Science in China

Planting a tall tree

A correspondent with wide experience of Chinese affairs describes the state of science in China in the wake of the Cultural Revolution and speculates on the possibilities for the future.

WHEN British Prime Minister Mrs Thatcher drank tea at the Shanghai Institute of Biochemistry on 25 September 1981, she became the first major foreign leader ever to visit a Chinese basic research establishment. Her call reflected not only the high priority now attached to science within China, but also China's rising profile in the world scientific community and the growing eagerness of Chinese researchers to participate in international scientific discourse.

After the chaos of the Cultural Revolution, the overwhelming impression of China nowadays is the dramatic progress achieved both in research and scientific education over the past five years. The contribution, actual and potential, of Chinese science is probably greater now than at any time since its eclipse in the seventeenth century by the mathematization of physics in Europe.

Coldest winter turns to spring

The ravages wrought on Chinese science between 1966 and 1976 by the demented anti-intellectualism of the Cultural Revolution as followed by the Gang of Four are now familiar. (For a comprehensive account of science in China, 1966–78, see ref.1). Universities and basic research establishments were closed; intellectuals in general and scientists in particular were vilified and humiliated as class enemies inspired only by personal ambition; anything foreign was automatically tainted: Einstein was denounced as a bourgeois intellectual and relativity was ridiculed. Although a handful of prestigious or strategic research projects (notably in the defence sector) were protected, the great majority were either cancelled or directed, with disastrous results, by ideologically selected cadres with no scientific education or experience; activity in some fields at the height of the frenzy was limited to seminars and discussions organized secretly and at great risk by a dedicated few. Researchers often had to justify their work with putative practical applications so that, for example, an ornithological study published in 1973 caused outrage in the west by pointing to the culinary values of various threatened species. Genuine scientific writing virtually ceased for several years.

This disruption did immense damage. Perhaps most serious was the loss of scientific personnel. Almost all universities had closed by 1967 and although some courses and applied research had resumed by 1973, the first batch of thoroughly trained graduates did not emerge until autumn 1981. It is the generation lost in this period which, now in its late twenties and early thirties, should be providing the creative thrust for Chinese research. (It is estimated, for example, that only 0.7 per cent of Chinese aged over 25 are university graduates, compared with some 5.5 per cent in Japan). To make matters worse, the preceding generation of scientists already productive by 1966 also sustained heavy losses. A large and unrecorded number were systematically broken in body and spirit by years of manual labour, bullying and humiliation often in remote and inhospitable regions. An official Chinese document has estimated that some 70 per cent of senior academics in 14 medical colleges and 11 institutes under the Ministry of Public Health were falsely charged and persecuted[2].

Apart from the consequent severe shortage of trained manpower, it would not have been surprising had such intense repression induced a state of paralysis in Chinese science. Indeed, by the time the Gang of Four was removed in 1976, very little original work was under way. However, with the subsequent return of the pragmatic Deng Xioaping and his supporters, new optimism grew as the leadership publicly identified the development of science and technology as the most fundamental of the "four modernizations", without which the other three (agriculture, industry and defence) would be impossible. This position was formally endorsed and amplified by the seminal National Science Congress convened in Beijing in 1978[1]. Attended by scientists and scientific administrators from all disciplines, levels and areas of China and addressed by senior leaders including Deng Xioaping and Fang Yi, the congress reaffirmed the value of science and scientists to the community. Under the slogan "Springtime for the people, springtime for science", it reestablished the respectability of expertise as opposed to blind ideological purity, elevated scientists from class enemies to members of the working class, guaranteed that rational and expert analysis would in future inform scientific decision-making, reanimated the scientific bureaucracy which had been established in the 1950s and identified research priorities for the coming eight years.

Perhaps the most significant aspect of the congress was its implicit recognition

The Great Wall

that while the prevailing interpretation of the socialist ethic should continue to characterize the behaviour and attitudes of researchers, scientific value judgements should nevertheless be freed from ideological shackles. Relativity was no longer fair game for political analysis. The congress implicitly served notice of the Party's intention to adopt a sueprvisory role, allowing day to day decision-making in science to revert to experts, in an atmosphere of open debate. This process was symbolized in May 1981 with the replacement of the politician Vice Minister Fang Yi by distinguished structural chemist Lu Jiaxi as President of the Chinese Academy of Sciences.

The conference remains a prominent reference point for Chinese science policy today. However, important changes have since taken place. The optimism inspired by the new post-Revolution attitude of the authorities and media towards science and technology, compounded with relief at the passing of chaos, engendered overconfidence and euphoria not without similarities to British optimism in the sixties about Harold Wilson's "white heat of technology". This has now been tempered by experience: over-ambitious research priorities have been replaced by others more consistent with development needs and structural changes in the bureaucracy have sought to ensure that future science and technology planning more diligently serves short and medium term economic goals.

How China runs its science

Not surprisingly for a planned economy, the administration of Chinese science differs most from that of Western countries in the degree of centralization

Hefei, in Anhui Province, is China's "science city".

attempted. The system strongly resembles that of the Soviet Union in the 1950s on which it was modelled. Guidelines for science and technology are drawn up by the State Economic Commission, as part of China's overall development strategy. Policy is then formulated and implemented by the State Science and Technology Commission (SSTC), which is essentially a ministry of science and technology. Its primary functions include:

(1) Detailed formulation of national research and development priorities and allocation of funds accordingly. Proposals are drawn up on policy, development, personnel planning, import of technology and coordination of research and finance by more than 60 specialist panels of scientists and administrators, relying increasingly on peer assessments and reviews.

(2) Coordination, partly through the provincial science and technology commissions subordinate to it, of research and development projects to ensure that priorities are reflected and duplication minimized.

(3) Guidelines for science and technology are drawn up by the State Planning Commission, in consultation with the State Economic Commission.

Although it commissions some large-scale strategic projects, the SSTC itself does not directly control subordinate laboratories. The major agencies of research are:

(1) The Chinese Academy of Sciences (CAS or Academia Sinica). This is the traditional stronghold of Chinese basic research. Although it is technically subject to SSTC control, its great prestige and direct links with senior leaders probably allow it considerable freedom. CAS draws up its own basic research priorities, which guide the selection of research projects for its 117 research institutes[3] encompassing between them most traditional areas of the natural sciences. CAS has an annual budget of around £180 million.

(2) The universities. Since the establishment of the present system of higher education in the 1950s, again on Soviet lines, universities have focused largely on teaching rather than research. This is now changing rapidly. University basic research is beginning to compete in quantity and quality with that of CAS, and universities are also becoming prominent in applied fields, especially engineering. The number of universities, currently 704 is also increasing[4].

(3) Central government. Many ministries and central organs have their own institutes and technical colleges, which form a large proportion of the applied research sector. Many government research and development subscribers control academies comprising specialist institutes — for example, there are some 20 research institutes in the Chinese Academy of Medical Sciences under the Ministry of Public Health. An important special case is defence research and development, under the National Defence Commission for Science, Technology and Industry (separate from and parallel to SSTC).

(4) Industry. Many factories and state enterprises maintain their own development laboratories, sometimes with government financial assistance.

(5) Regional science and technology commissions requirements of each province are identified and met by the provincial STCs, which commonly maintain around 150 research institutes, often in coordination with other local organs such as provincial agricultural commissions. Projects are generally applied and closely dictated by the demands of local industry and agriculture. A similar more rudimentary structure operates at prefecture and county levels.

This largely structural description is limited by the difficulty of obtaining budget statistics, and of interpreting such data as are available in the light of China's socialist accounting methods. In 1978, the last year for which figures are available, total research and development expenditure was estimated at £5,300 million, representing less than 1 per cent of gross national product. It is likely that this proportion is now significantly higher.

Another increasingly important body in Chinese science is the China Association of Science and Technology (CAST). An umbrella organization for the growing number of specialist societies, with a total membership of over 1.1 million it has the following three main functions:

(1) Popularization of science. CAST seeks to raise the level of scientific awareness amongst the population, in order to increase receptiveness to new ideas and eliminate conservatism and reliance on traditional methods (especially prevalent in agriculture). To this end, it organizes public lectures, seminars and demonstrations and helps to orchestrate an intense media campaign to educate the public.

(2) Inter- and intradisciplinary comminiction. The compartmentalization of Chinese science together with the relative immobility of scientific personnel have engendered severe problems of communication between scientists in related fields. The societies under CAST seek to promote the flow of ideas by organizing specialist symposia and academic exchanges and publishing academic periodicals.

(3) Provision of science and technology advice and services to government. In 1978, societies under CAST began to undertake consultancy projects which are becoming increasingly popular. For example, the site for the Yellow Sea deepwater port now under construction at Shijiusuo was chosen on the advice of a feasibility study by the Chinese Society of Oceanography and Limnology[5].

The "four modernizations"

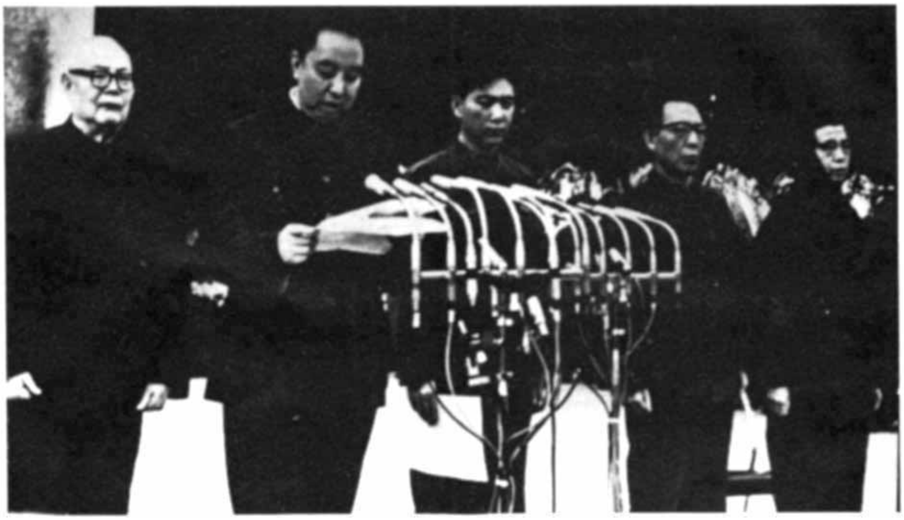
The central policy objective at present is to ensure that science and technology "serve economic construction"[6], meaning that although "research on basic science should not be neglected"[7], the emphasis is strongly on applied work. This is reflected in current priority areas. It is now recognized that the programme formulated at the National Science Congress was beset by "the shortcomings of making too rash demands, setting too high targets and envisaging too large scales". Consequently, for example, plans to build a 50 GeV proton synchrotron by 1985 have been shelved, as has an ambitious fusion energy project based on a tokamak device similar to the Joint European Torus, and sophisticated fields such as genetic engineering will for the time being receive less support than envisaged by the National Science Congress. But most other aspects of the 1978 programme[1] survive in the SSTC's recently announced priority areas within China's 15-year economic development plan due to begin in 1985[7]. These are:

- Agriculture (plant breeding, forestry, ecology and husbandry)
- Energy (exploration and conservation, energy economics for large-scale consumers, coal, hydraulic power, offshore development)
- Raw materials
- New technology (lasers, cryogenics, infrared spectroscopy, electronics and computers)
- Transport
- Communications
- Food
- Textiles
- Machinery
- Social sciences

In addition, considerable resources are being devoted to improving mechanisms for the wider application in industry and science of research achievements: this is the aim of the so-called "four transfers", from laboratory to production line, from military to civil, from advanced laboratories and enterprises to less advanced ones and from abroad to China. And at the planning level, the SSTC has recently lost part of its competence to the State Economic Commission (which is drawing up the development plans), in order to tie science and technology planning more closely to development aims.

Basic research

The shift away from basic research, which now accounts for around 5 per cent of total spending on civil scientific research, has not surprisingly generated opposition from researchers themselves, and from politicians who had hoped to enhance China's international prestige with high technology projects such as the 50 GeV synchrotron. Nevertheless, it is now widely accepted that a sensible balance has been struck: indeed the accelerator programme was initiated against the advice of many eminent Chinese and foreign particle physicists who felt that China would do better to use existing facilities overseas. Current policies are perhaps influenced by the obvious and, to some Chinese, embarrassing success of neighbouring Japan, in turning foreign basic research into domestic production capability. But Chinese planners have also noted that Japan is now herself beginning to attach a higher priority to creativity in fundamental science, and it is likely that given political stability and economic growth, basic research in China will gradually expand.



The new era begins — Premier Hua Kuo-feng reads Chairman Mao's funeral oration. Flanking him (left to right) are Yeh Chien-ying, Wang Hung-wen, Chang Chun-chiao, and Mao's widow Chiang ching.

How are these policies reflected in the selection of research topics? Although scientists are invited to apply for funds to pursue their specific interests, the likelihood of economic benefits is always a major criterion in deciding whether to grant applications; furthermore, the majority of university and CAST research projects are formulated and handed down by the central scientific authorities although eminent researchers often participate directly in the preceding consultative process. Thus, for example, zoological and botanical taxonomy receive strong support because: (1) they form part of the vast categorization which is currently under way of Chinese natural resources; and (2) they require little expensive foreign equipment.

The taxonomic findings are then built upon with extensive investigations into chemical and medical uses of plant and animal products. Chinese zoology and botany are not advanced in Western terms, due to lack of modern equipment and modern techniques. However, many new uses have been found for plant and animal products, especially in medicine, and areas such as phytochemistry have been strengthened by the development of new purification and analytical techniques.

In astronomy, China's lack of equipment limits her international contribution largely to the work of a growing number of brilliant theoreticians, while the experimental emphasis is on areas such as astronomical timekeeping and calendar correction, observations of satellites and solar physics.

Some institutes established originally for fundamental research have hastily diverted their resources to applied projects, so that for example, institutes of palaeontology now vigorously apply palaeontological knowledge and dating techniques to mineral prospecting, and institutes covering biological sciences usually have departments devoted to studying the economic uses of their subject matter. The general impression is rather ungainly: there is sometimes little in common between pure and applied projects within a given establishment. But this is largely due to the rapid and dramatic changes since 1966. A more rational research structure, better reflecting worldwide interests, will gradually emerge with experience, accelerated particularly by ever growing scientific contacts with the West.

China's scientific door swung open following the National Science Congress[1]. Contacts with the West, and particularly with the United States, Japan, West Germany and France, have grown rapidly. They range from the placing of Chinese research students in Western universities to exchanges of visiting scholars and large-scale collaborative research projects such as the Sino-French geotectonic survey of Tibet, reported in this journal[8]. Such exchanges are seen by most Chinese as a quick, and cheap, way of catching up with the developments that China ignored during the Cultural Revolution, and of educating China's brightest young scientists. The programme is limited by China's shortage of foreign exchange, but this has been alleviated by the generosity of some foreign governments, universities and foundations. Moreover, the benefits do not flow all in one direction. In many fields — geophysics, epidemiology, ecology, botany and meteorology to name a random selection — China's unique experimental conditions provide a strong incentive to Western researchers. In others, as diverse as biochemistry, microsurgery and pig breeding, China already has groups and techniques that lead the world.

Strengths and weaknesses

It has been said that the great strength of Soviet science it its ability to orchestrate large scale interdicsiplinary projects given political impetus at a sufficiently high level. This is certainly true in China. One of the most successful areas in Chinese fundamental science since 1949 has been the synthesis of biochemical molecules, notably bovine insulin and yeast alanine

Chuanshan University, Canton. China boasts 704 universities and the number is increasing. Most are controlled by the Ministry of Education.

t-RNA. Both of these achievements required long and painstaking collaboration between many establishments.

The tRNA synthesis, announced in January last year[9], merits closer attention. Work began in 1968, but owing to the disruption of science at the time, little progress is said to have been made before 1976. The 76-nucleotide molecule was synthesized by a combination of chemical and enzymatic techniques, through collaboration between the Shanghai Institutes of Biochemistry, Cell Biology and Organic Chemistry, the Peking Institute of Biophysics (all under CAS), Peking University Biology Department (under the Ministry of Education) and the Shanghai No. 2 reagent factory. Few conceptual advances were made; the significance of the task lies rather in its sheer complexity and the extent of collaboration between different groups[10]. The ultimate aim of the work is said to be gene synthesis by chemical methods; funding is justified in terms of medical applications.

This organizational strength of the Chinese system has also been demonstrated in other fields. China is good at large-scale surveys and has, for example, recently published important maps showing the distribution of types of cancer and other diseases. Intensive geographical surveys are regularly carried out in collaboration between diverse groups to map geological, pedological, climatological, hydrological and other properties of large regions.

It is ironic that the vertically oriented centralized structure that gives Chinese science this organizational strength is also largely responsible for its major weaknesses — inflexibility and compartmentalization, also part of the Soviet legacy. For without high level support in pursuit of a specific objective, communication between related disciplines, and even within single disciplines, is poor.

In fundamental science, this problem is illustrated by the gulf between CAS institutes and the universities, many of whose research interests now overlap considerably. The problem is partly due to the employment system, whereby researchers spend lifetimes at single establishments, with little opportunity for cross-fertilization. Furthermore, now that the universities are once again producing graduates, the gulf threatens to widen. As in other socialist economies, there is no job market: jobs for graduates are rather allocated according to Ministry of Education quotas by the universities, which can cream off their brightest students for their own laboratories. So although basic research in CAS institutes is generally better funded and equipped than that in universities, it often has to make do without China's brightest young graduates.

Another obstacle to cross-fertilization throughout Chinese science is the degree of specialization of most research establishments, so that members of the largely static staffs have little opportunity to meet workers in other fields (or even those in the same field but working at different laboratories), thus hindering the development of interdisciplinary subjects such as bio-engineering and environmental sciences. And within universities, teaching and research are usually undertaken largely by different groups of staff, so that graduates often have little appreciation for the demands of research work and researchers sometimes lose touch with the fundamental intellectual structures underlying their own fields.

Perhaps the most damaging effect of compartmentalization is the widespread wasteful duplication of effort. This is particularly prevalent in general areas which have been vaguely identified as priorities without closer definition and coordination of specific objectives: good examples are lasers and the applications of remote sensing, which are studied ubiquitously and with great vigour but with inadequate coordination under CAS, universities and some ministries. An important special case is the wide gulf between civil and military research: because of its completely separate administration, compounded by the secrecy with which it is conducted, the latter has gradually expanded independently into areas of purely civil interest, often unbeknownst to civil researchers.

Most of these problems are by no means unique to China; more important, most have now been identified as deficiencies and steps are being taken to overcome them. For example, CAS is now strongly advocating greater mobility for the staff of its institutes, university teachers are being encouraged to do more research (and vice versa) and organizations such as CAST seek to promote the "four transfers" referred to above.

However, there is another class of more insidious problems with their roots rather in the ideological contortions from which China has recently emerged than in the structural elements of the Soviet legacy. China's expanding scientific contacts with the West provide an example. Although the door remains firmly open, the light which shines through illuminates a crucial dilemma. The management of contacts with the outside world has for centuries been one of the major fault lines of Chinese society. The official position remains that Western culture, habits and lifestyles constitute a decadent and poisonous influence which must be shunned at all costs. This position will become more difficult to maintain as personal contacts and friendships form between Chinese intellectuals and foreign colleagues, encouraged by official recognition of the need for scientific exchanges with the West.

A second fault line divides researchers themselves and some of the cadres who control the administration of science and technology, many of whom rose to responsible positions during the Cultural Revolution, are identified with the policies of that time and have little understanding of science. The friction between them, generated in the Cultural Revolution, will take a long time to dissipate.

Legacy of revolution

Another problem with origins in the Cultural Revolution concerns the quality and deployment of scientific personnel. During the turmoil, many qualified researchers were transferred to applied work in which they had no experience or expertise; the task of identifying and relocating them has not been completed, and we have already seen that new graduates are not always optimally placed. Meanwhile, many posts in scientific institutions continue to be held by unproductive and untrained staff appointed for political reasons during the Cultural Revolution, accounting for the apparent average staff: student ratio of 1:3 at Chinese universities. Furthermore, trained researchers do not yet have the same incentives for creativity

A light-pen graphic alphanumeric display produced by a radio factory in Hunan Province.

as Western colleagues, either materially or in exposure to peer acclaim. Scientists are still encouraged modestly to avoid the limelight: heroes are made of those who try to avoid taking credit for their work. However, the SSTC has now sensibly resumed the award of scientific prizes (instituted before the Cultural Revolution) for outstanding research. In addition, there are now those who advocate a certain amount of competition between laboratories, despite the risks of duplicating resources and discouraging the dissemination of preliminary results.

Underlying all of these issues, perhaps the most important sociological question remains the status of the scientist and intellectual in Chinese society. Although no longer seen as class enemies, many scientists are still paid perhaps 20 per cent less than many factory workers, who, furthermore, can now often double their incomes with bonus earnings. The current media campaign emphasizing the need for better material conditions for intellectuals probably reflects a deep-seated concern that this disparity may direct new talent away from science.

Prognosis

These problems, however daunting, should not be exaggerated. They are perhaps less important than the sheer geographical and material obstacles to Chinese science: communications in many areas are poor and even the most prestigious laboratories cannot afford the sophisticated equipment of their western counterparts: there is a particular dearth of computing facilities and expertise. Nevertheless, the optimism and enthusiasm which prevail in most areas of Chinese research appear to be justified by the startling progress of the past five years. Most of the problems outlined above have been identified, widely debated and are beginning to be tackled with flexible and often controversial measures. The key importance of rapid improvement and expansion in scientific higher education has been recognized: visitors to Chinese universities who are aware of the disruption of less than a decade ago are impressed by the quality both of teaching and research, the atmosphere of enthusiasm and industry and often by what has so far been achieved with rudimentary experimental resources. Comparisons with other developing countries such as India, where a few centres of excellence tower over a minimally evolved scientific infrastructure, are usually favourable.

China's new pragmatic approach to science is exemplified by the growth of the basic research sector around the rather obscure city of Hefei, capital of Anhui Province. A small village before 1949, Hefei is a new town with a population of around 0.5 million. However, despite a relatively prosperous agricultural hinterland and recent growth in local light industry, its industrial base is weak and communications, especially with China's developed eastern seaboard, are not well developed. Therefore, when the decision was taken in the Cultural Revolution to decentralize science, rendering it (as it was argued) less vulnerable to Soviet attack and at the same time bringing it closer to the masses, Hefei was chosen as a suitable site for the relocation of the University of Science and Technology of China (USTC) formerly based in Beijing. Other important institutes were also moved or newly established there, including the fusion project (now the CAS Institute of Plasma Physics). By the time that the drawbacks of these policies were realized, Hefei's scientific identity was already established and it would now be impracticable to return the Hefei establishments to their original homes.

Instead, the opposite course is being taken. Basic science in Hefei is flourishing. The research institutes, which occupy a large self-contained site some 20 miles from town, are being expanded and reequipped. Although the original fusion project has been scrapped, the Institute of Plasma Physics is still constructuring a smaller torus, with the benefit of impressive engineering workshops. A new Institute of Solid State Physics is under construction, and the fledgling Institute of Intelligent Machines will shortly move there from the centre of town. The aim is to construct a "scientific base area" which will become a self-contained centre of excellence, better equipped, and drawing on better talent, than most Chinese research establishments.

Elitism allowed

But perhaps the most exciting institution in Hefei is the USTC. The only university remaining under the direct control of CAS, better equipped and more imaginatively run by younger staff than most of its counterparts, it enjoys increasing success as a cradle for China's scientific elite. Of some 100 young physics graduates from all over China selected in 1982 by Professor T.D. Li for further study in the United States, 22 were from USTC, including those who came first, second, third and fifth in the selection process; last year 66 per cent of USTC's graduates passed the national examination for postgraduate positions compared with a national average of well under 20 per cent. Such impressive statistics have not been achieved without controversy. USTC's relative unorthodoxy is resented in some circles; attempts were recently made to close its juvenile class, which draws on prodigies as young as 11 years of age from Chinese schools for early university entrance. The class is still open, but has no counterpart in other Chinese universities. But whatever the ideological anomalies of USTC, it is rapidly becoming one of China's most important educational institutions.

By Western standards, Chinese science, taken as a whole, remains relatively backward. It is impossible to predict when, and under what circumstances, China will be able to claim that the "four modernizations" have been achieved. But when they are, it is certain that basic science will have played a large part, and that the role of the scientist will be recognized. In the Cultural Revolution, there were many proverbs in wide use advising against excellence or prominence in any guise. It was said for instance that tall trees bore the brunt of strong winds. The creative individual in science is now rewarded (albeit modestly) rather than vilified, and at Hefei, tall trees are again being planted. □

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