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Fermenting Hope: Penicillin Technology Aid and Sino–American Cooperation in the 1940s

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Article

Keywords: Penicillin, Localization, Sino-American Cooperation, Techno-Social Network

Posted Date: November 16th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11185508/v1

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Additional Declarations: No competing interests reported.

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Abstract: This study explores penicillin technology's transmission and localization in 1940s China, mapping the transnational techno-scientific network linking U.S. aid agencies, military forces, and China's regime-controlled regions. Drawing on published historical data, unpublished archival documents, this paper compares KMT-CPC parallel trajectories: both accessed U.S. strains and documents, but resource disparities led to divergent models—laboratory standardization vs. guerrilla-style local innovation. By analyzing the Penicillin for China Project's stagnation and Beiping Penicillin Factory's adaptation challenges, it reveals transnational aid coordination failures and tensions between standardized technology and local material foundations. This paper thus argues that technology transfer in non-Western contexts is not a mere transplantation of equipment or importation of knowledge, but a localization process dependent on the constant restructuring of techno-social networks. The multiple trajectories of penicillin in China illustrate the possibilities and limitations of scientific and technological modernization in wartime East Asia, and provide a new analytical perspective for understanding how technologies move and transform amid aid, war and political conflicts, and resource asymmetry.

Keywords: Penicillin; Localization; Sino-American Cooperation; Techno-Social Network

Introduction

Studies on the development of medical and health services in China during the Second Sino-Japanese War serve as a crucial lens for integrating three core research agendas: the transformation of Chinese medicine, the interplay between war and society, and state-building. "During recent decades, the study of Chinese medical history has turned from the 'great physicians' and 'great inventions' perspective to the social history of medicine" (Fang, 2012, p. 5). In the past decade or so, a series of seminal works on the social history of medicine have emerged, focusing respectively on the Republican period (Watt, 2014; Lei, 2014; Barnes, 2018; Brazelton, 2019a; Soon, 2020; Ji, 2024; Pi, 2025), the People's Republic of China (Fang, 2012, 2021; Zhou, 2020), and the entire twentieth century of China (Andrews & Bullock, 2014; Chiang, 2018).

Medical relief emerged as a critical agenda during the Second Sino-Japanese War. The modernization of medicine in wartime China was a complex process co-driven by state institutions, civil society organizations, and foreign aid (Watt, 2014). External assistance from entities such as the League of Nations, the American Bureau for Medical Aid to China (ABMAC)[1], and the Sino-British Science Co-operation Office laid the institutional groundwork for the vaccine industry in China's wartime hinterland, embodying the dynamic tensions between global health

1 ABMAC was a humanitarian organization initiated in October 1937 and officially registered in December of the same year. ABMAC offered substantial support to the KMT government, particularly in medical supplies and equipment.

networks and localized Chinese practices (Brazelton, 2019a). Although ABMAC did not extend direct aid to the regions under the control of the CPC, the mobile medical teams of the Medical Relief Corps supported by ABMAC ventured deep into Yan'an[2](延安), delivering critical expertise for the establishment and operation of local hospitals (Soon, 2020, p. 75–85).

Among the technologies introduced via foreign aid, one further item merits our attention, namely penicillin. "The implications of penicillin for public health in Europe were substantial, but they were greater even in China." (Bud, 2007, p. 79) With the help of American aid organizations, both the KMT and the CPC border regions (*bianqu* 边区) acquired the techniques for penicillin production. The ABMAC contributed strains, experimental and manufacturing equipment to the National Epidemic Prevention Bureau's (NEPB) penicillin research, enabled Tong Cun (童村)[3] to study penicillin technology in the U.S., and relayed timely updates on the latest advances in American penicillin production. It also collaborated with the Indusco (Gung Ho 工合)[4] to establish the Penicillin for China Committee (PCC) and launched the Penicillin for China Project (PCP), aiming to build a penicillin plant in China. The China Aid Council (CAC)[5], relying on connections between the U.S. military and the CPC border regions, provided Yan'an with technical guidance, culture media, strains, and some equipment, and even considered building a penicillin factory in a CPC area. It is worth noting that all three of the institutions involved above were constituent organizations of the United China Relief (UCR)[6].

Among relevant studies, Zhou Xun has reviewed the history of the use and abuse of antibiotics in China from the second half of the twentieth century to the present (Zhou, 2023). She argues that penicillin, as a gift to war-torn China, provided alternatives to certain medical functions previously reliant on opium, transforming the paradigms of possibilities in Chinese therapeutic practices (Dikötter et al., 2004). However, the technical assistance for penicillin development is merely mentioned in passing and not elaborated on in detail. When it comes to research on this specific process, Mary Brazelton illustrates how the team at the NEPB overcame technical and material constraints to achieve the independent development of penicillin, the cognitive divergences and cooperative games that characterized the Sino-American interactions during the transfer of penicillin production technology (Brazelton, 2019b). While this research offers significant insights for the present study, it does not cover penicillin development in the regions under the CPC making it impossible to compare the distinct research paths of the two sides. Furthermore, several scholars in mainland China have also examined American

2 Yan'an was the capital of the Shaan-Gan-Ning Border Region (SBR 陕甘宁边区). Established on 6 September 1937, the SBR was an administrative unit under the leadership of the Communist Party of China (CPC 中国共产党).

3 Tong Cun (1906–1994) was a microbiologist who earned his doctorate from Peking Union Medical College in 1934. In 1940, he went to the U.S. to study at Johns Hopkins University, where he received a Doctor of Public Health degree in 1942. Tong returned to China at the end of 1945 and joined the NEPB. During his time in the U.S., he was engaged in research related to penicillin.

4 The American Committee in Aid of Chinese Industrial Cooperatives (Indusco) was a U.S.-based civilian aid organization supporting China's war effort from the late 1930s through the 1940s. Its primary goal was to promote the development of industrial cooperatives in China's rear areas by mobilizing resources, providing technical assistance, and conducting international advocacy.

5 The CAC was established in December 1937 as a branch of the American League for Peace and Democracy. It consisted largely of individuals sympathetic to the Chinese Communist revolution and the CPC.

6 Faced with the challenges of fragmented and uncoordinated fundraising efforts, several American aid leaders concluded that an effective contribution to China's relief efforts required a unified national organization. In February 1941, Henry R. Luce took the initiative to establish UCR, which brought together eight major U.S.-based aid groups, including ABMAC, CAC and Indusco.

technological assistance to China in the 1940s in their investigations into the early development of China's penicillin industry (Niu, 2001; Xu, 2015; Guan & Zhang, 2021).

From the perspective of source utilization, existing Western scholarship has not fully engaged with materials held in mainland China. Moreover, because these studies do not focus primarily on the interactions among American aid organizations, the KMT government, and the CPC in the development of penicillin, there remains substantial room for further use of relevant collections in the U.S. In terms of research orientation, existing studies often examine the medical systems of the KMT government and the CPC separately. Yet the most distinctive feature of China's wartime penicillin research lies in the fact that, despite reliance on foreign assistance, the KMT government and the CPC border regions pursued two markedly different technological trajectories. The former followed a laboratory-centered, academic route, whereas the latter relied on hands-on, site-based practical experimentation. As Angela Ki Che Leung argues, modern science and technology did not spread unilinearly from central regions to various peripheral areas; rather, "when Western culture encountered different 'local cultures,' it sparked distinctive forms of modernity." (Leung, 2007). Unlike the zero-sum logic often associated with wartime or political confrontation, both sides ultimately succeeded in the crude production of penicillin—an outcome that stands as a rare win–win case.

This study draws on archival materials from institutions such as Columbia University, the New York Public Library, and the United Nations Relief and Rehabilitation Administration, in conjunction with relevant Chinese sources. Adopting a transnational and translocal analytical framework, it examines the divergent technical strategies pursued by aid organizations such as the ABMAC and the Indusco in the course of penicillin assistance to China, and analyzes how inter-organizational communication barriers and institutional frictions ultimately contributed to the collapse of the PCP. It further reveals how the politically fragmented landscape during the war gave rise to pluralized and differentiated pathways of technological development, and examines the intertwined interaction between peripheral scientific practices and the localization of global knowledge.

This study argues that the ultimate achievement of penicillin production by both the KMT and the CPC—ranging from the relatively systematic experiments conducted with the infrastructure support of the Kunming (昆明) Laboratory to the manual fermentation methods implemented under the constraints of rudimentary equipment in the Yan'an base areas—was not merely a technological feat. Within the two distinctly different political contexts of the KMT and the CPC, penicillin was not a passively imported foreign technology. Instead, it evolved into a form of practice continuously translated, adapted, and materially reconstructed under the shaping influence of specific institutional environments and political conditions, ultimately giving rise to a technological configuration characterized by both territorial embeddedness and political orientation.

U.S. Aid and Wartime Penicillin Development in Kunming

The Second Sino-Japanese War was not only a test of China's national defense capabilities but also an extreme stress test for its medical and public health infrastructures. The overall medical capacity was roughly equivalent to that of the U.S. during the Civil War of 1865 (ABMAC Records, 1944c). This profound medical deficit compelled the KMT government to launch what

may be described as a program of technological emergency mobilization: on the one hand, importing vaccines and sera to mitigate epidemic risks among massive refugee populations; on the other, actively constructing transnational aid networks to enable the localized production of biological products (Brazelton, 2019a, p. 54-63).

As the Japanese forces advanced, the NEPB—responsible for communicable disease control and the production of biologicals under the KMT government—relocated to Kunming, Yunnan (云南), in August 1938 (Yip, 1995, p. 175). Situated at the intersection of the Burma Road and the Hump Airlift—the principal channels for external aid—Kunming's geographical advantage was transformed into a structural advantage for technological exchange. In late 1941, at a bureau-wide literature seminar, Technical Officer Wei Xi[7](魏曦) reported two *Lancet* articles on penicillin, which immediately attracted the attention of Tang Feifan (汤飞凡) and other scholars. As then director of the NEPB, a pioneer of Chinese microbiology and one of China's earliest researchers engaged in viral culture, Tang believed that penicillin could play a significant role in securing victory in the war (Tang, 1949). This moment marked the beginning of the NEPB's penicillin research program, which became the bureau's central focus over the following three years. At that time, however, penicillin research and production in Britain and the U.S. remained highly classified and under strict military control, leaving the NEPB unable to obtain strains through external channels. Inspired by locally made fermented tofu (霉豆腐), Tang drew on the idea that molds are ubiquitous in nature. This perspective triggered what researchers later described as a mold-hunting fever within the NEPB (Liu, 1999, p. 72). Researchers collected molds from shoes, old clothing, fruits, and even ancient coins. Based on Sabouraud and Czepek–Dox media, they incorporated locally available materials such as corn and brown sugar. After nearly two and a half years of experimentation, they succeeded in isolating eleven strains capable of producing penicillin, among which two strains—derived from a meat–broth medium and from shoe polish—proved most effective (Tang, 1949).

The year 1944 marked a decisive turning point in Kunming's penicillin research, signaled by the emergence of a transnational network of strains. In the spring of 1944, Tang and Huang Youwei[8](黄有为), supported by the Rockefeller Foundation, traveled to India to investigate public health conditions and brought back ten Penicillium strains previously isolated in the U.K. and the U.S. (Brazelton, 2019b) Around the same time, the British Red Cross donated another batch of strains to the NEPB (Liu, 1999, p. 72). In June 1944, Fan Qingsheng[9](樊庆笙) returned from the U.S., carrying three sand-tube strains donated by the University of Wisconsin and the ABMAC, along with glassware, chemical reagents, and other equipment supplied by ABMAC (ABMAC Bulletin, 1944). Significantly, Fan's dual institutional role—as Laboratory Director of the China Blood Bank (中华血库) affiliated with Kunhua Hospital (昆华医院), and as a collaborating researcher at the NEPB—helped forge a technical alliance between the two institutions. Drawing on his inspection of U.S. penicillin plants, Fan carried out technical benchmarking, concluding

7 Wei Xi (1903–1989), a Chinese microbiologist, studied at Xiangya Medical College and Shanghai Medical College before pursuing further training at Harvard University in 1937 under the mentorship of Hans Zinsser. He returned to China in 1939 and served as a senior technical officer at the NEPB.

8 Huang Youwei (?-1988), an overseas Chinese born in Hawaii, served as a senior technical officer at the NEPB and was a key assistant to Tang. He returned to the U.S. in 1948.

9 Fan Qingsheng (1911–1998) was a microbiologist who graduated from the Department of Agriculture at Jinling University, Nanjing, in 1933. He went to the U.S. in 1940 and earned his Ph.D. in philosophy from the University of Wisconsin in 1943. Returning to China in 1944, he served as a bacteriological testing technician at the Blood Bank.

that NEPB's methods were comparable to those in the U.S. (Tang, 1944)

A clear division of labor soon took shape: Tang oversaw strain preservation and the isolation of local variants; Zhu Jiming[10](朱既明) was responsible for assay development, standardization, and production; Huang handled extraction and purification; two staff members from the Blood Bank conducted clinical applications; Fan moved between the NEPB and the Blood Bank, conducting coordination and supervision (Fan, 1944). During this period, ABMAC regularly sent Tang and Fan the latest publications on penicillin production and clinical use (ABMAC Bulletin, 1944). All glassware, chemicals, and equipment required for penicillin research were purchased by ABMAC and stored at the NEPB, while the penicillin produced there was sent to the Blood Bank for testing and subsequent clinical trials in local hospitals.

The strains used by the NEPB included not only those isolated locally but also those obtained from international sources such as Lederle, Toronto, Wellcome, Eli Lilly, as well as strains from Haffkine, Bangalore, Evans, Panja 256, and Johns Hopkins (Chu et al., 1945). This local–international hybrid strain portfolio provided crucial support for penicillin research, and the NEPB succeeded in purifying penicillin at a concentration of 5,000 units per milliliter (Fan, 1944). As Tang later recalled, although the technical difficulty of this process was not insurmountable, progress was temporarily hindered by the lack of amyl acetate. The difficulty was resolved when U.S. military forces supplied several pounds of the amyl acetate, allowing extraction to continue smoothly. Tang further noted that once the preliminary phase was completed, the U.S. Army provided a 100,000-unit Pfizer penicillin preparation as a reference standard. Comparison showed no significant difference between the U.S. sample and the NEPB product. Subsequently, the U.S. Food and Drug Administration sent an official standard, and after verification against this benchmark, the NEPB initiated clinical trials. Huadian Hospital (惠滇医院) and Kunhua Hospital in Yunnan conducted treatments for surgical wounds, and patients recovered rapidly.

On September 5, 1944, the NEPB completed the first batch of domestically produced penicillin—five vials containing 5,000 units each—and publicly announced this achievement (Tang, 1949). One vial was retained for internal use, two were sent to the U.K. and the U.S. for testing, and two were dispatched to Chongqing (重庆) (Liu, 1999, p. 72). The achievement of this breakthrough was made possible not only by the knowledge reserves of the core research team but also by the transnational support provided by ABMAC, as well as the creative use of local resources. Among the central members of the NEPB penicillin research and clinical trial team, all but one had received training in the U.S., and the assistance of the ABMAC played a decisive role. ABMAC not only supplied essential technical support and material resources but also helped cultivate Penicillium spores, provided experimental and manufacturing equipment, and relayed updates on the latest U.S. methods of penicillin production through continuous correspondence with Chinese scientists. With this support, Kunming briefly became a major center of penicillin research in China.

The NEPB's trajectory in developing penicillin offers a microcosm of wartime China's technological emergency response. It reveals the complex pathways through which scientific and technical capacities emerged in peripheral regions—not as a passive transplant dependent on metropolitan centers, nor as an isolated form of innovation detached from global networks, but as a negotiated process shaped by a threefold dynamic of local problem definition, transnational

10 Zhu Jiming (1917–1998), virologist. After graduating from Shanghai Medical College in 1939, he served as a technician at the NEPB in 1940.

resource integration, and situated practical adaptation.

The wartime alliance forged turbulent cooperative relations between the U.S. government and the KMT government. Following the outbreak of the Pacific War, the KMT government became increasingly dependent on U.S. assistance for its war effort against Japan. Its political legitimacy and governing authority depended critically on U.S. recognition and support (Tao, 2016, p. 202). Leveraging its status as a wartime ally, it sought to secure material and technical assistance from the U.S. Against this backdrop, it is hardly surprising that the NEPB introduced American bacterial strains, adopted American laboratory equipment, and complied with U.S. potency standards. Core researchers such as Tong and Fan had received their scientific training in the U.S. and thus naturally embraced American conceptual frameworks and laboratory protocols in microbiological research. By aligning its pharmaceutical research with dominant international scientific standards, the KMT government sought to demonstrate its capacity for modern scientific research to the international community. These initiatives ultimately served the political objectives of gaining American endorsement, securing external assistance and shaping the image of a modern regime, rather than prioritizing the practical demands of wartime drug provision in remote areas and frontline medical relief. This developmental path was distinctly different from that adopted by the CPC in penicillin research and development.

Contesting the Penicillin Plant

The surge in wartime pharmaceutical consumption in China brought the structural tension between reliance on foreign aid and indigenous autonomy to the forefront. This was a concrete manifestation of infrastructural inequality in the pharmaceutical field: the circulation of technology was never a neutral exchange of commodities but a process embedded in power relations and resource distribution (Star, 1999). Around the project of establishing a penicillin plant, organizations such as the ABMAC and the Indusco along with some officials of the National Health Administration of the Republic of China, engaged in extensive communication and discussion.

The ABMAC and Indusco adopted a conservative stance regarding the penicillin plant. Their plan was to first build a plant in the U.S. and then transport it in its entirety to China. On 6 March 1944, ABMAC and Indusco planned to establish an experimental penicillin plant in the U.S. with a daily production capacity of 100 liters, and designated Tong and the chemist Norman Applezweig to determine the optimal method for penicillin production in China (Applezweig, 1944). On 14 March, Tong and Applezweig visited Dr. J. F. Mahoney at the Staten Island U.S. Marine Hospital, with the primary purpose of exploring a production method “adapted to Chinese conditions.” (Applezweig, 1944) Two days later, at an ABMAC executive meeting, ABMAC and Indusco jointly established the PCC and launched the PCP (ABMAC Records, 1944g).

The core goal of the PCP was to set up a pilot penicillin plant in New York to clarify how the highly mechanized U.S. industrial practices could be translated into simpler, more rudimentary conditions suitable for development in China, while also addressing the critical issue of producing penicillin using only materials available in China and without relying on indispensable U.S. raw materials. It assumed that technology could only function effectively when embedded within local material networks (Bray, 1997, pp. 369–372). Notably, under the transportation conditions of the time, shipping U.S. equipment directly to China was technically and logistically feasible, and

would have saved both time and money. ABMAC and Indusco's insistence on the U.S. first approach was largely shaped by previous failures in cooperation with the blood bank—the assessment that "sending trained teams and U.S. equipment to China was completely impractical" (ABMAC Records, 1944i)—which further entrenched an underestimation of local Chinese capacities and produced a center-to-periphery bias in technological judgment.

In its early stages, the PCP progressed rapidly. On 18 March 1944, ABMAC and Indusco officially announced the members of the PCC and set a budget of $25,000–35,000 for the New York pilot plant (ABMAC Records, 1944h). On 5 April, the PCC appointed Tong as director of the PCP (ABMAC Records, 1944d). The PCC also resolved that Indusco would prepare the necessary bottles and rudimentary refrigeration equipment, and proposed preliminary localization measures, such as substituting brown sugar for lactose, oil drums for autoclaves, churns for mixers, and cream separators for Sharples centrifuges (ABMAC Records, 1944d). At the PCC meeting on 17 May 1944, it was decided that ABMAC and Indusco would each apply to the UCR for $15,000 as funding for one year of the PCP, and agreed to rent laboratory space at the Brooklyn Polytechnic Institute for $300 per month, with Applezweig serving as co-chair of the PCC (ABMAC Records, 1944e).

Just as the PCP appeared to be on the right track, the differences within the PCC quickly intensified and developed into a fundamental rupture. Applezweig and Tong insisted on a "New York laboratory first" approach, believing that only domestic production could achieve true technological autonomy (Applezweig, 1944). Donald Van Slyke advocated "large-scale procurement first, production later" (ABMAC Records, 1944f). Chinese officials such as Lin Kesheng[11](林可胜,Robert K. S. Lim) and Liu Ruiheng[12](刘瑞恒) supported "building a factory directly under Kunming's existing conditions." Lin proposed establishing a small plant by relying on the resources already available at the National Central Laboratory; Liu suggested immediately transporting equipment to the NEPB and dispatching experts, arguing that "setting up a plant in New York would be a waste of time." (ABMAC Records, 1944b) Jin Baoshan[13](金宝善) likewise supported beginning with the NEPB and the Northwest Epidemic Prevention Bureau and then expanding gradually (Jin, 1944). The collision of these viewpoints was, in essence, a contest between technological autonomy and aid-based dependence, a fundamental disagreement over standardized models versus local conditions.

The penicillin meeting of 13 June 1944 became a crucial turning point for the PCP. The statement by Co Tui, chairman of the ABMAC, directly undermined the foundation of the project. Citing the "rapid iteration of penicillin production techniques and control mechanisms," he called for the establishment of a special committee of scientists to evaluate "whether it remained necessary to continue developing production methods suited to China," and announced the suspension of commitments to procure equipment for the factory until the committee's report was completed (ABMAC Records, 1944a). Although this justification appeared technically sound, it was in fact untenable. As early as 14 March, during Tong's visit to the Marine Hospital, Dr.

11 Lin Kesheng(1897–1969) served as Chair of the Department of Physiology at Peking Union Medical College from 1925 to 1935. After the outbreak of the war, he took office as Commander of the Medical Relief Corps, and was appointed Director of the Military Medical Administration in 1944.

12 Liu Ruiheng (1890–1961) was one of the founders of modern public health in China. He received his M.D. from Harvard University in 1915 and later served as the dean of the Peking Union Medical College and as Minister of Health from 1928 to 1937.

13 Jin Baoshan(1893–1984) was a public health scientist who served as the Minister of Health from 1940 to 1947.

Mahoney had already informed him that “penicillin could already be produced on a large and inexpensive scale in the U.S., and the technology was advancing rapidly” (ABMAC Records, 1944j)—a fact of which Co Tui was fully aware.

The real reason behind Co Tui’s decision was that the PCC had by then learned of the technological breakthroughs made by the NEPB in Kunming. By May 1944, NEPB had already obtained five indigenous strains of penicillin, a number that had increased to twelve by July. Chinese officials’ insistence on establishing a domestic plant was grounded precisely in their detailed knowledge of NEPB’s progress. The disappearance of this information asymmetry” shattered ABMAC’s prior assumption that China was incapable of producing penicillin.

Existing sources indicate that by July 1944 at the latest, the laboratory in Kunming possessed the technical capacity to produce penicillin. On 22 July, Tang wrote to Jin and enclosed a dried sample containing 1,500 units of penicillin (Tang, 1944), asking him to use this evidence to request equipment from the American Red Cross or the ABMAC with the aim of raising output to roughly 25,000 units per day. Although ABMAC may not have known every detail, the frequency of correspondence between the two institutions makes it clear that ABMAC was aware that NEPB had already mastered penicillin production on a laboratory scale.

Against this backdrop, ABMAC came to view purchasing and shipping penicillin to China as more feasible than establishing a pilot plant. On 25 July, its Executive Committee resolved to withdraw from the pilot-plant project. Because the plant had been conceived as a commercial undertaking, they argued, questions of policy, staffing, and expenditure required unified control; and since the initiative had originated with the Indusco, the project should be left entirely in Indusco’s hands. ABMAC itself shifted its focus to procuring penicillin and supporting Chinese researchers’ technical training in the U.S. (Van Slyke, 1944); notably, the resolution did not cite China’s emerging production capability as the reason for ABMAC’s withdrawal.

On September 22, 1944, the PCC convened a meeting at the New York office of the ABMAC. Meanwhile, China had already acquired a certain level of production capacity (ABMAC Records, 1944i). ABMAC thus formally withdrew from the PCP and transferred all authority to Indusco. It simultaneously resolved to expand penicillin procurement for China, to purchase equipment for Tang, to expedite Tong’s return to Kunming, and to urge Chinese officials to lobby the U.S. government for a larger national allocation of penicillin (ABMAC Records, 1944i). On 28 September, Indusco’s board likewise voted to terminate all penicillin-related activities. Their reasons included: Tong’s pending return to China, which would leave PCP without leadership; ABMAC’s plan to redirect equipment originally intended for a U.S. plant to Kunming; China’s demonstrated ability to produce penicillin; and the fact that penicillin experiments conducted in China by the U.S. Department of Agriculture and the Henry Ford team already promised far greater capacity than the proposed pilot plant (Pruitt, 1944). Indusco consequently withdrew fully from the project. With these decisions, the PCC was dissolved and the PCP effectively came to an end.

The termination of the PCP deeply frustrated Tong, who stated that he “had no immediate intention of returning to China” (Tong, 1945). He clearly recognized that the dual constraints of the explicit system of “protecting trade secrets” and the implicit logic of “center-periphery technological hegemony” had preemptively blocked the path to acquiring penicillin production experience through American commercial factories (Stevens, 1944). This insight drove him to break free from the linear mindset of technological transplantation and shift toward indigenous

technological restructuring—he proposed a modular tank-based factory scheme, planning to distribute and replicate production facilities regionally after their shipment to China (Stevens, 1944). He established close ties with the Northern Regional Research Laboratory and the War Production Board to obtain technical information, transmitted strains and inspection reports to Tang via the ABMAC, and repeatedly advised that "Tang should go to the U.S. for an inspection as soon as possible—the earlier, the sooner China could achieve penicillin production." (Tong, 1944). Yet Tong was ultimately powerless to reverse the project's decline. Because Tong lacked the institutional authority to determine the PCP's trajectory, his individual endeavors remained perpetually constrained by transnational organizations.

The collapse of the PCP stemmed from the interplay of multiple intertwined factors. First, it resulted from the disconnection between technological imagination and local practices. The breakthroughs in China's indigenous penicillin technology—exemplified by the NEPB successfully developing penicillin in underdeveloped conditions—rendered ABMAC's "industrial transplantation" plan obsolete and unnecessary. Second, it stemmed from the communication breakdown and the shirking of responsibilities among transnational organizations. In a memo to Helen K. Stevens in late 1944, Tong explicitly pointed out that "the lack of equipment and materials was one of the primary causes of the project's failure" (Tong, 1945). Some supplies, which were supposed to be provided with the support of the American Red Cross, never materialized. Tong's lament that he "wished they would honor commitments as faithfully as the ABMAC" (Tong, 1945) vividly reflected the fragmentation of this institutional landscape.

The three-month delay between the PCC's budget resolution in May 1944 and the eventual funding notice in August, as well as the informal shift by the UCR to move the PCP from joint institutional oversight to Indusco's sole responsibility, both revealed structural deficiencies within the transnational aid network—namely, slow decision-making and unclear boundaries of authority. Had the disbursement of funds been more efficient, Tong might well have proceeded with the construction of the New York pilot factory in time, poten+tially altering the project's fate.

The termination of the PCP marked the withdrawal of the Americanized technological template, while simultaneously highlighting the consolidation of the NEPB's "simplified, clinically oriented" pathway to penicillin production—a pathway that, although it did not achieve industrial-scale output, was precisely aligned with wartime China's severe resource constraints. The history of the PCP demonstrates that the success of technology transfer depends on respecting the material conditions and technological agency of peripheral regions, rather than rigidly adhering to standardized models developed in metropolitan centers. It is worth reflecting that if evaluated by conventional criteria of technological success, the PCP was undoubtedly a failure. Yet it provided a paradigmatic case for understanding the complexity of wartime technology transfer. Its collapse revealed that the core obstacles to transnational technological exchange often lie not in the technology itself, but in institutional cognitive biases and failures of coordination.

Transnational Science under Wartime Conditions: Sino–American Cooperation in Penicillin Development Within the CPC-Controlled Areas

The CPC's development of penicillin provides a paradigmatic case for understanding the transnational circulation of scientific and technological knowledge during wartime. This process was not merely a technological journey from nothing to something, but a dynamic practice in

which science, politics, and geopolitical strategy became deeply intertwined. The story of Yan'an penicillin demonstrates how peripheral regions within global scientific networks achieved localized innovation through translation, while simultaneously exposing the power relations embedded beneath the rhetoric of humanitarian aid.

In sharp contrast to the technical approach adopted by the KMT government, the CPC did not copy established laboratory research systems. Instead, it adopted localized, makeshift innovations by utilizing available local resources. This strategic choice was neither a passive compromise resulting from inadequate technical foundations nor a deliberate rejection of modern scientific paradigms. Rather, it emerged as a wartime emergency technological mobilization mechanism amid prolonged military blockades, economic embargoes, and the complete severance of formal external technical exchanges imposed by the KMT side. Penicillin research and development in border regions never aimed to conform to international academic norms or seek external recognition. Its core objectives centered on battlefield casualty treatment, public health maintenance in border areas, and self-sufficiency in strategic pharmaceuticals.

The CPC's pursuit of penicillin began in Yan'an, and its technological starting point was closely intertwined with the involvement of the CAC. In September 1944, the organization—working through the U.S. Army Observation Group—supplied a more systematic package of crucial materials, including a steam-pressure sterilizer, six tubes of Penicillium notatum strains, agar, lactose, corn starch, calcium carbonate, test tubes, a collection of printed manuals and microfilms on penicillin production and clinical use (Frey, 1945), as well as a strain of Staphylococcus aureus (Frey, 1946a). By late April 1945 at the latest, the Affiliated Hospital of the Chinese Medical University in Yan'an had successfully produced penicillin and cured five patients within a span of just over twenty days (Frey, 1945)—the earliest documented evidence of penicillin research under the CPC.

Behind this breakthrough lay the dual logic of the U.S. wartime scientific aid network. CAC's support embodied a characteristic humanitarian–strategic duality. On the one hand, the organization assembled a team of professional scientists to design a customized production plan for Yan'an, hoping that this case would draw American public attention to the medical institutions in the CPC-controlled areas and their urgent needs (Aaron, 1945). The prevalent belief in Western modern scientific medicine's life-saving capacity during wartime profoundly shaped the philanthropic ethos underlying China's medical assistance programs (Barnes, 2018, p. 128). On the other hand, the initial penicillin strains in Yan'an were delivered by U.S. military aircraft coordinated by the Cultural Division of the U.S. Department of State (Carte, 1945) through the CAC. Furthermore, given the stringent blockade imposed by the KMT at that time14, U.S. military aircraft constituted the only viable means to breach the tight encirclement. As China's war against Japan entered its final phase, the U.S. military sought to leverage the extensive guerrilla bases that the CCP had established behind Japanese lines in order to gather military intelligence and rescue downed American airmen. After repeated setbacks in military cooperation with the KMT forces, General Stilwell and his staff were also eager to explore the possibility of coordinating U.S. and CCP military activities (U.S. Department of State, 1944). Such strategic considerations underscore that U.S. assistance carried not only humanitarian significance but also explicit military objectives.

14 To suppress the CPC, the KMT government constructed a three-tiered concentric network of blockhouses surrounding the SBR. By the end of 1940, there were as many as 2,000 such blockhouses.

On May 17, 1945, *Liberation Daily (*解放日报)—the official newspaper of the CPC Central Committee—first revealed that the SBR would report progress in penicillin development at a medical academic conference ("Liu yan guoji you ren," 1945). At this conference, Richard Frey (1917–2004), an Austrian-Jewish physician and key figure in penicillin research and development in Yan'an, introduced the main process of developing penicillin by a three-person team including himself ("Fu lai yisheng jiang cu zhi," 1945). Compared with the NEPB's over 30-month journey of penicillin research and development, this process was called the penicillin legend.[15]

Behind the legend lies differentiated innovations of two distinct technological practices within the unified framework of modern microbiology. The rapid progress achieved in Yan'an cannot obscure the profound disconnection between imported scientific protocols and local material conditions. While the cognitive logic of microbiology remained consistent, and no fundamental divergence existed in the research procedures for strain screening and indigenous strain isolation adopted by both CPC and KMT sides, the material logic of production underwent a thorough transformation. The KMT practice operated within relatively standardized laboratory frameworks to minimize experimental variables, whereas research teams in Yan'an followed a guerrilla-style improvisational logic. The absence of unified standards compelled researchers to actively regulate all practical variables.

As a national epidemic prevention institution under the KMT government, the NEPB, though displaced before relocating to Kunming, had government support and a relatively solid foundation. With strong assistance from the ABMAC, it could already produce smallpox and rabies vaccines in early 1939, and even built a new campus in 1942 (Liu, 1999, pp. 58-61). Yan'an, by contrast, faced multiple predicaments. The first predicament stemmed from the research team. Unlike the professionally trained staff of the NEPB, the Yan'an team lacked sufficient training in modern science. We do not know the disciplinary backgrounds of Frey's two assistants; Frey himself had only received training in clinical bacteriology and lacked knowledge of industrial chemistry. The printed materials provided by the CAC also failed to cover all aspects of penicillin research, forcing them to read, experiment, and explore simultaneously. The second predicament was the discontinuity of external support: while the NEPB could constantly maintain contact with the U.S. to obtain first-hand information, Yan'an's development relied on a one-time one-way connection (Frey, 1946a). The greatest difficulty came from laboratories and equipment: Yan'an had no modern workshops, advanced fermentation equipment, or precision testing instruments—even nails and sewing needles were hard to produce.

Such predicaments gave rise to a distinctive practice of knowledge translation. The Frey team transformed aseptic operations and constant-temperature cultivation requirements of standardized laboratories into functional zoning designs adaptable to cave dwellings, and converted written technical specifications for fermentation and purification into indigenous crafts feasible with local materials and manpower. Such reconstruction of Western bio-manufacturing knowledge did not rewrite biological principles, but rather restructured the laboratory in both physical and social dimensions. It was merely the hardware and operational frameworks that underwent reconstruction, rather than scientific theories themselves.

15 Madame Sun reports by Zhongguo fu li hui; Song, Qingling, 1948, 27–28. Available at https://archive.org/details/madamesunreports00zhon/mode/2up.

While the materials provided by the CAC laid the theoretical foundation, their implementation in practice necessitated prior localization—the construction of cave (窑洞) laboratories. To satisfy the core conditions including constant temperature, aseptic isolation and light avoidance required for penicillium cultivation, researchers in the border regions renovated cave dwellings in light of local conditions and established uniquely localized cave laboratories. See Figure 1. Frey divided the experimental space into a sterile corridor, an isolation buffer room, and several small experimental chambers. To maintain a constant temperature, an underground heated brick bed controlled by external fire was built beneath the floor to accommodate microbial growth. To ensure aseptic operation, staff members entering from outside were required to first enter the isolation buffer room, change into sterile clothing, caps, and shoes, clean their hands, put on masks, and then enter the constant-temperature workroom through the sterile corridor (Jiang, 2015, pp. 48-58).

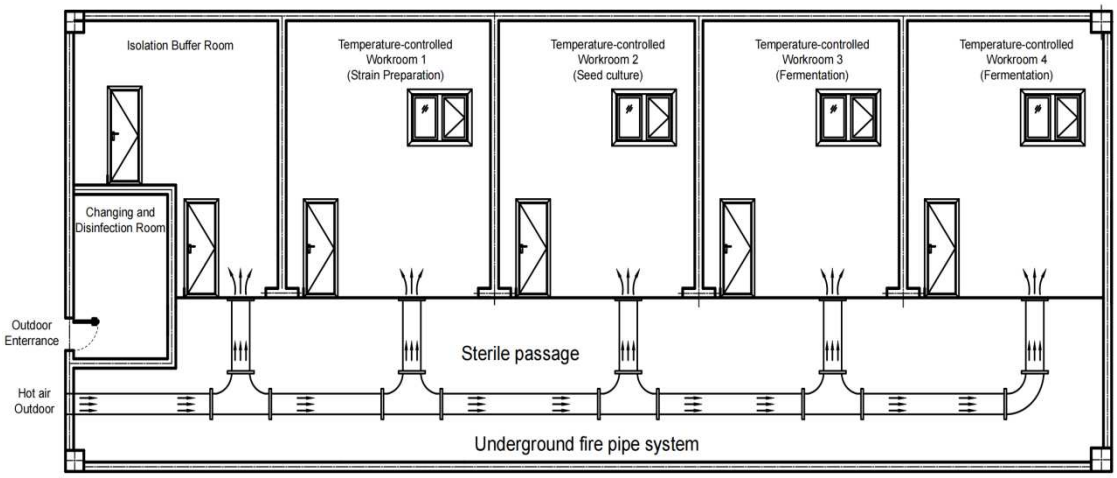


Figure 1 Plan view of the Penicillin laboratory in the cave of the 1940s in Yan'an

From the perspective of technological spatial logic, Yan'an cave laboratories were not low-end replicas of Western bio-manufacturing systems. Instead, under resource-scarce material conditions, they realized the localized decomposition, reconstruction and creative reorganization of core technological processes such as Western-style aseptic zoning, constant-temperature cultivation and isolated operations.

Starting from March 1945, using the Penicillium notatum spores provided by the CAC (Frey, 1946a), Frey's team conducted penicillium cultivation experiments on more than 20 types of local specialty culture media native to northern Shaanxi (陕西), including millet, rice, beans, tofu, flour, and potatoes. Eventually, they found that the culture medium composed of corn starch, sugar, and calcium carbonate yielded optimal mycelial growth. In the operation, they utilized narrow-mouth glass bottles of 1-liter, 2-liter, 5-liter, 10-liter, and 20-liter capacities as fermentation equipment. To ensure sufficient dissolved oxygen in the culture broth, only a small volume of broth was added to the larger fermentation bottles. In the absence of stirrers, team members regularly entered the constant-temperature incubation room to manually shake the fermentation bottles at fixed intervals. Lacking an air compressor, they supplied oxygen through manual aeration; without air filters, they filtered air via small tubes packed with sterile cotton and filter cloth before introducing it to the bottom of the fermentation tanks (Frey, 1945). After over 150 adjustment experiments, the team

successfully harvested the first batch of penicillin-containing liquid. In early April 1945, several batches of crude penicillin were sent to the International Peace Hospital (国际和平医院), where Frey personally applied them to patients' dressings for treatment, achieving encouraging results (Frey, 1945).

In November 1945, Richard Frey left Yan'an and arrived in Zhangjiakou (then commonly known as Kalgan, 张家口), the capital of the Jin-Cha-Ji Border Region (晋察冀)[16]. In January 1946, he resumed penicillin research and development to serve the military. Compared with Yan'an, Zhangjiakou could provide stable running water and 220-volt electricity, eliminating the need for constructing new facilities. After June 15, the team replaced the original Penicillium notatum spores with new Penicillium chrysogenum spores provided by the CAC (Frey, 1946a). From January to July, they conducted a total of 280 experiments. Employing surface culture, submerged culture, and the Beam fermentation method, the penicillin produced reached a potency of 20 to 40 units per milliliter. Staphylococcus aureus inhibition tests showed that the inhibition zone of the 1:5 diluted crude penicillin solution was 18 millimeters, while that of the undiluted solution was 25 millimeters (Frey, 1946a). The penicillin was immediately put into clinical use. By August, the team had produced 112,420 milliliters of penicillin culture broth, 45,800 milliliters of crude penicillin, and 3,566 pieces of penicillin-soaked gauze. Among the selected patients, the success rate of penicillin treatment exceeded 88%(Frey, 1946b).

The progress achieved in Zhangjiakou prompted the CAC to propose a more ambitious plan: the establishment of a penicillin factory with an estimated monthly output of 1 billion units, a construction period of six months, and a budget of $102,300. The plan required the factory to be constructed in full compliance with American standards, with its initial operations to be entirely overseen by American experts. Specifically, it intended to dispatch a qualified biochemist with experience in antibiotic production to China. Furthermore, three technical staff would be hired. Upon their arrival in Zhangjiakou, the four-member team would not only engage in penicillin research and development but also take on the task of training local Chinese operators (CAC Records, 1945–46a). The plan was approved internally by the CAC and submitted to Soong Ching-ling (宋庆龄) as well as the staff of the International Peace Hospital. Similar to ABMAC's projects, it was designed as a long-term initiative—factory construction alone would take at least one year, covering phases such as construction, experimentation, and transportation (CAC Records, 1945–46b). However, with the occupation of Zhangjiakou by the KMT forces in October 1946, this ambitious plan was left unfulfilled.

It is noteworthy that the factory constructed later in Zhangjiakou strictly adopted American standards, with all operational affairs and technical supervision fully dominated by American experts. This decision was not accidental, but jointly determined by three intertwined structural factors. In terms of historical continuity, despite a vast disparity in hardware facilities and technological proficiency compared with practices in the Yan'an era, the Zhangjiakou project shared an inherent lineage with early crude production trials in Yan'an, both receiving assistance led by CAC. From the global landscape of penicillin technology at that time, the U.S. had established absolute superiority in technology and production capacity after World War II, ranking first in global penicillin output and dominating the relevant industrial production systems (Richards, 1964). Most crucially, there existed only one exclusive organizational access channel.

16 The Jin-Cha-Ji Border Region was one of the CPC's base areas, mainly located around the border area between today's Hebei and Shanxi provinces.

Subject to comprehensive military blockades imposed by the KMT government, the U.S. became the sole external source for the liberated areas to acquire industrial penicillin technologies and equipment. As the only intermediary linking CAC and the liberated areas, the China Welfare Institute led by Soong Ching-ling relied entirely on the U.S. aid framework for technical supplies. Accordingly, the adoption of American standards by the Zhangjiakou factory constituted an inevitable structural outcome constrained by specific historical, technological and institutional circumstances. This further confirms that technological choices concerning penicillin in modern China were never mere issues of craftsmanship and production, but were profoundly shaped by political patterns, intermediary institutional mechanisms and geo-technical orders throughout history.

The CPC's penicillin research and development demonstrates that technological implementation relies on local material conditions and practical innovations. From Yan'an to Zhangjiakou, technological maturation depended on experimental cycles and the optimization of local conditions, rather than mere reliance on external materials or operational instructions. Thus, the development of penicillin in Yan'an was not merely an event in the history of wartime medicine, but a process encompassing technological embeddedness, the cycle of knowledge practice, and political intermediation. It illustrates how technology, society, politics, and material conditions collectively shaped the path of innovation, while simultaneously revealing the limitations and complexities of external aid in knowledge production.

From the scientific logic of modern microbial pharmaceuticals, as an emergency technological outcome developed amid military blockades and extreme material shortages, the CPC's manual fermentation mode based on local complex organic substances bore insurmountable inherent limitations. Problems involving penicillin yield and potency, potential risks concerning the biochemical purity of manually fermented products, finished product stability and batch consistency could not be resolved under the prevailing circumstances. Its historical contributions ought to be assessed within specific historical contexts. We should acknowledge its irreplaceable role in saving lives of wounded soldiers and breaking the pharmaceutical embargo, while objectively recognizing its scientific drawbacks as an early technological form, and refrain from making ahistorical judgments by applying the criteria of the modern pharmaceutical industry.

Postwar Humanitarian Aid and the Constraints of Penicillin Manufacture

The establishment and operation of the penicillin factory of Beiping NEPB after the war not only inherited the complex logic of transnational scientific and technological circulation in the wartime era, but also revealed profound contradictions beneath the ostensible technological modernization against the changing post-war geopolitical landscape. In the upstream sector, key fermentation raw materials, special chemical reagents and sterile consumables were heavily dependent on overseas imports, and stable domestic alternatives could not be realized. In terms of production support, there existed prominent shortages in precision instrument maintenance, supply of specialized spare parts and reserve of skilled technical personnel, along with the lack of a systematic industrial maintenance network. From the perspective of operational guarantee, hampered material transportation and inadequate overall material allocation capacity during and after the war made it

impossible to sustain the continuous, stable and closed-loop material supply required for standardized production.

In November 1945, with the support of the ABMAC, Tong returned to China from the U.S. and joined the NEPB in Beiping (北平). He took charge of the penicillin laboratory at the NEPB and formally embarked on his mission to produce penicillin in China. Prior to this, arranged by ABMAC, he had visited the Northern Regional Research Laboratory, as well as several major pharmaceutical companies including Squibb, Merck, and Eli Lilly. During these visits, he not only learned the latest production methods but also received donations of penicillium strains (Lu, 1994, pp. 708-714). This arrangement was not merely a simple transfer of technology, but an integral part of ABMAC's post-war scientific and technological reconstruction program. The organization positioned the Beiping Penicillin Factory as the final wartime donation project, aiming to shape American influence in China's post-war public health sector by providing "the most modern weapons against death and disease" (ABMAC Records, 1947a).

In January 1946, Jin Baoshan promoted the relocation of the NEPB from Kunming back to its original site in Beiping. The scale of aid far exceeded that during the wartime period: on June 25, the bureau received $16,000 worth of equipment donated by the ABMAC; on September 25, the American Red Cross delivered 32 crates of equipment weighing 7 tons. The total value of aid from the two organizations reached approximately $40,000, covering all the equipment, instruments, and raw materials required for penicillin production ("Mei hongshihui zhu wo," 1946). On January 1, 1947, the inauguration ceremony of the first penicillin factory in the Far East was held at the Temple of Heaven in Beiping. Distinguished figures from the military, political, academic, and educational circles attended the event, including Li Zongren (李宗仁) and Hu Shi (胡适) (ABMAC Records, 1947c). This high-profile aid initiative and inauguration ceremony, while seemingly a celebration of scientific and technological modernization, implicitly served as a display of power. By providing standardized equipment and technical solutions, the U.S. integrated China's penicillin production into the global health system under its leadership.

Despite being equipped with a complete set of American-style equipment, the Beiping Penicillin Factory was constantly confronted with a crisis of technological system disembedding—its operation was highly dependent on external material supplies and technical support, making it difficult to truly integrate into China's local industrial system. This predicament was first reflected in the irreplaceability of raw materials. Although Tong and Tang attempted to source local raw materials to achieve independent operation, China's underdeveloped basic industry repeatedly frustrated their efforts. Corn steep liquor, amyl acetate, and special activated carbon for penicillin extraction had to be supplied from the U.S. ("Guochan pannixilin dingming," 1947). Meanwhile, the use of substitutes such as lactose and high-quality rendered lard directly led to a decline in product quality. The persistent shortage of such core raw materials created a structural bottleneck within the penicillin production process, forming a reverse salient in the technological system. As a result, researchers were forced to continuously adjust local technical paths, yet they never managed to achieve the expected goals.

Equipment failures and the lack of infrastructure further exacerbated the fragility of the system. On March 22, 1947, the NEPB reported that significant progress had been made in penicillin manufacturing technology after numerous experiments ("Guochan pannixilin xiaoye," 1947). However, frequent power outages limited production expansion. Compared with power outages, the impact caused by mechanical breakdowns was even more severe. In November 1948,

the Population Mission of the Rockefeller Foundation visited the penicillin factory. On the second day of the visit, a freeze-dryer malfunctioned, requiring urgent replacement of parts. Fortunately, Mr. Evans, a member of the mission, happened to be a personal friend of the company's president. He immediately sent a letter to Philadelphia requesting the replacement parts. Only nine days later, the NEPB received the required components — otherwise, the freeze-dryer would have remained idle for six months. A basket centrifuge, ordered by the ABMAC for separating penicillium from culture broth, never arrived in Beiping. The equipment, originally destined for Shanghai, went missing during transit. To address the emergency, the NEPB constructed a homemade centrifuge in the summer of 1948. Unfortunately, due to the lack of balancing devices in the workshop, the equipment shook violently during operation, resulting in unstable performance (ABMAC Records, 1947c).

Even amid multiple predicaments that prevented effective guarantee of penicillin quality, the factory's output still showed an upward trend. Tang stated in a report to the ABMAC on July 11, 1947, that Beiping was already capable of producing 1,000 bottles of penicillin per day, with each bottle containing 10,000 units (ABMAC Records, 1947b). By the end of 1948, as the war situation evolved, the government ordered the NEPB to increase penicillin production. In response, the bureau doubled its monthly output. Furthermore, through communications with relevant departments of ABMAC, the NEPB successfully secured two 300-gallon fermentation tanks (ABMAC Records, 1948). This made the factory one of the few in China that did not reduce penicillin production during the Civil War.

In December 1948, fearing that the Civil War might spread to Beiping, the Ministry of Health instructed Tang to relocate the NEPB and its penicillin factory from the city (Liu, 1948). However, Tang resolved to keep the factory operational, with all staff remaining in Beiping and no evacuation plan formulated. On December 14, KMT military forces and hospitals in Beiping attempted to occupy the NEPB's facilities, but Tang stood his ground. In a letter to Magnus I. Gregersen, the representative of the ABMAC, he noted that the laboratory had experienced significant personnel turnover over the past year, including staff going abroad, resigning, and pursuing further studies (Tang, 1948). In particular, Tong had left the laboratory on September 26, 1948, which dealt a heavy blow to the factory. Aside from himself, only seven staff members remained in the laboratory (ABMAC Records, 1948). After the liberation of Beiping in February 1949, the NEPB was taken over by the Military Control Commission of the CPC. Penicillin production surged from 100 million units per month to 400 million units, marking the factory's transformation from a "legacy of the Republican period" to "the cornerstone of New China's pharmaceutical industry."

The Beiping Penicillin Plant stands as a "paradoxical specimen" of postwar East Asian technoscientific modernization. It embodied the U.S. ambition to export modernity through technological aid, yet simultaneously exposed the challenges of adapting standardized technologies to non-Western contexts. It demonstrated Chinese researchers' efforts to navigate and recalibrate within structures of technological dependence, while also revealing the decisive impact of political circumstances on the fate of technological systems.

The mature industrial standards and production paradigms for penicillin in the U.S. were deeply rooted in its sophisticated industrial system, complete industrial chains, stable raw material provision and professional talent support network, constituting an integrated technological solution embedded in domestic foundational facilities. When directly transplanted to Beiping,

such standardized production procedures could hardly be implemented in line with established norms, for modern China lacked compatible supporting industrial infrastructure and solid supply chains. This trajectory offers an important insight into debates on technology transfer and localization: technoscientific modernization in non-Western regions was never a matter of merely importing equipment or imitating techniques. Rather, it required the reconstruction of socio-technical networks to achieve a deep coupling between external knowledge and local conditions. The evolution of the Beiping plant thus served as an early historical rehearsal of this coupling process.

Concluding Remarks

In East Asia, medicine has always been the central issue in the contest between modernity and tradition. It serves not only as a stage for social transformation but also as a driving force behind such changes (Daidoji & Karchmer, 2017). The circulation of penicillin manufacturing techniques in wartime China resists reduction to a linear narrative of "technological diffusion" or "humanitarian aid." Instead, it unfolded through the persistent entanglement and disjuncture of transnational scientific networks, geopolitical interests, logistical infrastructure, and local technological practices. American China-aid organizations, including the ABMAC and Indusco, sought to construct a penicillin pilot plant in the U.S. for complete relocation to China, aiming to achieve the institutionalized replication of technology. Nevertheless, breakdowns in internal organizational communication, strategic rifts, and breakthroughs in localized research at the NEPB in Kunming collectively thwarted the plan's timely implementation. For its part, the CPC established a rudimentary laboratory in Yan'an, leveraging limited supplies and technical support from the U.S. Army Observation Group and American aid agencies. Drawing on local resources and adopting improvisational innovation strategies, it similarly succeeded in producing crude penicillin for clinical application.

These two parallel technological endeavors offer reciprocal illumination. First, while the aid architecture and medical diplomacy steered by non-governmental organizations furnished critical resources, they simultaneously laid bare inherent vulnerabilities. Second, scientific research actors in peripheral regions offset institutional deficits through highly flexible local innovation capacities, forging a guerrilla-style model of technological generation. This underscores that the wartime transfer of penicillin was not a simplistic center-periphery diffusion, but a complex process of constant restructuring and reconfiguration, enmeshed within international aid networks, institutional fragmentation, and local practices. These interwoven cases reveal an insightful implication: technology transfer in non-Western contexts is never a mere transplantation of equipment or a passive uptake of knowledge, but a dynamic process necessitating the continuous reconfiguration of techno-social networks. The localization of penicillin in China demanded iterative calibration and renegotiation among aid agencies, military intermediaries, and local researchers over standards, materials, equipment, and political authority.

The technological imaginaries of external aid, the resource constraints of local institutions, and the political variables of the war frequently stood in tension. In this regard, the tortuous trajectory of penicillin in China epitomizes scientific and technological modernization in wartime East Asia: technological systems are never transferred in a prefabricated form; their ability to take root hinges on the establishment of stable coupling relationships within new socio-technical

milieus.

The dual evolutionary trajectories of penicillin technology in 1940s China reflect a process where political orientations dominated technological choices. The academic research model pursued by the KMT government transcended simple technology importation and became a medical diplomatic demonstration directed toward the Western world. The establishment of the NEPB in Kunming and the penicillin factory in Beiping were intended to prove to American allies that the KMT government possessed the technological competence to govern a modern state. The deliberate choice of the Temple of Heaven, a symbolic site of Chinese civilization, stood as a concentrated manifestation of such diplomatic posturing, in which technological achievements were turned into visual symbols of political legitimacy. On the contrary, technological practices initiated by the CPC constituted an emergency mobilization mechanism brought about by the full-scale blockades enforced by the KMT side. The three-tier concentric blockade network imposed upon the SBR in the 1940s cut off regular channels for acquiring advanced technologies, driving researchers to redefine penicillin development as a practical survival strategy. Cave dwellings were reconstructed into constant-temperature laboratories, millet and potatoes replaced corn steep liquor as culture media, and manual shaking flasks took the place of mechanical oscillators. This guerrilla-style innovation was never a product of technological romanticism. Instead, it was an adaptive technological survival mechanism formulated to satisfy the urgent needs of battlefield casualty treatment under the dual constraints of physical isolation and intellectual embargo. The divergence between the two approaches therefore went beyond superficial gaps in resource conditions, and rose to a historical theme concerning the in-depth interaction and mutual shaping between political ecology and technological rationality.

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Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This study does not include any research involving human participants, and therefore, informed consent was not applicable.

Data Availability

The materials underpinning this study are primary archival documents and published sources. The research is based primarily on the United China Relief records held by the New

York Public Library Manuscripts and Archives Division (MssCol 3078), which include reports on the manufacture and use of penicillin, medical aid to China, and related correspondence, as well as archival materials held by the Columbia University Rare Book & Manuscript Library. Published books, newspapers, and other printed materials were also consulted. No new datasets were generated. The source guide for the archival materials can be accessed at:

https://archives.nypl.org/mss/3078#c178847
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