnongbing* usually worked several years before entering college.

8. *Brief Report of the National Natural Science Foundation of China*, Nos. 5 and 6.

9. Bai Chunli, for instance, became the first Chinese scientist to spend time at the Jet Propulsion Lab since aerodynamicist Qian Xuesen was forced to give up his position there in the 1950s for security reasons. Wang Zhixin spent three years at Cornell and North Dakota State Universities. Li Jinghai conducted research at the City University of New York, and Liu Depei at the University of California, San Francisco.

Job mobility. Most of the interviewees hold a senior professional rank (such as full professorship) at Chinese universities and research institutes, achieving these positions, on average, in slightly more than five years, a period shorter than that needed by foreign scientists to achieve tenure.

Until recently, Chinese have not been able to choose and change their jobs unless arranged by the government, and scientists were no exception. Of the 30 interviewees who received their doctorates in China, 23 stayed on to make a career at their degree-granting institutions. Three medical researchers returned to their alma mater after getting their MD's elsewhere. Of those with foreign doctorates, seven chose to return to the institutions where they received their bachelor's degrees (two changed their *danwei* later), another two went to the institutions to which they were attached before they left for abroad. Only ten with foreign doctorates settled down at institutions with which they had had no previous connection.

Opportunities for changing jobs have become more numerous, however, and offer the prospect for greater job satisfaction and professional performance. Thus, when the needs of young scientists are not given enough attention by the leaders of their work units, they are inclined to leave for another *danwei*. A computer scientist hinted that he would rather go to a Singapore university or apply for a Cheung Kong Scholar position at another university (informant no. 51). Another interviewee mentioned that a fellow DYS awardee left his university for a CAS institute (informant no. 15). A pharmacologist who moved from the same university to another university said that he transferred because he was asked to set up a new research institute (informant no. 26). But probably the underlying story for changing work units is the level of job satisfaction. With Chinese institutions of higher education and research now actively seeking young talent, they can't afford to lose new recruits by creating the impression that they are doing a bad job in their treatment of young scientists.

Importance of foreign doctorates. The Chinese scientific community claims to be moving towards judging scientists on merit, instead of simply where they have received their degrees. Whether doctorates from China (*tuboshi*) and those from foreign countries (*yangboshi*) were being treated equally was, thus, of considerable interest to the interviewees. Although one *tuboshi* had an excellent working environment, he indicated that only those who had foreign experience could expect a notable rise in status (informant no. 24). In general, *yangboshi* were seen as enjoying more opportunities for lab space, instruments, students, funding and promotion (informant no. 49). But the interviewees agreed that there was a need for preferential policies toward *yangboshi* to help them settle down and give them seed money for research.

Again, it should be recalled that almost all the DYS awardees have foreign experience, and that such initiatives as the Hundred Talent Programme (*bairen jihua*) at CAS and the Cheung Kong Scholar Programme at MOE also target those who have been abroad. Many attributed this bias towards those with foreign experience to the higher standards and strict training of foreign graduate education. One life scientist with a Chinese doctorate, but who had also spent a couple of years in the United States before getting his Chinese degree, conceded that compared with *yangboshi*, *tuboshi* have gaps in scientific thinking and lack the contacts in the international scientific community which would make a difference in the long run (informant no. 23). Another life scientist with a Chinese doctorate shared the same view. Realizing the importance of foreign research experience, *tuboshi* have tried to take off their "*tu*" caps through foreign post-doctoral research, and this is becoming a routine career path for *tuboshi*. On the other hand, a lack of a research base and mentors in China are a minus for *yangboshi*. They often have to start from scratch when they return, and get less support from senior scientists. Thus, they tend to make slower progress initially (informants no. 26, 31, 32 and 44).

Launching Successful Research Programmes

These prominent young scientists earned their reputations through cutting-edge work which has been recognized nationally, if not internationally. To function at this level of performance, they have had to build research teams, bring in money for research, decide what to do and how to do it in a relatively autonomous setting, publish their findings, and communicate with colleagues at home and abroad. Because their time is limited, scientists do not want to be involved too much in administrative and social activities, but find that such involvement is both inevitable and necessary in the life of Chinese science.

Research teams of the interviewees varied in size, depending on whether the work is of a theoretical or experimental nature. On average, they had ten members. Running a research team is a more complicated chore in China than in more scientifically advanced countries. A team leader is responsible not only for obtaining funding, recruiting staff and seeing to the conduct of research, but also for wrestling with various peripheral issues. A cancer research lab chief, for example, described the extra-scientific side of being a team leader as involving a responsibility for the "eating, drinking, defecating and urinating" (*chi, he, la, sha*) of the team's members (informant no. 7). At the same time, a team leader's authority for hiring qualified personnel, and firing the unqualified, is somewhat limited.

In addition to support from the DYS programme, the interviewees have also received grants from other NSFC programmes, the 863 High-Tech Development Programme, and from ministerial and regional sources. They have witnessed the gradual improvement and maturation of China's science funding system, including its increased reliance on peer review mechanisms, and they are generally happy with the way they have been treated by fellow members of the scientific community. One biologist indicated that as long as evaluations are conducted fairly, he can get the grants he applies for (informant no. 1). Almost all praised the peer review process of NSFC, especially that for the general (*mianshang*) projects which are fair to young scientists, are based on merit, and don't involve institutional consideration (and politicking) in determining who should get awards. But interviewees also expressed dissatisfaction with funding practices in other programmes. NSFC's key (*zhongdian*) and major (*zhongda*) programmes, which make larger awards, were seen as relying too much on the reputation of the prospective principal investigators, rather than on the intrinsic merits of a proposal, in making decisions. Famous senior scientists, *yuanshi* in most instances, were seen as having inappropriate influence in recommending the types of projects which should be included in the guidelines for proposals. This influence, reportedly, allowed them to secure funding for themselves, and/or their own research teams, or for others in their work units (informants no. 13, 16 and 20).

During the three-year period for which there are accurate data (1996–98), young scientists had received an average of 1.55 million *yuan* ($187,000) for their research from all sources. In some cases, scientists received significant support from industry because of the technological implications of their work. For example, a mining expert had received 1 million *yuan* annually for a number of years (informant no. 40), and a petroleum scientist reported that he had never worried about money for his research (informant no. 41).

Some respondents complained that current levels of DYS funding could only meet part of their research needs. For example, one geophysicist indicated that the DYS grant was only enough for data processing (informant no. 30). Major instrument purchases could not be made out of the DYS awards. Young scientists also noted that they have to spend part of their grants on rent, utility bills and stipends for graduate students, among other things. Overhead charges, of course, are not unusual in international practice, but given the size of the grants made to Chinese scientists, overhead becomes significant.[10]

In a country where resources are scarce and egalitarian norms still prevail, with the DYS awards being as generous as they are (600,000 *yuan*), its awardees were sometimes asked not to apply for other funds, or have had a hard time securing money for other sources even if merit warranted such opportunities (informant no. 31). A zoologist received an award from another special fund for young scientists run by NSFC which was to last for three years. But when he was awarded the DYS grant, he lost the third-year funding from the original grant (informant no. 39).

In addition to money, support from researcher's work unit, referred to as "the requirement for a 'local environment' (*xiao huanjing*)," seems to be necessary and more important for the smooth implementation of

10. Complaints from scientists about the inappropriateness of grant procedures, as they apply to overhead charges, have led to some changes recently, as reflected in the regulations for the State Key Basic Research and Development Programme issued by MOST. Chat with a cancer researcher (Washington, D.C., 4 September 1999).

research programmes. The strikingly different treatments of two cancer researchers when they returned from abroad illustrates the importance of *danwei* support for this "local environment." The first individual received his doctorate from a Japanese university and intended to work at a research institute in Beijing instead of returning to his original unit. But, the latter was able to attract him back with an offer of excellent research conditions – exceeding those of his advisor's lab in Japan. These included an initial research budget of 5 million *yuan* ($600,000), a research group of a dozen researchers, more than 40 medical doctors and other staff, and 90 hospital beds for clinical research. With this kind of support, he has been able to develop several promising anti-cancer drugs using genetic engineering techniques (informant no. 10). By contrast, when the second young scientist returned to his alma mater upon finishing post-doctoral research in the United States, he was denied work space for three months until the State Education Commission (the predecessor of MOE) and the Ministry of Personnel intervened. Even after he received several grants from NSFC, he still was not given the facilities he needed (informant no. 11). Different institutional treatment, thus, affects the career chances of young scientists; those with an excellent "local environment" get advantages in competing for resources which, in turn, will affect research achievement (informant no. 31).

Having scholarly visits abroad is important if young scientists are to keep up with trends in international research. Although the growing use of the Internet and greater availability of other forms of telecommunications make it easier for scientists to get quick access to information for their research, Chinese science still faces the difficulty of not having timely access to important international science journals. As a result, returnees worry that they will fall behind if they do not have regular contact with their foreign peers (informant no. 32). For them, visiting the institutions where they had studied not only reinforces relationships with their mentors and former colleagues and classmates, but it also permits direct observations of what the latter are doing. Young scientists value such opportunities very much, and try to visit abroad or attend professional conferences at least once a year.

In addition to keeping abreast of information about foreign research, visits abroad have other benefits. For example, after spending six months visiting American laboratories, one biochemist came to realize the importance of attracting and recruiting high-quality students and intends to do so rigorously in his lab (informant no. 20). At the same time, not all young scientists want to go abroad. One biophysicist who got his Ph.D. from Germany indicated that when visiting foreign colleagues abroad, it is inevitable that the results of one's research will be shared with foreign scientists with whom one may be in competition. At certain points in the course of research, in this view, it would be better to stay home (informant no. 3). This attitude was also expressed by another biochemist with a Chinese doctorate (informant no. 24).

Attitudes towards Publication

Publishing is central to the life of science. Through publications, scientists communicate their research results with peers and identify themselves as active members of the scientific community. Collectively, scientific publications from a country reflect the strength of scientific research of that country, and its contribution to the world scientific community.[11]

Publication – including where, and in which language to publish – has become an important concern for scientists in China. Despite reporting significant findings, papers published in Chinese journals usually have a smaller readership since few foreign scientists understand the language. Thus, in order for research to be known to the world scientific community, many Chinese scientists feel they should publish in English, in international journals. This is a position which has been promoted by a number of eminent senior scientists in particular. For Zou Chenglu, a Cambridge-trained biochemist and a CAS member who is now in his 70s, Chinese scientists are obliged to participate in international scientific publication activities so as to claim a position in international science. Zou has taken the issue so seriously that he has used the impact factor of journals measured by the *Science Citation Index* (*SCI*), the citation database compiled by the Institute for Scientific Information (ISI) in Philadelphia, as the benchmark to judge the performance of Chinese life scientists.[12] He regularly encourages his colleagues and students to devote their energies to producing high-impact-factor papers (informant no. 3). Those who oppose using *SCI* papers to measure scientific production cite such reasons as an alleged bias of *SCI* against Chinese journals,[13] and the questionable appropriateness of using it to rank individual scientists and institutions. In addition, the question of where to publish has become entwined with Chinese nationalism, and the publication patterns of scientists are taken by some as a measure of patriotism (informant no. 44). Disagreements about the importance of publications are also evident among young scientists.

But publishing papers in international journals or at least in those Chinese journals included in *SCI* has become a priority for young scientists. They indicated that international journals are like a stage and

11. W. Wayt Gibbs, "Lost science in the Third World," *Scientific American*, Vol. 273, No. 2 (August 1995), pp. 92–99; Robert M. May, "The scientific wealth of nations," *Science*, Vol. 275 (7 February 1997), pp. 793–96; Svein Kyvik and Ingvild M. Larsen, "The exchange of knowledge: a small country in the international research community," *Science Communication*, Vol. 18, No. 3 (March 1997), pp. 238–264.

12. Foreign scientists just do not quite understand why *SCI* publications and their impact factor are so emphasized in China. During an international symposium held in Beijing, a Stanford biologist criticized China's pursuit of *SCI* papers by pointing out that Stanford does not use *SCI* papers in the faculty promotion. A Chinese biochemist commented that while publications by Stanford scientists are in all *SCI* journals, for Chinese scientists, the difference lies in how many have *SCI* publications (informant no. 42).

13. In 1996 *SCI* included only nine journals published in China in its database. Wang Pingxian, "Cong chubanwu kan Zhongguo de diqiu kexue" ("Publications and Chinese earth science"), *Zhongguo diqiu kexue fazhan zhanlüe de luogan wenti* (*On the Developmental Strategy of Chinese Earth Science*) (Beijing: Kexue chubanshe, 1998), pp. 64–77.

Chinese scientists should perform on it, Chinese scientists have to represent China to make statements, which is not an individual's behaviour, but a national behaviour (informant no. 3), and publishing internationally has nothing do with patriotism, it could raise the level of scientific research in China (informant no. 30). They also praised the fact that peer review in international journals creates a desirable exchange between reviewers and authors, and scientists could raise the quality of their papers as well as their research through the submission, revision and publication process (informant no. 18).

During the three years surveyed, those interviewed had published an average of 15.42 papers (conference presentations are not included). Of these, about 30 per cent have appeared in international journals in languages other than Chinese.

The young scientists have tried to practise what they have been preaching. A biochemist has published 26 *SCI* papers with the impact factor of 2.0 or higher (informant no. 21). A biophysicist from Zou Chenglu's Institute was proud of having published two papers in journals with impact factors of 4 and 7 respectively (informant no. 3). Another biochemist who received his doctorate from Cambridge University and then spent his post-doctoral years in Harvard and Yale Universities insisted that except for reviews, he has never published in Chinese. When he did reviews, he chose only high-quality journals, that is, those included in *SCI* (informant no. 26). Those with significant international publication records know that what really matters in the peer review process is the research itself (informant no. 23), and they do not perceive language to be a significant barrier.

Not all DYS receipts have international publications. Some claimed to be too busy to publish abroad (informant no. 40), or too pressed by other business to prepare for international submission (informants no. 36 and 51). Out of concern for the protection of intellectual property rights, an agricultural biologist concealed his research from international publications (informant no. 31), while a mechanical engineer was too busy working on a prototype machine to publish, in Chinese or in English (informant no. 47). In general, it is difficult for engineers and those working on technology to publish abroad (informant no. 29).

Some returnees claimed that to be visible to their colleagues, and to establish their positions in the scientific circles of China, they have to publish in Chinese journals (informant no. 50). Yet their choices are *Zhongguo kexue* (*Science in China*) (the impact factor is around 0.3) and *Kexue tongbao* (*Science Bulletin*) (informant no. 34). The decision to publish in Chinese journals also reflected the gap between research conducted by Chinese and foreign scientists (informant no. 52).

Other returnees, especially experimental scientists, claimed that the processes of setting up laboratories, purchasing necessary instruments, recruiting students and applying for grants, kept them from publishing (informants no. 7, 8, 14, 15, 37 and 50). They felt that they needed a couple of years to adjust to the Chinese environment, but they foresaw a productive future.

Leadership Roles

Because of the generational gap in the Chinese scientific community noted at the outset, young scientists have had to shoulder significant administrative as well as research responsibilities. Among the 52 interviewees, 21 had assumed administrative positions (university vice-president, associate dean, department chair, director and deputy director of research institutes).[14] Several DYS awardees have also been elected deputies to the National People's Congress (NPC) or members of the Chinese People's Political Consultative Conference (CPPCC). Their inclusion into the nation's political process is not necessarily one of their own choosing, and the significance of these roles remains to be seen. Apart from the requirement that they attend annual sessions, such political involvement does provide opportunities to participate in the development of legislation and to perform consulting and advisory work, as requested by the Party.

Young scientists have tried to exploit the authority they possess by pushing for reforms which fall within their jurisdiction. The case of Yuan Yaxiang, a 1994 DYS awardee, is instructive. In 1988, Yuan returned to the CAS Computation Centre upon finishing his doctoral study and research at Cambridge University. Seven years later, he was appointed executive deputy director of the CAS Institute of Computational Mathematics and Scientific and Engineering Computation, a successor to the Computation Centre. In that position, Yuan initiated reforms to eliminate the social service burdens – such as the shuttle buses, clinics and dining halls – which have been so characteristic of (and consume so many resources in) the typical Chinese *danwei*.[15]

Similarly, a director of an institute of materia medica (*yaowu yanjiusuo*) used his position to introduce a bonus system which linked compensation for research groups to performance as measured by research grants secured and papers published (informant no. 33). As department chair at a prestigious polytechnic university, an engineering thermophysicist initiated reforms to involve members of the department in the administration of departmental affairs (informant no. 16). Since his promotion to CAS vice-president, physical chemist Bai Chunli has come up with many innovative ideas to strengthen the Academy. He helped set up scholarship programmes at prestigious Chinese universities as a way to lure their graduates to join CAS and has advocated special arrangements for spouses, and for the education of children, as part of a strategy to attract promising young scientists back from abroad. Bai also maintains contacts with young scientists in order to learn more about their concerns (informant no. 44).

Those who have already assumed leadership positions in important national research programmes have advocated the involvement of more young scientists in them. A cancer research project which is part of the

14. We have noticed from news reports that additional interviewees got promoted recently.

15. Zeng Defeng, *Zhongguo shui lai duo Nuobei'er Jiang* (*Who is Going to Win a Nobel Prize for China*) (Beijing: Zhongguo qingnian chubanshe, 1998), pp. 73–75.

State Key Basic Research and Development Programme is led by a five-person expert panel, only one of whom is over 45 years old. Chen Zhu, the chief scientist of the genetic disease project under the same programme, is to use the impact factor of publications of the participants as a filter to select who should participate in the next round of the project: publishing at least one paper with an impact factor of 5 or above will be required.[16] Using her position as an NPC deputy, a cancer researcher has worked with fellow "scientist deputies" to lobby for more funding for basic research (informant no. 12).

Having bright young scientists in leadership positions is an important asset for Chinese scientific and technological development, and also gives young scientists an opportunity to get access to useful information of relevance to major national policy issues (informants no. 48 and 50). An environmental scientist who is an NPC deputy found that it was much easier to gain access to important information during study tours he made to inspect environmental problems (informant no. 6). Another NPC deputy felt that the ideas of young scientists actually carried little weight in policy discussions (informant no. 50).

Of course, involvement in administration can also be costly in terms of lost time. Administrators find that they have to spend a lot of time balancing "relationships" (*guanxi*) among colleagues (informant no. 46). The materia medica institute director mentioned above has only an hour a day for talking to his students (informant no. 33); a university vice-president found that with more than 90 per cent of his time going to administration, his only opportunities for research or for advising graduate students had to come at night or at weekends (informant no. 48); two deputy directors at CAS were unable to find any time for research during the day (informants no. 36 and 39), while other respondents reported that it was impossible to maintain continuity in their research (informant no. 4). Such cases point to the problem of losing research contributions from young scientists who are supposed to be at the peak of their research careers; for some, having a high-level administrative position does not compensate for this loss.

The ambivalence towards administrative and political appointments reflected in the discussion above is further complicated by organizational realities in China. It is still the Party leadership which decides who should be a department chair, an institute director or a deputy to the NPC. In some cases prospective appointees were not consulted before their appointments were announced (informants no. 43 and 45). On the other hand, the pervasive bureaucratism of many aspects of Chinese society, and the traditions of official prerogatives rooted in the Confucian past, makes the holding of political and administrative positions appealing for ambitious young scientists:

In China only those occupying the right position have information and resource access. For example, NSFC's review panel is full of administrators; the nation's

16. About 50% of life science papers are published in journals of the impact factor of less than 1, 80% in those of the impact factor of less than 2, while only 1% in those of the impact factor of 5 or higher. Chat with a cancer researcher (Beijing, 23 June 1999).

science programmes appoint administrators to be in charge. The orientation towards those in administrative positions confuses young scientists. On one hand, they do not want to be administrators too early; on the other hand, a scientist is not great unless he is in the leading position, (a fact) which has forced some young talent to depart from research. As a result of the kind of official fetishism, some young scientists are keen on seeking personal gain through becoming (a) semi-scientist, semi-politician and being involved in these quasi-political activities. That is the unfortunate side of Chinese science (informant no. 42).

Young scientists who succumb to such temptations are sometimes regarded by their peers as lacking the right professional values (informant no. 13), but overall, the question of taking on administrative and political positions, with the various costs and benefits involved, appears to be a matter causing some confusion among the younger generation of scientists (informant no. 39). In a 1999 get-together, DYS awardees in the life sciences reached the conclusion that for the sake of their own research and administrative effectiveness, they should not rush to become administrators (informants no. 42 and 43).

Expectations for the Chinese Research Environment

In a letter to *Science*, commenting on a guest editorial on China's new emphasis on basic research written by then Minister for Science and Technology, Zhu Lilan, MIT bioscientist Zhang Shuguang suggested that:

In order to ensure the continued success of science and technology development in China, and to move at an accelerating pace, scientists must (i) be free of political interference and top-down interference from management; (ii) be free to access information on the Internet; (iii) have no charges for Internet access (especially students); (iv) have easy access to the latest research journals and books (especially young researchers and students); (v) have freedom of selection of research projects; (vi) have a system of merit-based promotion and funding, not promotion based on seniority or political connections; (vii) have generous provision of state-of-the-art equipment and training; (viii) have rapid provision of necessary materials for research; and (ix) have free exchange of ideas, so as to attract other researchers to form productive collaboration.[17]

While there is room for improvement in all of these areas, more progress has clearly been made on some than on others. Considerable improvement is evident in conditions (ii), (iv), (v) and (vi), and gradual progress is being made on conditions (iii) and (vii), but conditions (i) and (ix) remain troublesome.

National programmes. Young scientists see problems with top-down interference in science in some of China's major national research projects, such as the 863 High-Tech Development Programme and the

17. Shuguang Zhang, "Basic research in China" (letter to Editor), *Science*, Vol. 283 (19 March, 1999), pp. 1850–51.

State Key Basic Research and Development Programme.[18] The latter was a response to the arguments from leading members of the Chinese scientific community that more attention be given to basic science. During the 1997 annual sessions of NPC and CPPCC, scientist-deputies to these two national assemblies again called on the government to invest in basic research for the long-term good of the country. Begun in 1998, the State Key Basic Research and Development Programme was placed under the leadership of MOST, a move questioned by some young scientists who believed that MOST's record in directing national science programmes was not as strong as it might be. The 863 Programme, for instance, was seen by some as not yielding achievements commensurate with the amount of funding it had received. Many young scientists would rather see funds for the State Key Basic Research and Development Programme controlled by the NSFC, which, with its more than ten-year experience in administering basic research funding through peer review, would be a more effective administrative agency for the programme. They also felt that the State Key Basic Research and Development Programme, in spite of its name, was really not a national programme in basic research, but was instead designed to address national needs in agriculture, natural resources, information, environment, genetic research and materials as defined by the state (informant no. 28). And despite its high profile and expectations, the funding for the programme – when it reaches the level of sub-projects – is not significantly more than NSFC general (*mianshang*) projects (informants no. 16 and 39).

The Nobel Prize issue. Included in the thinking behind the State Key Basic Research and Development Programme was the hope that a major basic research project of this sort, along with the CAS Knowledge Innovation Initiative, and the MOE Cheung Kong Scholar Programme, would lead to a Nobel Prize for a Chinese scientist in the early 21st century.[19] Reportedly, then NSFC Director Zhang Cunhao, CAS President Lu Yongxiang and Chinese-American Nobel Prize winner Chen Ning Yang all endorsed this objective.[20] While all these programmes aim to recruit and support young scientists from at home and abroad, and while they provide enhanced material support for Chinese research and development (which will benefit young scientists), they also reflect a

18. Another example is the Knowledge Innovation Initiative in CAS where its administration adopted a top-down approach to design its institutional reform. Interview with a CAS official (Beijing, 23 November 1998). At least one such innovative reform – the marriage of the CAS Institute of Computer Technology and its spin-off Legend Corporation – proved to be unworkable after only two years of trial. For related reports, see *Jisuanji shijie* (*China Computerworld*), No.1 (3 January, 2000), pp. A17–A24.

19. For a discussion of new science initiatives in the late 1990s, see Richard P. Suttmeier and Cong Cao, "China faces the new industrial revolution: achievement and uncertainty in the search for research and innovation strategies," *Asian Perspective*, Vol. 23, No. 3 (October 1999), pp. 153–200.

20. *Kexue shibao* (*Science Times*), 18 November 1998, p. 1; 11 March 1999, p. 1. Tsung Dao Lee, the Chinese-American Nobel Prize winner who shared the Nobel Prize with Yang, however, did not endorse the slogan of marching toward the Nobel Prize. See *Shijie ribao* (*World Journal*) (New York), 7 November 1999, p. A8.

top-down, prestige-driven approach to the support of research which some young scientists believe does not serve science as well as a bottom-up, investigator-driven approach.

The quest for a Nobel Prize reflects not only an eagerness for quick scientific success, but also the political concern and motivation of the Chinese leadership. Six scientists of Chinese descent have now won Nobels,[21] but all were either trained in the period before the People's Republic was founded, or attended universities and did their work outside mainland China – in Taiwan, Hong Kong and the United States. Thus, their achievements in no way reflect positively on the post 1949 Communist regime which, after 50 years of supporting scientific development, has yet to claim a Nobel.

Nobel Prize mania is understandable from a regime which has placed such great emphasis on scientific development during the past 20 years, and from a technical community which believes that its ranks contain Nobel Prize calibre scientists. There is thus pressure on Chinese scientists to achieve the highest international recognition, and this pressure is felt especially among the more promising younger scientists, the DYS awardees. Some of these, however, question whether such pressure, with its concern for quick results, is good for the development of Chinese science over the longer term.

As a long-range strategic vision, winning a Nobel Prize will definitely stimulate and encourage Chinese scientists who try to produce creative and innovative works. But young scientists are sceptical about placing the winning of a Nobel Prize as a strategic objective, seeing it as a reflection of a misguided "Great Leap Forward" mentality. Nobel Prizes will come, they believe, when there is genuine achievement coming out of the Chinese research system. They are inclined to cite a Chinese proverb: "where water flows, a channel forms" (*shuidao-qucheng*); only when conditions are ripe will success come. Rather than pursuing a quest for a Nobel Prize, young scientists would rather see policy efforts focused on getting those conditions right in order to create a productive research environments in China.

Generational tensions. A major concern among young scientists is to have their voices heard on important matters of research policy. Young scientists are caught in complex intergenerational relations which have been made more difficult by a missing age cohort as a result of the Cultural Revolution, and by the brain drain. The absence of a productive, well-trained and internationally recognized cohort of middle-aged scientists to exercise academic leadership results in a curious situation in which the young are pitted against an ageing cohort of senior scientists in setting the direction of the nation's research. The young scientists are often impatient with their seniors, many of whom are no longer active researchers. Yet, seniority still matters a great deal in the Chinese

21. Chen Ning Yang and Tsung Dao Lee in 1957, Samuel Chao Chung Ting in 1976, Yuan Tse Lee in 1986, Steven Chu in 1997 and Daniel C. Tsui in 1998.

academic community, and young scientists are expected to follow the norms of seniority.[22] Thus, young scientists are often reluctant to speak out in the presence of *yuanshi*, or academicians (informant no. 36). In evaluating important projects, even young academicians like Chen Zhu are reportedly reluctant to speak with candour (informant no. 20). The situation for less prestigious younger scientists is even less favourable, and they are thus hesitant to challenge authority for fear of putting their careers at risk (informants no. 24, 41 and 45). According to some informants, senior scientists who are not up-to-date in their fields are too often deciding the fates of young researchers and are often competing for grant money against them. As one interviewee put it: "If those in their 70s and even 80s are still competing for grants, where is the hope and the future of Chinese science?" (informant no. 16).

Young scientists, of course, appreciate the importance of recognizing the contributions of their seniors, but believe that they should be stepping aside once they are no longer working at research frontiers in order to allow young scientists to play a more active role (informant no. 17). Using a military analogy, one biochemist in his late 30s proposed that scientists in their 50s should play the role of strategists, with the younger generation without strategic planning experience – those in their 30s and early 40s – commanding tactical operations. This would allow the younger generation to charge forward towards the frontier (informant no. 20). Many young scientists believed that by giving them a more prominent voice, Chinese science in the new century would be more likely to prosper.

Material rewards. Generational tensions are clearly related to the material conditions faced by scientists, both young and old. Because salaries have remained very low, having access to research grants helps make up for low income. Professors at universities and research fellows at research institutes earn a monthly salary of about 1,500 *yuan* ($180), which is a pittance in comparison with the incomes that can now be made by working for multinational corporations, joint ventures and high-tech start-ups. Academic science, thus, is at risk of being marginalized as individuals and institutes engage in short-term, contract research to augment incomes.

This situation – referred to as "inexpensive but excellent" (*jialian-wumei*) – is not sustainable even if many young scientists stay with an academic career out of their passion for science. But, as Wang Xuan, a CAS member and a professor of computer science at Beijing University has pointed out, scientists cannot maintain "excellence" if the "inexpensive" salary situation is not improved. One young scientist pointed out, in the presence of top CCP leaders, that senior intellectuals

22. It is only in 1998 that CAS and CAE succeeded in forcing their *yuanshi* over 80 years old to become senior members (*zishen yuanshi*), being relieved of their duty in nominating and electing new members, among others. However, the original age was set to be 75 years old. Interview with a CAS member (Beijing, 11 January 1996).

fared much better, materially, under the Kuomintang then they do today (informant no. 20).[23]

While salary and living conditions for most scientists remain poor, there are signs of improvement. For instance, with a large donation from Hong Kong tycoon Li Ka-shing, MOE launched the Cheung Kong Scholar Programme (noted above) to establish endowed professorships in Chinese universities. Three rounds of awards have been made thus far, resulting in 612 new academic positions in 119 universities and colleges. Some 287 Cheung Kong Scholars whose age generally does not exceed 45 years old have started their tenure, with each receiving an annual stipend of 100,000 *yuan* ($12,000) in addition to regular salary.[24] CAS's Knowledge Innovation Initiative includes an effort to recruit 300 scientists under the age of 45, mainly from abroad, with an offer of 2 million *yuan* ($240,000), including money for research, a housing subsidy and a moderate salary.[25] In addition, Qinghua, Beijing, Nanjing, Wuhan and Fudan Universities have recently significantly increased professors' salaries.[26] Although these increases are probably not enough to induce scientists abroad to return, and are not competitive with salaries which can now be had in industrial research, they were nevertheless welcomed by the interviewees as a step in the right direction.

But all of these steps also have the potential to create new problems of morale, since they involve the creation of new kinds of inequalities in the research community. Success in recruiting young scientists to return from abroad, while good for science in China, also means that young returnees who have been accustomed to higher salaries and standards of living, and who have typically built up family savings while abroad, now become the colleagues of large numbers of Chinese scientists whose income and accumulated wealth is markedly different. Interviewees expressed concern that a type of clash of cultures could lead to corrosive envy and a weakening of morale within the technical community (informants no. 23 and 32).

Too often in China, in part because of the limited number of people doing internationally recognized work, scientists serve the function of both reviewers and grant applicants (or in the words of the interviewees, both "referees" and "athletes") at the same time. The potential conflicts of interest are a source of widespread concern. Moreover, there have been cases where second- or third-rate "referees" evaluate the work of first-rate "athletes" (informant no. 28). Therefore, some interviewees proposed setting up a "bank of experts," selection for which would be

23. In the 1930s, a professor at Beijing University could afford to own a car and employ a private driver and chef. See Nie Leng, *Wu Youxun zhuan* (*A Biography of Wu Youxun*) (Beijing: Zhongguo qingnian chubanshe, 1998), pp. 83 and 131.

24. *Renmin ribao* (*People's Daily*) (Overseas edition), 24 March 2000, p. 3.

25. Funding of 2 million *yuan* ($240,000) is significant even in international comparison. For example, the Canadian government established research chairs for "rising stars" or young faculty at universities, which carry funding of $70,000 a year. See "Massive hiring plan aimed at brain gain," *Science*, Vol. 286 (22 October 1999), pp. 652–53.

26. *Renmin ribao* (Overseas Edition), 24 November 1999, p. 8; *Qiao bao Zhongguo kexue zhoubao* (*China Press – The Chinese Science Weekly*) (New York), 27 February 2000, p. C9.

based on citations to scientists' current publications as recorded in *SCI* databases (informant no 11). With such a mechanism, advice on the directions of research policy and decisions on the allocation of support would rest with those who had demonstrated achievement, regardless of their geographical location. It was felt that this would be a boost for morale, and would help ensure that as expenditures on science increase, fairness in their distribution would be maintained.

The interviewed DYS awardees also pointed to room for improvement in the NSFC funding. A biochemist suggested adopting the American NIH system in which scientists have to apply for a small project first and then become eligible for larger awards after its satisfactory completion (informant no. 7). A geophysicist suggested basing continuous support on grantees' international publications (informant no. 13). A biophysicist recommended that only those with *SCI* publications receive further funds (informant no. 4). In this way, output relative to input, research productivity and performance, rather than other factors such as fame, seniority and *guanxi*, will govern the distribution of awards, and the weaker performers will be excluded.

In spite of the concerns for distributive fairness noted above, interviewees were critical of efforts to achieve "balance" in the distribution of funds when distributive decisions were not based on merit:

> A quota for the Cheung Kong Scholars was established for universities by MOE, with the result that candidates from lower-quality schools are inferior to those who are not chosen from elite schools because of the quota restriction. The DYS faced the same problem when the amount of money was increased to 180 million *yuan* and many institutions suggested selecting more awardees (informant no. 42).

Adequate research funding is not the only factor in the research environment which concerns young scientists. Even when the money is available, the infrastructure for research in China is often unable to supply consumable materials such as reagents, cell lines and plastics products in a timely fashion. Such materials from domestic suppliers are often unreliable or unstable, being of low quality or even fake. When trying to procure from abroad, scientists face complicated application and approval procedures, higher prices and even commissions, and delays in shipping and delivery. Life scientists complained a lot about these issues (informants no. 7, 11, 24, 26, 31, 37 and 49). The DYS grant of 200,000 *yuan* a year is often far from enough for adding expensive but infrequently used instruments in life and earth science laboratories. At the same time, those who own such instruments do not want to share them with scientists from other institutions, for fear of their being broken and not having the infrastructure for prompt repairs. Based on their experiences abroad, several interviewees suggested setting up central instrumentation centres to allow researchers from different institutions to use specialized instruments, and thus raise the efficiency of their use.

China has long had a system of awards for research achievement, such as the Natural Science Award, the Technological Invention Award and the Scientific Advancement Award, with versions of these given at the national, provincial, ministerial and even county levels. The awards bring not only fame in public recognition, but also promotions, increases in salary and better housing to awardees. Over time, these awards have come to be regarded as an attractive bonus (*jiangjin*) for scientists. Young scientists are sceptical about the value of the award system for scientific development, however. Potential recipients are not nominated by their peers, but must apply for the awards themselves. Because of this, some scientists have spent much time networking with those sitting on review panels, promoting their research to news media, and inflating their results in applying for awards. Other problems of the award system include the black-box operation of award selection (informant no. 16), exaggeration of research results (informant no. 31), and the practice of enlisting reviewers on the panel for support (informant no. 35). Given that such behind-the-scenes activities damage the image of science, the interviewees favoured eliminating all awards for science and technology, or just keeping awards at the national levels, and using strict criteria, say, publication and citation records, to select scientists for the Natural Science Award.

Following such assessments from the scientific community, the Chinese government has revised its regulations governing the awards system, and has eliminated all but three of the ministerial level awards.[27] It has also established a State Supreme Science and Technology Award, or Chinese Nobel Prize, to be given annually to at most two scientists. The award will carry a grant of 5 million *yuan* ($600,000), including a 500,000 *yuan* ($60,000) bonus and 4.5 million *yuan* ($540,000) used for research at discretion of the awardees.[28] Following rigorous nomination and evaluation procedures, the first such award was granted to the mathematician Wu Wenjun and the rice expert Yuan Longping in early 2001.[29]

The Party's commitment to science. In reflecting on the environment for scientific development in China, interviewees observed that in order to fulfil the Party's strategy of "revitalizing the country with science, technology and education (*kejiao xing guo*)," announced at the 1995 National Science Conference, China first had to revitalize science and education (*guo xing kejiao*). The Party's 1995 "Decision on Accelerating Science and Technology Progress" stipulated that by the end of the century the national research and development (R&D) expenditure was to be increased to 1.5 per cent of the GDP, from the then 0.5 per cent.[30] While some progress has been made towards that goal, the target has yet to be met. There are significant economic and institutional factors to

27. The three ministries which still could reward scientific achievements are the State Commission of Science, Technology and Industry for National Defence, the Ministry of Public Security and the Ministry of State Security.

28. *China Daily*, 5 January 2000.

29. *Qiao bao Zhongguo kexue zhoubao* (New York), 15 February 2001, p. C8.

30. *Renmin ribao* (Overseas edition), 6 June 1995, pp. 1 and 4.

explain why the goal has not been reached,[31] but many interviewees expressed the belief that ultimately, it reflects the fact that science and education are still not high priorities for political leaders, in spite of rhetoric to the contrary.[32] The Cheung Kong Scholar Programme is encouraging, but one young scientist questioned: "Why didn't the government launch such a national programme itself to show its willingness to support education, instead of seeking support from a Hong Kong businessman?" (informant no. 52).

To the interviewees, the reforms in the scientific and technological system since 1985 have placed too much emphasis on making research serve the needs of the of economy. As a result, research and education institutions have put too much effort and resources into linking technology with production. Now, as China continues its quest for eminence in science, it finds itself struggling to gain the necessary momentum for first-rate research. Young scientists would like to see less hyperbole and more action from the leadership to revitalize science and education. They believe that the nation should invest more in R&D, just as it does in the military (informants no. 28 and 37), and should, perhaps, at least invest a fixed-term amount of money in theoretical research (informant no. 46).[33] In addition, the leadership should try to solve the contradiction between science having a high occupational status (in terms of perception) but low social status (in terms of income) so as to really make the scientific profession an honoured and admired one.

Assessment and Outlook for the Future

The existence of the DYS recipients is a sign that Chinese science has established a strong core of younger scientists who can help both to compensate for the missing cohorts in the Chinese scientific community and shape the direction of scientific development and China in the early 21st century. At the same time, there are still many puzzles about the strengths and weaknesses of the scientific enterprise in China. The challenges faced by the DYS awardees in promoting an outstanding research tradition in China are many, since Chinese research has a way to go before it reaches the standards of quality to which it aspires. For instance, there were no first-class awards made in four of the six most recent rounds of the National Natural Science Awards (awards for research reaching high international standards).

The quest for internationally recognized scientific distinction is intricately tied up with the problems of the Chinese scientific diaspora. Many of those who took advantage of the opportunities to study abroad, and

31. Suttmeier and Cao, "China faces the new industrial revolution."

32. Compared with the 2.5 billion *yuan* allocated to the now well-publicized State Key Basic Research and Development Programme, the state is going to invest 3.54 billion *yuan* to construct a national theatre. *Renmin ribao* (Overseas edition), 24 January 2000, p. 1.

33. The fortunes of some fields of science – including those of relevance to dual use technologies – seem to have improved as a result of China's reconsideration of its strategic options following the U.S. bombing of the PRC embassy in Belgrade.

who have returned, have assumed leadership roles in China's education and research institutions. These scientists, along with those trained at home, are moving Chinese science forward. But China has also suffered a very significant brain drain; most of the outstanding Chinese scientists who have left the country are still abroad. Over the 1986–98 period, of the more than 21,600 Chinese who earned doctorates in science and engineering from American universities, 17,300 planned to remain in the U.S.[34] And, those who stay may be the most talented.

For example, among some 300 China-born life scientists who are recognized as leaders in their fields (in terms of their appointments at high-quality institutions, their leadership of laboratories and their substantial research grants), only five have returned to China, and none of these is among the top 20 per cent.[35] Similar stories could be heard from other disciplines. Although there are no detailed statistics, one young scientist indicated that many of those who have returned are working in high-tech industry, where they can find more opportunities and where their expertise is more appreciated in China than abroad; those who are really excellent in science are not willing to return (informant no. 16).

Because of the brain drain, some young scientists believe that China will lag behind the world scientific community for quite some time. They point to the need to improve the quality of China's scientific journals and to the fact that in some fields, Chinese research trails that of other developing countries. A realistic goal for the life science community, according to one plant biologist interviewed, is to have one Chinese journal which would surpass India's best and become as good as what is available from Japan (informant no. 25). Another biologist felt that a realistic career goal would be to publish regularly in international journals with impact factors of 3, 4 or 5, roughly equivalent to the performance of professors at second-rate American universities (informant no. 42). A virologist predicted that most research in China would continue to be derivative of work done abroad (informant no. 32). The fact that some returnees are mainly continuing work on lines of research that were begun abroad has raised the question in the mind of one interviewee of who would hold the intellectual property rights to any invention which might result (informant no. 25).

As noted above, most of China's programmes to encourage younger scientists have a strong component directed at reversing the brain drain. There is some indication that these efforts are having an effect, as inflows of Chinese scientists have picked up. For example, Beijing and Qinghua Universities have in recent years each added more than 300 faculty members who got their doctorates from abroad and returned;[36] Nanjing University attracted back from Harvard Medical School Liu Jianning, an associate professor of medicine, and four of his Chinese associates with

34. National Science Foundation, *Statistical Profiles of Foreign Doctoral Recipients in Science and Technology: Plans to Stay in the United States* (Arlington, VA: The Division of Science Resources Studies, National Science Foundation, 1999).

35. *Keji ribao* (*Science and Technology Daily*), 13 May 1999, p. 1.

36. http://dailynews.sina.com.cn/culture/2000–3–9.

the promise of an opportunity to set up a laboratory in Nanjing similar to the one he had in Cambridge.[37]

In addition, there has been much talk about implementing a "dumbbell model" for Chinese scientists abroad in which they would have research bases both overseas and in China. This has led to efforts to build new research teams and establish new facilities in China. With joint efforts of young Chinese scientists at home and abroad, for instance, a new institute of neuroscience affiliated with CAS was established in Shanghai.[38] In another case, Fu Xinyuan, an associate professor of pathology at the Yale University School of Medicine, and ten other Chinese-American biologists, set up a molecular and medical biology lab at Nanjing Normal University where they will help train three to five post-doctoral fellows each year.[39] But there have been cases in which returnees have exaggerated or even falsified credentials and achievements abroad so as to take advantage of the government's urgent need for the talent.

Doubts exist as to how effective the "dumbbell model" can be, however.[40] Some young scientists felt that it is unrealistic to expect those who have labs and teaching responsibilities in foreign institutions to work in China for three to six months a year, as the "dumbbell model" would require (informant no. 49). They also wonder whether such arrangements would be good for Chinese science, even if such collaboration would lead to greater visibility for Chinese research in the world. There are concerns about how Chinese and foreign institutions would share credit for any published research involving expatriate scientists working at Chinese institutions, especially how to insure China's right to equal status in any international collaboration. Finally, while having foreign based scientists come back to China for short periods might be useful, cynics also observe that sometimes it appears that Chinese institutions are using the money to support work for a couple of months in China (such as from the Cheung Kong Scholar Programme) to buy themselves high-impact-factor papers (informant no. 37).

In short, the transnational existence of younger scientists, and the extended scientific community it creates, leads to strong feelings of ambivalence. Quite a number of DYS grantees have foreign permanent residence status, and now have a vested interest in acquiring the services of bright Chinese graduate students. One interviewee indicated that ten students waited for his foreign grant to come through for their nominal stipends (informant no. 29). Younger Chinese scientists who are making

37. *Renmin ribao* (Overseas edition), 20 March 2000, p. 3.

38. *China Daily*, 29 November 1999.

39. See recruitment advertisement in *Renmin ribao* (Overseas edition), 11 January 2000, p. 6. On a separate but relevant note, Jiangsu provincial government pledged 200 million *yuan* ($24 million) to Nanjing Normal University for its development (informant no. 15). Fu also directs a genomics research institute at Qinghua University. See *Qiao bao Zhongguo kexue zhoubao*, 19 November 2000, p. C2.

40. In the wake of the Cox Report alleging Chinese spying in the United States, for instance, scientists of Chinese origin may be deterred from co-operating with Chinese colleagues as fully as they might like to for fear of attracting political attention in the U.S.

successful careers abroad at times elicit criticism from younger scientists working in China who see the former as "fishing for fame and compliments" (*guming-diaoyu*), and even political advantage when they return for brief professional visits to the land of their birth (informant no. 39). For such critics, the key to the development of Chinese science depends primarily on those who work hard in China. Thus, in the words of some DYS awardees, China should devote fewer resources to supporting those pursuing the "dumbbell model" and should make clear instead that those scientists who wish to contribute to Chinese science should do so wholeheartedly and "return with their bedrolls" (*pugai*) (informants no. 49 and 50).

This question of keeping the "pipeline" full is manifest most clearly in concerns over graduate education. Interviewees thought that students should enter the scientific profession as competent scientists who have already begun a process of growth as scholars, as teachers and as members of a scientific community. To achieve that goal, graduate students who aspire to scientific careers should be regarded as "scientists-in-training" in all aspects of the job and have opportunities to see and even perform the full spectrum of scientist's roles as early as possible. However, China's graduate education is not positioned to prepare students with such competence. On one hand, it has not been possible to staunch the flow of better students to graduate education abroad, with the result that China's leading institutions are losing their lifeblood (informant no. 25). Beijing Medical University, for example, has seen many of its undergraduates depart for foreign graduate study, with the result that it must recruit graduate students from second-tier Chinese universities whose ability is lower than that of its own undergraduates, a situation common at other leading institutions as well. From those who are recruited into graduate programmes, many go abroad upon obtaining master's degrees, which further lowers the quality of its doctoral students (informant no. 37). CAS institutes have also been at a disadvantage in recruiting the best students (informant no. 45). Weak financial support for graduate education has also made graduate students more dependent on their mentors, and this has led to graduate research work which has been less creative and more derivative. And attractive new job opportunities for Chinese undergraduates with technical training in multinational companies, joint ventures and high-tech start-ups firms have also lured students away from graduate study in the sciences in China.

China's graduate education itself also has problems to overcome. For one thing, admission is tough while graduation is easy. Almost all of the enrolled students get their degrees so that there is no incentive to study hard; students get low stipends so that they have trouble supporting themselves. According to some interviewees, graduate students seem to lack the passion for science which is necessary for a successful research career. They don't show a desire to improve, and often complain to advisers that standards and expectations are too high (informants no. 17, 31 and 44). Although the number of applicants for graduate school in the year 2000 reached an all-time high, students are opting for programmes in business and finance, computer technology, law, and other fields offering the potential for lucrative income.[41]

Concerns among young scientists about the quality of graduate students were nicely captured by one interviewee who noted that "80 per cent of the graduate students either could not keep their minds on science or do not know how to do science. The best shot is, therefore, to find those 20 per cent of students before they are influenced by the other 80 per cent" (informant no. 25). Interviewees were worried that without vigorous action to improve graduate education – with a dramatic overhaul of how China's graduate schools recruit, prepare and retain good students – the future of Chinese science would be in doubt.

Conclusion

The new generation of elite scientists in China is a fascinating group. It clearly includes individuals of remarkable talent. They are, for the most part, quite cosmopolitan in their experiences. Most show signs of having mastered the institutional environment for research; individually, they seem to be able to find the resources and autonomy to build successful research enterprises. At the same time, as the elite seeks to bridge the norms and practices of the best of international science and Chinese realities, the collective lives of these outstanding young scientists are subject to tensions, uncertainties and contradictions which make the building of a dynamic scientific community especially challenging.

These issues are quite complex. Some can be traced to understandable problems of material scarcity. Others reflect the persistence of norms of seniority. Others still are the result of a dynamic institutional environment which generates very mixed signals as to the balance between professional and commercial values of research. This same institutional environment has, as a result of reforms, become markedly more friendly to the research enterprise over the past 20 years. But, as shown above, there are still many aspects of it which are in need of further reform.

Undoubtedly, many of the problems in the collective lives of China's young scientists are problems of transition – from a very poor country to one of growing wealth, from a centrally planned, publicly owned system of research and economic institutions to a market-driven one, from a somewhat isolated and autarkic research system to one that is becoming deeply intertwined with international science. How transitions of this sort are ultimately managed may, in the end, be a function of the political environment for science. Chinese science enjoys an environment of political liberalization which would have been unimaginable two decades ago, and it enjoys sympathetic ties to a political system which is dominated by a political elite which, itself, has strong technical training. Yet, it still does not experience the formal autonomy which scientific communities do in other countries. Formal autonomy of this sort, of course, awaits a change in the country's political formula, but it also

41. *Daxuesheng* (*College Life*), No. 3 (1998), p. 64.

requires that members of the community assume active responsibility for the affairs of the community. The attitudes and orientations of China's rising scientific elite give mixed signals as to whether China's distinguished young scientists wish to assume that responsibility. While they express dissatisfaction with the way things are at present, their comments also point to wide-ranging and often inconsistent attitudes and values about collective professional life. They thus raise doubts as to whether the necessary normative consensus exists for a more self-governing community. One suspects that it is on this question that the success of China's aspirations for scientific greatness – both those of the state and those of the incredibly talented young scientists – ultimately turns.