9 February 1979, Volume 203, Number 4380 SCIENCE

China in Transition

This issue includes accounts of a 3-week visit to the People's Republic of China by the AAAS Board of Directors. The aims of the visit and some cooperative arrangements that were made between AAAS and the Chinese Scientific and Technical Association are outlined on page 533. The following three articles are personal impressions of the editor of Science, *the executive officer of AAAS, and the then president of the Board of Directors.*

Education, Science, and Technology in China

Philip H. Abelson

President Carter's decision to normalize relations with the People's Republic of China has fostered expanded scientific interchange between the two countries. In consequence, the visit to China by a delegation from the AAAS from 14 November to 3 December 1978 was particularly timely.

In one sense, the delegates were following a well-trodden path. Numerous U.S. scientific groups have visited China during the past 6 years, some private, but many under the sponsorship of the Committee on Scholarly Communication with the People's Republic of China. However, in general they have concentrated on specific areas of science such as solid-state physics. The AAAS delegation was unusual in its broad representation of disciplines and consequently in its broad outlook. It was comprised of people who had knowledge of university and medical education, libraries, medicine, the natural sciences, economics, sociology, technology, management, and politics.

Members were fascinated with what they learned about all levels of education. They tried to estimate the status of scientific research in the various fields. They were alert to discover whether and how research would be applied to societal needs. Questions about policy and management were frequent.

After a visit such as ours, participants are tempted to become instant experts. It is too easy to generalize from limited data. Beyond that, our hosts set much of the agenda. But there are factors that lend confidence in the validity of our observations. One is that we could check with groups who had been there before us (*1*). A second factor is that we asked many questions of many people. Some of our questions and comments were tough, even impertinent. Responses were such that we felt we were dealing with honest and forthcoming people.

One of the major questions about China that over the years has puzzled me is, "Why hasn't China developed faster and more extensively?" The country has substantial resources of coal, oil, hydropower, minerals, and agricultural land. Most of its area lies within the temperate zone. It has tremendous human resources. In the United States, Chinese scientists have performed admirably. In New York City youths of Chinese extraction do exceptionally well in the city-wide mathematics competition.

The problems of modernizing a large, populous country are enormous and complex, and so I return from China with my question not fully answered. However, I have no doubt that ideology has had a dominant role in influencing the development of education, science, and technology.

After Chairman Mao and his colleagues triumphed in 1948, a decade of remarkable progress followed. Chairman Mao's leadership and teachings were crucial in unifying China and in the achievement of great national goals. Education was fostered; literacy was increased from 20 to more than 95 percent. Higher education was expanded. Many research institutes were created and their personnel greatly increased. Infectious disease, including venereal disease, was practically eliminated, as were prostitution and traffic in drugs. Production of many chemicals and pharmaceuticals was initiated. China became essentially self-sufficient with respect to antibiotics. In the last two decades there have been advances, but progress has been uneven, largely because of repeated twists and turns in ideology. One of the ideological twists with broad relevance to future scientific exchanges was the Cultural Revolution (1966 to 1976), which had a great impact on education and research.

Impact on Education

At virtually every university or institute that the AAAS group visited, the briefings included a denunciation of the Gang of Four. This was a small ingroup headed by Mao's wife. For many years they controlled the major propaganda organs and the Ministry of Education. The Gang of Four were blamed for the severe disruptions of education and research that occurred during the Cultural Revolution. Worst hit was education. The universities were closed in 1966, and classes were resumed only on a limited basis in 1970. At that time a poorly qualified group of students were admitted who

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Professor teaching class at the Institute of Nationalities, Academy of Sciences, Peking.

had been selected on the basis of ideological considerations. In contrast, earlier students were chosen on the basis of nationwide examinations.

But the damage to education went even deeper than that. Prior to 1966, primary and middle school covered 12 years. This was cut to 10 years and before students could attend universities, they were required to spend 2 years in the countryside or in factories. Attendance at universities was diminished to 3 years, with much of the time devoted to ideological and other nonacademic matters. From 1966 to 1978 graduate school training was practically nonexistent. The study and use of foreign languages were discouraged.

Medical education and research were also hit. Medical schools were closed from 1966 to 1970. When they were reopened, the 4- to 7-year course was cut to 3 years. Students were selected from the army, communes, and factories on the basis of ideology. In general, their previous training did not go beyond the secondary school level. During the Cultural Revolution most medical research was discontinued, professionals were transferred to the provinces, and the Chinese Academy of Medicine was forced to move to a remote village.

Following the death of Chairman Mao and the arrest of the Gang of Four in late 1976, drastic shifts in policy occurred. The new ideological line emphasized the four modernizations—agriculture, industry, defense, and science and technology. Correspondingly, the official attitude toward education and research changed and new policies were quickly implemented. University curricula have been restored. Graduate training has been resumed. Students young and old will be sent abroad. Foreign schools and lecturers will be invited to China.

Today, training in the middle schools is heavily oriented toward the natural sciences and mathematics. The best students want to become physicists. Training in foreign languages begins in primary schools and continues through middle school.

Student bodies at universities have not yet been restored to their 1966 enrollment of 900,000, but the intention is that by 1985 the number will rise to 3 million. Most of them are expected to become scientists and engineers. Were these policies to be implemented, China would then be producing more technically trained graduates than the United States.

Impact on Research

Although research activities in the universities and institutes were not disrupted so severely as education, the impact of the Cultural Revolution was extensive. In China most research is carried out at institutes affiliated with the Chinese Academy of Sciences. A lesser amount is conducted at universities. During the Cultural Revolution, fundamental research was largely interrupted, although some applied work continued. The institutes fared relatively better, but they also had difficulties. We were told that in 1966 there were 100 research institutes, but that in 1976 only 40 remained. We were also told that during that 10-year interval few new research instruments were procured, and much existing equipment was damaged.

Some of the institutes came through the Cultural Revolution much better than others. For example, the Institute of Silicate Research in Shanghai has achieved significant results that could only have been reached by sustained effort over a period of many years. My impression, which has been reinforced by those of other groups, is that members of institutes and universities around Shanghai fared better in general than those in Peking. A possible explanation is that the Gang of Four came from Shanghai.

At all the universities and research institutes we were impressed with the people we met. They were informed about their subject fields, aware of relevant material that had appeared in the literature, and enthusiastic and energetic in their approach to science. We met and talked with more older staff members than with younger ones. The proportion of high-level women scientists in China appears to be greater than in the United States.

For the present and for the next several years, scientific leadership in China will rest with foreign-trained Chinese. Those educated in the United States are particularly prominent. Most of them came here between 1932 and 1949. Their memories of the United States are many and warm. In 1950 to 1960 a number of Chinese were trained in the Soviet Union, but only a small fraction were scientists. Their role is minimal.

In the ideological turmoils of the past two decades U.S.-trained scientists encountered difficulties, but perhaps not as great difficulties as are generally believed. True, they were special targets for abuse and "reeducation" because they were privileged, lived in urban settings, had usually come from wealthy families, and had foreign connections. True, most of them spent a year or more in the countryside or in factories. However, few were killed, their comparatively large salaries were maintained, and they were ultimately restored to their positions. To a large degree it is they who will provide a warm welcoming atmosphere for American scientists who accept invitations to lecture in China. A survey of reports from various scientific delegations indicates experiences similar to those of the AAAS group. We were most courteously received. Lectures given by members of our group were well attended by appreciative audiences who asked many good questions.

For the most part, the equipment with which the Chinese work is deficient in

quality and quantity. This is not surprising in view of the cost of such equipment and the restrictions against buying it that prevailed during the Cultural Revolution. Typical items are about 15 years behind the times, and even these are relatively few in number.

In leading U.S. laboratories one often sees equipment that has been developed locally and is more advanced than the usual state of the art. This is particularly true of some of our principal industrial research laboratories. In contrast, I saw no example in China of laboratory equipment that surpassed Western state of the art, and few pieces that even matched it.

In view of the handicaps under which Chinese scientists have worked, their accomplishments are fairly impressive, and one is led to believe that under more favorable conditions they would be remarkably creative. However, much of the work we saw was a duplication or modest variant of Western accomplishments. Some of the work was original and up to Western standards. I saw no instance in which the Chinese were notably ahead.

This view of Chinese research is broadly shared by the many visiting groups who have been drawn from every major branch of science. There is considerable variation in estimates about how far in years the Chinese are behind us. In this matter it appears that there are wide differences from field to field and within fields. The Chinese put emphasis on some areas, particularly those with quick applications, while not touching others. They are furthest behind and will find it hardest to catch up in areas of the physical sciences and computer technology where access to excellent equipment and instrumentation is essential. In some aspects of the biological sciences they are not far behind and indeed may have some lessons to teach us.

An example is their procedures for dealing with agricultural insect pests. Although they employ chemicals if necessary, they prefer to use biological controls. In any event, they refrain from overkill and treat only areas that are found to be substantially infested. They employ parasitic wasps, mites, and viruses and are developing additional biological agents.

Another example of work that merits continuing attention is Chinese studies of the incidence and etiology of cancer. Their cancer control program monitors the prevalence of the disease throughout the entire country. They find that in China 80 percent of cancers occur in the alimentary tract. The commonest sites are the stomach and the esophagus. The incidence of some tumors may be 100 times as great in one geographical area as in another. Such variations merit close studies, which the Chinese are making. They are sharing findings and specimens with Western medical scientists.

Most visiting experts from the United States agree that the Institute of Biochemistry in Shanghai is good. It is the site where the first chemical synthesis of insulin was carried out. Currently it is the scene of much activity in molecular biology, including research with recombinant DNA techniques. The Institute has carried out the tedious chore of isolating restriction enzymes. One recent visitor, an expert in DNA studies, was impressed with what he saw and the people he talked to. He believes that if the Institute enjoyed the kind of support in equipment and supplies that prevails in the United States, it would soon be among the world leaders. At present it is no more than a year or two behind. The AAAS group that visited the Institute was also favorably impressed.

Today, much of the frontier research in the United States is dependent on superb new equipment. Usually this instrumentation has as an essential component a mini- or microcomputer. Often the data obtained from the equipment are further processed in a larger computer. The use of large computers in research is commonplace, and many undergraduates as well as most graduate students in the physical sciences are familiar with computers and how they can be used.

In China we rarely saw instrumentation that included as a component a dedicated computer. The Chinese have no large computer whose capabilities approach those of large U.S. computers. We were told of only one that could process 2 million instructions per second, and most of the computers in China have about a tenth of this capability. There is very little training in the use of comput-

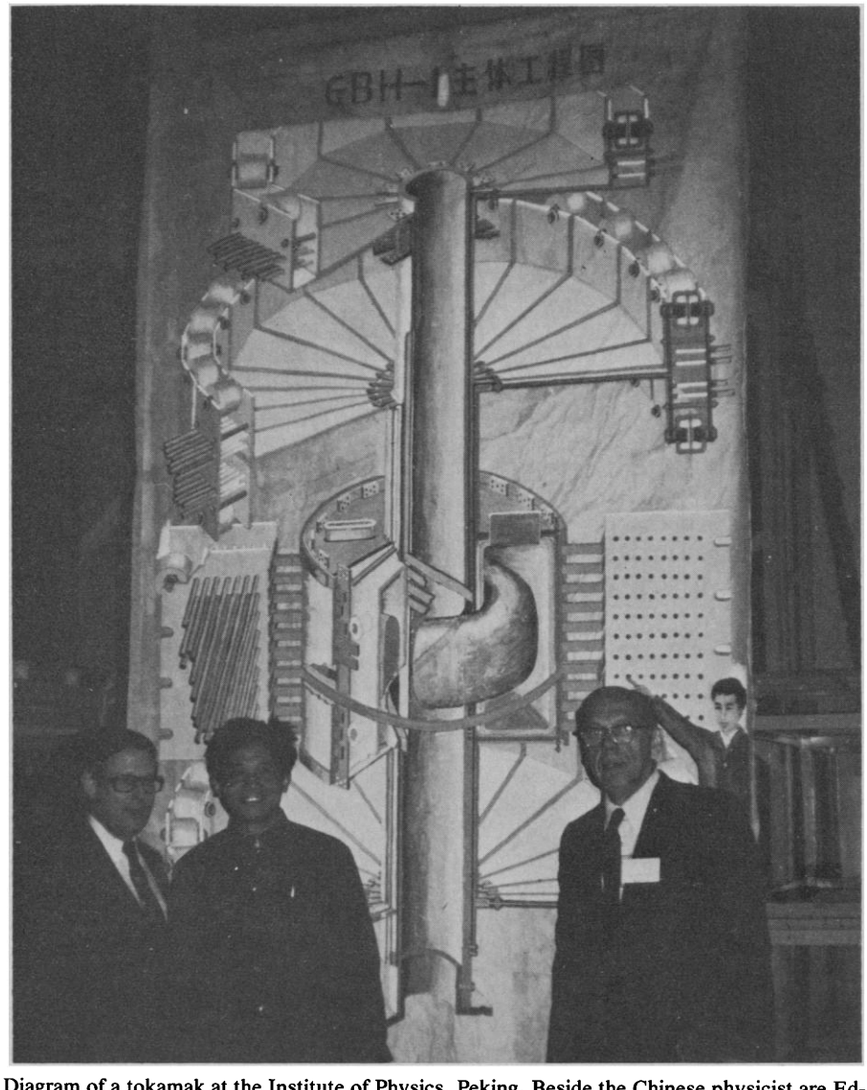

Diagram of a tokamak at the Institute of Physics, Peking. Beside the Chinese physicist are Edward E. David, Jr. (left), and Philip H. Abelson (right). [Photos from E. E. David, Jr.]

ers and only a few students program them.

In high-energy physics the Chinese do not have, nor could they have for a decade or more, equipment that might match that of advanced countries. Despite a lack of up-to-date equipment and computers the Chinese are succeeding in applying science to national needs. However, their problems in catching up with the West are enormous. The gap is great, and the target keeps moving ahead as advances in high technology continue.

In their research in the physical sciences the Chinese are active and knowledgeable in most of the fields currently worked in by Western scientists. Emphasis is on areas that are known to have practical applications. For example, in geophysics there are substantial efforts in earthquake prediction. In chemistry, much effort is devoted to petrochemicals, to natural products, and to polymers. In physics, lasers and a wide variety of solid-state devices are receiving much attention.

A useful insight into the level of Chinese applied science and technology can be obtained at their industrial exhibits. The AAAS delegation visited such an exhibit in Shanghai. There we saw about 1000 items whose preparation required a good level of competence in chemistry, biochemistry, metallurgy, physics, chemical engineering, and mechanical engineering. On display were many plastics, including synthetic rubber, Lucite, polystyrene, polyimide, and Teflon. Pharmaceuticals included a large number of antibiotics and drugs for hypertension, coronary disease, and nervous disorders. China produces ample steroid contraceptive drugs for domestic use as well as some for export.

Also on display were high-temperature alloys, titanium tubes, rare earth metals and salts, and semiconductor materials, including silicon crystals of 99.9999+ percent purity.

Essentially every consumer item that one could think of was there, including household goods, fabrics, musical instruments, radios, television sets, automobiles, and trucks. Production of automobiles is about 130,000 per year. The industrial exhibit also features some large machines, such as an automated milling machine with 48 cutting tools, a vertical lathe capable of machining an object 3 meters in diameter, and a machine for converting steel wire 15 millimeters in diameter into threaded bolts with hexagonal inserted sockets. The machinery appeared to be well engineered. However, many of the machines exhibited are not mass-produced, but one of a kind.

R & D Policy

Necessarily, in implementing the four modernizations, China will emphasize applied research. Average per capita annual income is about $340. In comparison to filling urgent present-day needs, a long-term unknown payoff cannot command priority. During our visit the delegation had an audience with Vice Premier Fang Yi. He is the person within the ruling group who sets policy in scientific and technological matters for China. During the conversations he said flatly, "If there is no application of research, then the research is worthless." This statement sounds familiar to Americans, who have repeatedly heard similar comments from some of their politicians. However, in China the comment is likely to have more weight than it would in the United States.

Our hosts told us repeatedly that the leadership in China is now determined to catch up with the advanced countries in science and technology. They hope to reach our current level by 1985 and to surpass us by 2000. These are inspiring goals but achieving them is problematic. As for getting to the first goal, one could scarcely devise a more unlikely springboard than the Cultural Revolution with its impact on the training of experts. Beyond that, the rulers of China apparently have little experience in the effective integration of advanced research and development into major industrial complexes.

In our contacts with directors of institutes and officials of the Chinese Academy of Sciences we repeatedly inquired about mechanisms for transfer of findings from research to applications. The standard response was to give an example of the use of improved seeds in the communes. Mechanisms for transferring results from the physical sciences to industry seem weak. At various places we were told that someone from a factory would occasionally visit an institute.

The current situation in China with respect to utilizing research is reminiscent of the attitudes of some U.S. companies during the 1950's. At that time it was the fashion to erect a beautiful laboratory off somewhere on a hill, staff it with the best scientists money could buy, and then wait expectantly for miracles. That era has long gone. The U.S. companies that maintain large research and development laboratories have made determined efforts to ensure that there is adequate interaction between research, patent counsel, development, engineering, production, quality control, marketing, and corporate management.

Competition in International Trade

In the recent past the economy of China has been little influenced by outside developments. But the new goals that have been outlined for the country will cause it to interact more strongly with the rest of the world. Enormous sums of money must be spent if China is to be modernized, amounting to as much as many hundreds of billions of dollars.

In part that money will be supplied by foreign investors, but they will provide funds only as long as they believe they will be paid back and make a profit. Oil is another possible source of money, but large reserves have not yet been found and substantial proceeds are distant at best. A more practical source of funds to pay off debts and for further investment is expanded sale of finished goods. But competing in world trade is a tough game. The goods must be attractively priced and of excellent quality. Before World War II the Japanese attempted to compete with price alone. At that time their shoddy merchandise was laughed at. Following World War II the Japanese instituted strict quality control which, coupled with cost-cutting, has made them wealthy, respected, and feared competitors.

Thus far Chinese industry has largely been oriented to produce for domestic customers. In a controlled economy costs are not always important or visible. For a customer in a socialist country to complain about the quality of a state-produced item borders on dissidence. The disciplining influence of the marketplace is absent.

I was first alerted to some of the problems that the Chinese will face by observing the quality of their bricks. There were many piles of them to be seen. I became sufficiently interested to look at thousands of bricks. They were comparatively fragile, and no two were alike.

Members of our group visited six places where various kinds of manufacturing were being conducted. These were small installations with simple, old machines. In general, the workplaces were dusty and poorly lighted. Despite the low wages paid to the workers, it was difficult to believe that low-cost high-quality products could be made in those locations.

Observations at a computer factory pointed to one of the problems the Chinese will encounter. In 1971 they assembled a computer based on integrated circuits on silicon chips. This admirable feat was accomplished with locally produced components. The small factory where the computer was assembled had

previously made door handles. In the interval since 1971 production has ranged up to ten computers of the same design per year. But in the same period great advances have been made in the United States and a U.S. computer costing a hundredth as much as the Chinese version can accomplish the same calculations at similar speed. The computer is not the best model the Chinese have produced, and the factory cited is not their most efficient one. However, the contrast in cost illustrates a problem that China will face when it engages in international competition.

If the Chinese are to compete in many of the items of international trade, they must bring to the undertaking more than cheap labor, patriotism, and self-discipline. Improving their capabilities in science and technology will help, but alone they will not be enough. Once truly committed to modernization, the Chinese may find themselves facing no end of changes, pressures, and social problems.

But the Chinese are an intelligent, energetic, and moral people. They have come far in the last 30 years. They will continue the development process. It is even possible that in spite of shifts in policies and direction that at times are destructive and self-defeating, they may yet arrive at a better, more livable social structure than others have thus far achieved.

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The Chinese Scene

William D. Carey

Coming from Tokyo, the contrast on arrival at Peking could not be sharper. Peking is the fabled Xanadu, pleasure dome of Kubla Khan. But today very little pleasure is visible. The city is proletarian in all its features. The population fills the sidewalks, streets, and avenues: on foot, on bicycles, stacked in buses and open trucks. Rush hour sees streams of bicycles flowing, crowds queuing at bus stops, patiently and without shoving or pushing. There is a universal atmosphere of organized existence. There are no beggars, few loungers. Dress is simple, colorless, and drab, but clean. Facial expressions range from deadpan to the glowing joy of teenagers. This is by no means a sullen people. They eye Americans with curiosity and often with smiles and a stray word or phrase of English.

The AAAS group saw no signs of teenage hoodlumism. The bicycle brigades swept down the avenues in good order, the crowds on the streets were well-behaved, and the mornings dawned with the sight of hordes of young people running through the streets singing and exercising on the way to school. No police sirens ever sounded, day or night, and uniformed police were hard to find. On the other hand, who was a policeman? When we were taken to see the Forbidden City or the Summer Palace, we noticed that as the proletariat crowded around us and listened to our guides, other proletarian-looking men would suddenly step forward and send them packing. And no back talk or sullen looks. The only sign of behavioral independence was jaywalking into the traffic stream or driving a bicycle or truck across the bows of a madly honking official car.

Work and Leisure

Although the populace appears to be in a constant state of motion, coming and going to nameless destinations on nameless errands in a permanent rhythm of organized futility, one senses beneath it all an explosive energy and power, a human machine in the process of being shaped, directed, controlled, and harnessed.

China is a nation of toilers. On any journey, short or long, one sees laborers at work, on farms or on the roads. Their work is backbreaking and powered largely by human muscle. A new road is laid by pick and shovel, with an ancient coal-burning steamroller waiting to smooth out and pack the stones. In the fields, water buffalo pull wooden plows steered by the peasants. Women do everything that men do, with no relief from the hardest kind of labor. A common sight from the window of the luxurious official limousine (the "Red Flag") is long lines of handcarts loaded with bricks, pulled by women between the shafts and pushed by others at the rear, bent almost horizontal. At the foreign visitors' hotels, guests' bags are hauled up to the rooms by teen-age girls who do not seem to mind at all. Hundreds of millions of people are doing these things 6 days a week, taking a short break only to spoon a bowl of rice, vegetables, and bits of fish or meat. Nobody looks hungry or inadequately clothed.

On Sunday, Heroes' Square is dense with silent and orderly regiments of people waiting by the hour to enter the massive mausoleum of Chairman Mao and glimpse the body as it lies in state with an honor guard of soldiers armed with bayonets. Once back in the streets, they pack the sidewalks and the shops, crowd around the ice-cream vendors, and stand 30 or 40 deep, reading the wall posters. They find pleasure in books, radio, museums, the arts, and the movies. Although they follow the Marxist line and emphasize pragmatism and realism, they turn to fantasy for entertainment. We were treated to movies and an operetta, all of which featured romantic fables out of the long ago, with lovers separated and then rejoined by the interventions of good fairies, bad fairies, magic, and dragons. The singing was haunting and the dancing exquisite, but the plots would not meet a Western standard of realism. But the cinemas are crowded and the people cannot get enough of them despite the poor quality