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ILLUSTRATION BY SEÑOR SALME

How science saved China

Shellen Wu traces the rise of the dominant force in science, in the second of a series of essays on the ways in which the past 150 years have shaped today's research system.

The opening ceremony of the 2008 Olympic Games in Beijing featured ancient China's four great inventions: the compass, printing press, paper and gunpowder. The lesson on display, as taught in classrooms across the country that today publishes the most research papers, is that Chinese innovation in science and technology changed the world.

Yet less than a hundred years before, the Chinese philosopher Feng Youlan wrote the provocative essay '*Why China Has No Science*'[1]. The scholar — trained at Columbia University in New York City — argued that from antiquity, the nation's philosophical traditions and unique understanding of the human relationship to nature had prevented the spirit of scientific inquiry from taking root. Feng, like many others at the time and since, urged that science was the only salvation for a nation in precipitous decline.

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Placing the efforts to change the perceived lack of science in the context of China's turbulent modern history is key to understanding how the nation arrived at its current superpower state. The red thread that runs through China's past 150 years is its unwavering belief in science as the path to wealth and power. The entangled relationship between research and nationalism in China has obscured how this belief grew ▶

from a combination of foreign influence and Chinese adaptation[2,3]. Particularly in the 1960s and 1970s, the Chinese government tried to focus on home-grown science, and succeeded in areas such as agriculture and medicine. But in the longer view, the periods of greatest advancement were those when China opened to outside influence.

It's a salutary lesson as we brace for the challenges of the next 150 years, including climate change, resource depletion and space exploration. These require a broad engagement with the world.

BESET BY DISASTERS

Catastrophes created the conditions for the development of science and technology in China. The last imperial era, the Qing dynasty (1644–1912), faced a series of humiliating defeats to foreign powers in the nineteenth century, starting with the First Opium War in 1839. These, and the subsequent opium crisis, led to one of the largest ever domestic uprisings. The Taiping Rebellion (1850–64) laid waste to the wealthiest region in the middle of the country, and resulted in as many as 50 million deaths.

In 1868, the year before *Nature* was founded, the first textbook of Western science was published in Chinese, *Introduction to Natural Philosophy* (*Gewu Rumen*). It was intended for students at the Interpreters' College, a school opened by reformers who sought to adapt the empire for a changing world by teaching aspiring officials foreign languages and knowledge from the West. The American who translated the book, William Martin, had no background in science, but understood its importance for improving the fortunes of a country beset by disasters. The book contained illustrations of microscopes and trains, and basic explanations of an idiosyncratic assortment of concepts in chemistry, electricity and physics.

Martin and other Protestant missionaries who headed to China in the nineteenth century saw the country as the next frontier in spiritual salvation. The introduction of science through Martin's textbook and other translated works provided an opening and a way to improve the material well-being of the vast population of an impoverished country. The Chinese people who worked on the translations were less interested in spiritual salvation, but recognized the importance of science as the foundation of the West's growing military and economic might. They saw its lack as the reason for China's state of backwardness.

By 1863, mathematicians Xu Shou and Hua Hengfang built China's first steamship, using illustrations from a missionary magazine as a guide. They then helped to establish a translation bureau that introduced numerous scientific works to China. By the end of the nineteenth century, many more Chinese people were convinced that what made the West rich and powerful was science and technology. Thousands of students ventured abroad to study, many to Japan. Seeing science as the way to alleviate their country's woes, they returned home eager to establish their fields.

As the dynasty collapsed in slow motion, missionaries and other representatives of foreign powers became increasingly assertive in the interior. In the hot, dry summer of 1900, simmering tensions burst into the open. Rebels, aiming their ire at foreigners, laid siege to the diplomatic quarters in Beijing. In the first international news sensation of the new century, troops from eight countries, including Britain, the United States and Japan, rescued the trapped diplomats.

"The country's biggest challenges were to feed and improve the living standards of a vast and growing population."

In the frenzy of destruction and looting that followed, French and German soldiers claimed the observatory on the outskirts of the old city that contained astronomical instruments made for the court by Jesuit priests in the seventeenth and eighteenth centuries. The Germans shipped home a haul of astrolabes and sextants, elaborately decorated with dragons and other royal motifs. (These were displayed in the grounds of a palace at Potsdam outside Berlin until 1919, when the Treaty of Versailles stipulated their return). Worse, the eight invading countries imposed sizeable indemnity payments. These bankrupted the Qing state and hastened its demise.

With part of their spoils, the Americans established a scholarship fund — money that a generation of the best Chinese students used to study in the United States. In January 1914, a group of them established the Science Society of China at Cornell University in Ithaca, New York.

NATION BUILDING

So it was that the flagship organization of Chinese science in the first half of the twentieth century came to be abroad. The founders and subsequent students mostly returned to China and became leaders of their fields, at a time when political instability and lack of centralized funding made research a herculean task. Trained in disciplines that many viewed as essential for the building of a modern country, they set to work on agricultural science, genetics, biology, chemistry and more[4].

For example, a group of mostly foreign-trained geologists persistently called on the government to sponsor a national resource survey. One, Ding Wenjiang, who co-founded the China Geological Survey in Beijing in 1915, became a prominent public intellectual, engaging in widely publicized debates and calling for increased state funding for the sciences[5]. His tireless promotion helped geology to become the most cohesive and internationally respected Chinese science in the first half of the twentieth century.

Meanwhile, Xu Chongqing and Li Fangbai, two Chinese physicists educated in Japan, introduced Einstein's theory of relativity[6]. Rockefeller fellows Li Ruqi and Tan Jiazhen returned from the United States to head leading biology and genetics departments. The biologists Hu Xiansu and Bing Zhi advocated for taxonomic study of Chinese flora and fauna[7,8]. In the decades that followed, these scientists grew increasingly wary of basing their research agenda on foreign models, seeking instead to build a specifically Chinese science.

Around this time, the phrase 'saving China through science' ('*kexue jiuguo*') appeared frequently in popular writings. Poverty and political turmoil haunted the overseas students. Learning plant physiology and genetics at Cornell, Jin Shanbao was sent spoilt food as a prank by US students, who teased him that it was for his starving countrymen. Deeply upset and eager to alleviate China's suffering, Jin returned home before finishing his graduate degree. He went on to develop high-yield varieties of wheat, writing "food is the first necessity of people, agriculture is the foundation of the country"[9].

The belief that science would save the nation reached its height during the Japanese invasion, starting in 1937. Facing vastly superior forces, the Nationalist government retreated far west to the mountainous province of Sichuan. Many scientists willingly followed. Geologists, for example, continued their work from a farm house outside the wartime capital of Chongqing.

Photos taken by the British biologist Joseph Needham when he visited in 1943 capture the meagre facilities and the spirit of patriotism among the scientists he encountered. Entranced, he started to study the history of science in China. (Needham went on to publish a monumental book series called Science and Civilisation in China that helped to popularize the idea of the four great ancient inventions inside the country, as well as around the world.)

In sum, an eagerness to solve national problems through science prevailed even before 1949, when Marxist ideology prioritized the applied over the theoretical. Throughout the twentieth century, the country's biggest challenges were to feed and improve the living standards of a vast and growing population. Whatever their political affiliations, most of the leading Chinese scientists of each era devoted themselves to meeting these challenges.

SCIENCE FOR ALL

This year — 2019 — is a year of anniversaries. The May Fourth Movement of 1919, a response to the allies' betrayal of China at Versailles, defined a generation of Chinese

JASON LEE/REUTERS

Liu Yang became China's first female astronaut in 2012.

intellectuals. Student protests in Tiananmen Square in 1989 built on this tradition, and became a turning point in China's era of 'Reform and Opening'. This month marks the seventieth anniversary of the founding of the People's Republic.

In hagiographic accounts of an era replete with horrors, 1949 was the beginning of a 'New' China. Such misleading histories gloss over the continuities in the sciences across the regime change. When the Communists crushed the Nationalists in the civil war that followed Japan's defeat in 1945, most scientists stayed to help rebuild. The new regime continued efforts to develop science that had begun in the previous era.

Although the ranks of Chinese researchers remained largely the same, in the first decade of the Communist regime, the rhetoric changed dramatically. Science was now explicitly defined as an endeavour of and for the people. Einstein and relativity were out, surveys and mass-health campaigns were (even more) in. At the peak of Sino–Soviet cooperation in the 1950s, 10,000 Soviet advisers worked across China to provide technical and scientific aid to the country's industrial development.

The Communist Party oversaw a complete restructuring of the country's universities and research institutions to remove US and European influence and model them after those in the Soviet Union. Academia Sinica, China's premier research institution, established by the Republican government in 1928, was reorganized into the Chinese Academy of Sciences (CAS). Soviet specialists helped to set the first five-year agenda of CAS to focus on resource extraction and other practical applications.

In fact, this agenda did not differ radically from the war-time research focus of many Chinese scientists[10]. Nor did the Chinese scientific community capitulate entirely to Soviet influence. For example, the pseudogenetics of Lysenkoism, so disastrous for agriculture elsewhere, never became the official position owing to strong resistance from prominent Chinese biologists, despite intense political pressure.

The material constraints of conducting science in a poor country shaped this generation of Chinese researchers. Those who continued to make significant progress downplayed their Western training and expertise, emphasizing instead their empathy for the masses. After receiving his PhD at the University of Minnesota in Minneapolis in 1949, entomologist Pu Zhelong returned to mainland China and called for the use of insects over expensive chemical pesticides (which turned out to be the more environmentally sustainable route). In the 1970s, agricultural scientist Yuan Longping and others created hybrid rice, leading to China's own green revolution. Yuan is said to have learnt from his interactions with farmers in the fields[11].

The Maoist era also diversified the scientific workforce. Women, peasants and young people were encouraged to challenge the social hierarchy in their villages and workplaces and extolled for their contributions to science. For women, in particular, the 1950s and 1960s dramatically opened up horizons and allowed them to participate in science to an unprecedented degree. Tu Youyou, for example, who won a Nobel Prize in Medicine, did the bulk of her research on the antimalarial qualities of artemisinin during these years. (The transformation was temporary. In the past four decades, gender biases have returned along with market reforms.)

But scientists who had longed for a robust state and support for research were quickly disappointed. The Cultural Revolution starting in 1966 shut down the CAS and all universities. Overseas educations became a liability, and the same researchers who had stayed in China out of patriotism in earlier decades found themselves the targets of attacks against elitism. Revolutionary credentials were seen as more important than specialist knowledge. The engineering of dams and other large-scale projects to build socialism by overcoming nature sometimes proceeded against expert advice[12,13].

ADRIAN BRADSHAW/EPA/SHUTTERSTOCK

Yuan Longping helped to create hybrid rice that gave rise to China's green revolution.

Projects important to national defence, including nuclear, rocket and satellite research, designated the 'Two Bombs and One Satellite' programme, continued to receive much state support and were protected from political intervention. Led by Chinese scientists, most of whom had trained in Europe and the United States, China became a nuclear power in 1964, and had its first successful satellite launch in 1970.

Fifty years ago, the outlook for science in China more generally was bleak. Many fields ground to a halt as the very institutional structure supporting the advancement of science shut down during the decade of the Cultural Revolution. Elders of science spent years labouring on remote farms and in reform camps. In the personal diaries of CAS vice-president Zhu Kezhen, a meteorologist trained at Harvard University in Cambridge, Massachusetts, stretches of days in the 1960s featured little but "sweeping". Many fared much worse, some even died. But the idea that science and technology formed the bedrock of modern society never completely disappeared.

When the United States and China re-established relations in 1972, US scientists were quick to visit[14]. Most did not realize the extent of the political suppression their colleagues had faced and were excited by the prospect of exploring socialist science. They noted the stagnant state of theoretical research; fields such as particle physics were decades behind the West.

The visitors were impressed by some advances made given the straitened circumstances. In addition to its green revolution, the nation had made significant progress in public health: mass campaigns helped to wipe out schistosomiasis, an infectious diseases that was killing around 400,000 people per year. Many of the scientists involved had spent years in remote fieldwork sites without seeing their families.

After the death of Chairman Mao in 1976, the emphasis on science and technology bounced back. In 1978, Deng Xiaoping formally launched a policy known as 'Four Modernizations', which placed a renewed focus on agriculture, industry, national defence, and science and technology. By then, the universities and CAS had reopened, and their leaderships were eager to get cracking.

In the decades since, the Chinese economy has outwardly come to resemble that of a capitalist country. But the top-down approach forged in the Mao years is still clear. It created a centralized educational and institutional infrastructure for science, which has made it easy to direct strategic investment quickly. The robotics industry, for example, one of the key components of China's plan to move into high-tech manufacturing by 2025, is based in the northeast of the country because of the proximity to the CAS robotics research centre in Shenyang. Other areas of strength, such as materials science and engineering, also built on the previous era's interests in overcoming resource shortages and environmental challenges.

During this period of reform and opening, scientists who had trained abroad in the 1930s and 1940s and had survived the turmoil of the previous decades found their international networks had value again. A second wave of Chinese students embarked on overseas studies — 5.86 million between 1978 and 2018. Big government investments in the past few years have attracted that talent to return.

OPEN TO IDEAS

Over the past century and a half, the belief that science and technology can improve the nation has become deeply embedded in Chinese culture, visible in slogans painted on walls and posters from cities to the countryside. Unacknowledged in these displays is the connection between science and an openness to influences and ideas from abroad.

To walk around Beijing today is to see traces of the history of science everywhere. On the east side, on the Second Ring Road, are the Jesuit astronomical instruments, which rode the turbulent geopolitical tides of the twentieth century. On the other side of town, in a quiet corner of Beijing Zoo, a small sign indicates the place where, in the waning days of the Qing dynasty in 1906, the Ministry of Agriculture, Industry and Commerce opened the first station for agricultural experiments on 70 hectares of land.

In the northwest corner of the city, the Interpreters' College has become the elite Peking University; down the road, another college with historical ties to the United States is today's Tsinghua University, the leading science and technology school in China. Posters and public displays celebrate scientific development. In book shops, science fiction is the trendiest genre. In well-funded laboratories and state of the art field stations, China is rushing forwards with a firm belief in its status as a scientific superpower.

There is another story along this route, that of the engagements with the outside world that transformed the country. In the peaks and valleys of that story is a message — the future requires the internationalism that propelled China's rise in the past 150 years. ■

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