V

Qing Reformism and Modern Science

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Government Arsenals, Science, and Technology in China after 1860

In Chapters 8 and 9, we explained the relative success of traditional Chinese natural studies and Western science in developing together among literati elites from the 1860s under the rubric of investigating things and extending knowledge (*gezhi xue*). Most historical accounts of the post-1865 era portray those who were drawn to scholarly and technical work in the new industrial arsenals or who accepted translation positions in the official Foreign Language Schools, as marginal literati because they usually had failed the more prestigious civil examinations. In this chapter, we will discover that a decade before anything comparable in Meiji Japan many literati and artisans saw in Western learning and the modern sciences an alternative route to fame and fortune.[1]

This chapter will also reassess the naval wars that the Qing dynasty lost in the late nineteenth century. Historians have used the Sino-French naval battles of 1884–1885 and the 1894–1895 Sino-Japanese War to prove the failure of the Self-Strengthening reforms after the Taiping Rebellion (1850–1864). In particular, my account below will address how Chinese naval defeats contributed to the transformation of official, elite, and popular perceptions in the Chinese and missionary press, which shaped the emerging national sense of crisis among Han Chinese.

Chinese elites increasingly opposed the Manchu dynasty in power. Their disappointment with the military losses convinced many Chinese that more radical political, educational, and cultural changes were required to follow Japan's lead in coping with foreign imperialism. Chinese quickly forgot or repressed the earlier adaptation of new technological and scientific learning that had begun before the Meiji government's industrial programs of the 1870s. Many Protestant missionaries and experts who had aided in the Qing dynasty's scientific translation projects concluded that the Qing dynasty, the Chinese language, and traditional culture were doomed. We will first problematize and then refute the received wisdom concerning late nineteenth-century developments in science and technology.[2]

From Chinese Working for Missionaries to Missionaries Working for the Dynasty

After the treaty ports were opened in 1842, Protestant missionaries quickly established links with literati and common people in their assigned areas, as the Jesuits, Franciscans, and Dominicans had in the seventeenth century. Not until the devastations of the Taiping Rebellion did literati who were trained in the sciences by working with the Protestants, such as Xu Shou and Li Shanlan, establish links with the ruling dynasty by serving as official advisors and translators.

Not only Chinese who had worked for Inkstone Press in Shanghai, for example, moved from Protestant missions to the dynasty's arsenals and new schools. Just as the Jesuits had changed their focus from proselytizing among Chinese literati to working in the Qing bureaucracy to gain access to the imperial court, Protestant missionaries such as Fryer, Wylie, Allen, Dr. John Macgowan, and Carl Kreyer came to work in the translation department of the Jiangnan Arsenal after it was established in Shanghai. They remained committed to the gospel of science in China because they also thought its success in the precincts of the Qing government would redound to Christianity.

In the 1850s, Xu Shou, Li Shanlan, and Hua Hengfang had been hired by LMS to work as translators with Wylie and Macgowan in the Inkstone Press. Now in the 1860s, Wylie and Macgowan were employed by the Qing government as translators to work with Xu, Li, and Hua in the Jiangnan Arsenal. A small coterie of exceptional Chinese literati also joined the translation project as editors and proofreaders. In this milieu, Zhong Tianwei (1840–1901) grasped modern evolution long before Yan Fu (1853–1921) did in the 1890s, and Zhao Yuanyi (1840–1902), a cousin of Hua Hengfang, became a pioneering translator of Western medical works.[3]

Like the Jesuits in the late Ming, many leading Protestants in China moved from serving their missions in the 1850s to becoming minions of the Qing dynasty in the 1860s and 1870s. This transition troubled many Protestant missionaries, as it had their Jesuit predecessors, because their medical and scientific work soon outweighed their missionary activities. From the very beginning, Christians faced the quandary of presenting the progressive aspects of Western Europe and the United States to the Chinese primarily via medicine and science or via religious instruction. These endeavors were theoretically complementary, but in practice each took up a sizable part of a missionary's daily work.[4]

Wylie, for example, worked with Xu Shou on translating Mains's *Manual of the Steam Engine* for designing and building a steam engine, which was published by the Jiangnan Arsenal in 1871. Nevertheless, both Wylie and Allen returned to missionary work after working in the arsenal for several years because their translation and teaching work for the Qing dynasty distanced them from their calling as missionaries. On the other hand, the more secular Fryer and William Martin, the latter teaching English, political economy, and international law in Beijing from 1864, spent their careers as well-paid and hardworking servants of the Qing state. Martin publicly announced his teaching position in the Beijing Foreign Language School as "Professor of Hermeneutics, Political Economy and International Law in the University of Peking."[5]

During this era, conservative Manchu officials, such as Woren (d. 1871), and traditionalist literati echoing earlier critics of the Jesuits such as Yang Guangxian attempted to derail the movement to enhance foreign learning in official schools such as the Beijing School of Foreign Languages. Literati who feared that Western learning would again subvert state orthodoxy produced three major nineteenth-century anti-Christian tracts, each of which contained substantial sections from Yang Guangxian's early Qing work: (1) an edition of Xu Changzhi's work titled, the *Collection of the Sacred Qing Exposing Heterodoxy* (*Shengchao boxie ji*), published in 1855; (2) *A Veritable Record to Ward Off Heterodoxy* (*Bixie shilu*), printed in 1870; and (3) *A Record of Truths to Ward Off Heterodoxy* (*Bixie jishi*), published in 1871. Although never as successful as early Qing xenophobes had been, Woren and others affirmed classical learning and ancient models.[6]

As a result of the 1860 Conventions of Beijing, when the capital was occupied by British and French forces, the northern city of Tianjin became a treaty port, and Beijing became a site for Western embassies and Protestant missions. Portions of the capital, especially the imperial residence and gardens of the Lofty Pavilion (*Yuanming yuan*) in the northwestern suburbs, were sacked. Under duress, the dynasty began an era of reform known as Self-Strengthening (*ziqiang*) to cope with the external threats the dynasty faced from the superior military firepower of Western navies. In this period the technological competition between Britain and France to influence China via technology surpassed the eighteenth-century disputes between the French Jesuits, Germans, and the Portuguese in China over astronomy and influence in the Astro-calendric Bureau.[7]

Post-Taiping Reformers and Late Qing Science

The court leaders of the 1860s innovations in Beijing were Prince Gong (Yixin, 1833–1898), who signed the 1860 Conventions on the behalf of the dynasty, and Wenxiang (1818–1876), who assisted in the negotiations. Zeng Guofan, Li Hongzhang, and Zuo Zongtang took the lead in the provinces after Nanjing and the south were recovered from Taiping rebels. Prince Gong and Wenxiang together led the Grand Council and the newly founded General Affairs Office (*Zongli yamen*) in 1861. Until Wenxiang died and Prince Gong lost power in the 1870s, these capital-based and provincial groups were largely responsible for the Qing appropriation of the Protestant missionaries as westernizing servants of the dynasty.[8]

The 1861 proposal by Prince Gong and Wenxiang to establish the General Affairs Office had also included a proposal for a School of Foreign Languages in Beijing. Like the 1712 Kangxi emperor's Academy of Mathematics, students for this school were drawn from the eight Manchu banners and not from Han literati. Li Hongzhang advocated similar schools in Guangzhou and Shanghai in 1863. His proposal was based on Feng Guifen's 1861 recommendation for establishing an arsenal and shipyard in each Chinese port for better arms and ships to defend the coast. Feng also stressed establishing schools in Guangzhou and Shanghai for instruction in Western languages.[9]

The dynasty's pursuit of Western technology began in earnest when Zeng Guofan established the Anjing Arsenal in Anhui province in 1862. Two former LMS translators, Xu Shou and Hua Hengfang, served as directors. Yung Wing (Rong Hong, 1828–1912), a Cantonese who graduated from Yale in 1854, represented Zeng in buying all-purpose machinery in Europe in 1864. Yung had advised Zeng in 1863 to launch an ironworks in Shanghai. Li Hongzhang initially established two small arsenals in 1863, the first in Shanghai under Ding Richang (1823–1882) and another in Songjiang under Halliday Macartney, a former British army surgeon who had commanded an army under Li against the Taipings.[10]

The Songjiang arsenal moved to Suzhou in 1864 when the Qing court arranged for a machine shop to be brought to China as part of the Lay-Osborn Flotilla engaged in 1862. Zeng moved the arsenal to Nanjing, and it was then called the Nanjing Manufacturing Bureau (*Jinling zhizao ju*). Although formally under a Chinese director, Macartney actually managed the Nanjing Arsenal. He was granted an annual appropriation of 50,000 taels (69,500 silver dollars) to produce fuses, shells, friction tubes for firing cannon, and small cannon for the Anhui Army. New machinery was added in 1867– 1868 along with some British mechanists. By 1869, Nanjing was producing rockets and was trying to forge larger guns.[11]

In 1866, Zuo Zongtang suggested creating a modern navy yard in Fuzhou to build and operate Western-style warships. Prince Gong and the regents of the Tongzhi emperor (r. 1862–1874) quickly authorized the proposal. Although Zuo had initiated the project, Shen Baozhen (1820–1879) became

director-general of the Fuzhou Navy Yard in 1867 when Zuo was sent on military campaigns to the far northwest in Chinese Turkestan (Xinjiang) to put down secessionist rebellions. Depending on French engineering and technological know-how, Fuzhou quickly became the largest and most modern of all the Chinese military defense industries established in the 1860s and 1870s. It also had the largest gathering of foreign employees. Until the Sino-French War of 1884–1885, Fuzhou remained a major center of French interests.[12]

Subsequently, in 1866–1867 the court approved a proposal to add a Department of Mathematics and Astronomy to the Beijing School of Foreign Languages. The goal was to teach students about modern science through instruction in chemistry, physics, and mechanics. When William Martin returned to Beijing in 1869 to teach physics after more advanced study in the United States, he assumed the leadership of the School of Foreign Languages.

The addition of mathematics and astronomy in particular was vigorously opposed by Woren in an 1866 memorial sent while he was a Hanlin academician and imperial tutor. Although not against the teaching of mathematics per se, Woren—like Yang Guangxian before him—was incensed that foreigners such as Martin would be the teachers. When he was asked by the court to recommend native mathematicians and astronomers for service in the new department, however, Woren—again like Yang—pleaded for time. Subsequently he used an illness as an excuse to avoid an assignment in the General Affairs Office to supervise foreign affairs. He was soon relieved of all duties. Later some followers of his student, a prince in the court, openly sponsored the Boxers during their 1900 uprising.[13]

When Woren failed to stem the reformist tide in the Manchu court, Li Shanlan left Shanghai and the Jiangnan Arsenal in 1869 and accepted an appointment as professor of mathematics in the Beijing School of Foreign Languages. Unsympathetic with Woren's agenda, Li moved only after the Beijing School was upgraded to a college and a department of mathematics and astronomy was secure. Earlier Zou Boqi (1819–1869) had turned down an invitation to teach mathematics there in 1864 and 1867–1868. Li taught mathematics at the school for thirteen years. A special civil examination in mathematics, however, was opposed in the 1870s, although Li's mathematics examinations at the School of Foreign Languages were influential.[14]

The Jiangnan Arsenal in Shanghai

In the summer of 1865, Li Hongzhang, then Jiangsu governor, and the Shanghai customs intendant Ding Richang rented a machine shop in the Hongkew section of Shanghai from Thomas Hunt and Company, an American firm in the Shanghai Foreign Settlement that was the largest foreign machine shop in China. Li also approved the purchase of the machine shop and the shipyard of Hunt and Company for the Suzhou Foreign Arms Office. Additional machinery was imported, and subsequently the Jiangnan Machine Manufacturing General Bureau (*Jiangnan jiqi zhizao zongju*), usually called the Jiangnan Arsenal, was established to administer the industrial works and educational offices.[15]

Initially, the Jiangnan Arsenal used 250,000 taels (348,000 silver dollars) for production facilities, drawn mainly from maritime customs funds collected at Shanghai. Ding Richang was appointed director in 1865, and Ying Baoshi (b. 1821) was appointed 1866–1868. The arsenal moved outside the old Chinese part of Shanghai in the summer of 1867. By 1870, according to Mary Wright, the arsenal had arguably become the greatest manufacturing center of modern arms in East Asia.[16]

Zeng Guofan, Li Hongzhang, and their advisors considered building machines to be the fundamental building blocks for industry. In their view the three basic ingredients for constructing such new industry were: (1) manufacturing machines; (2) creating a new institutional category of engineers (*zhiqi zhi ren*, lit., "machine workers"); and (3) the translation of scientific and technical texts. Via armaments manufacture, the Qing state would master contemporary useful knowledge and break the Western monopoly of warships and cannons.[17]

Technical work at the arsenal was left in hands of foreigners such as Hunt's chief engineer, the American T. F. Falls, who was the superintendent. Eight of Hunt's machinists were retained, and six hundred workers from Hunt and Company were transferred directly to the Jiangnan Arsenal. Many others were later added. They produced serviceable muskets and small howitzers after initial failures in rifle production. By mid-1867 the arsenal was producing fifteen muskets and a hundred twelve-pound shrapnel daily. Twelve-pound howitzers were produced at rate of eighteen per month and used as munitions in the northern Nian wars of the 1860s. In 1871 the arsenal finally produced breech-loading rifles of the Remington type. By the end of 1873, 4,200 were produced, but they were more costly than and inferior to imported Remingtons. In 1874–1875, Li Hongzhang advised establishing a branch to produce powder and cartridges instead.[18]

John Fryer and the Translation Department

In 1867, Xu Shou, Hua Hengfang, and Xu Jianyin initiated the translation department at the Jiangnan Arsenal, which Zeng Guofan enlarged in 1868 to include a school to train translators (see Figure 10.1). In addition to relying on foreign manufacture, Zeng and Li Hongzhang regarded translation as the

foundation for learning the techniques of modern manufacture and the engineering mathematics, that is, the calculus, on which it was based. Their precedent was the late Ming and early Qing translation projects that had enabled successful reform of the imperial calendar in the Astro-calendric Bureau based on new techniques and models introduced by the Jesuits.[19]

John Fryer had worked at the Jiangnan Arsenal since he left the Anglo-Chinese School in Shanghai in 1867, but he was not officially hired until November 1868. Before that, Fryer was professor of English in the School of Foreign Languages in Beijing from 1863 to 1865, but he was forced to resign when his fiancé, who had been seduced by the captain on the ship from England, arrived in Beijing in 1864 apparently pregnant. When Fryer officially joined the arsenal as a translator of scientific books, he indicated that he welcomed the appointment over teaching, which he did not enjoy, and missionizing, for which he was considered too secular. The scandal concerning his wife also made his religious ordination impossible.[20]

Figure 10.1. The Translation Office in the Jiangnan Arsenal: Xu Shou, Hua Hengfang, and Xu Jianyin.
Source: Chuanshi yanjiu 8 (1985).

In Shanghai, Fryer also edited the *Chinese Missionary News* (*Jiaohui xinbao*) from 1866 to 1868. The paper may have reached some five thousand readers because Fryer's articles were reproduced in three other Chinese newspapers. When Fryer officially moved to the arsenal in 1868, he turned the editorship over to Young J. Allen to avoid a conflict of interest with the Qing government. Allen worked as translator and teacher in Shanghai for ten years.[21]

Others whom the Jiangnan Arsenal hired in the Translation Bureau included Alexander Wylie (who stayed eight years), Macgowan, and Rev. Carl Kreyer (who stayed for nine years). They were free to choose books for translation without direction from the imperial government. Wylie, for instance, was contracted to work with Xu Shou on Mains's *Manual of the Steam Engine*. Fryer worked with Xu Jianyin to translate William Burchett's *Practical Geometry* (1855 edition), and with Li Shanlan he began a translation of Newton's *Principia*. Macgowan joined Hua Hengfang to translate Charles Lyell's (1797–1875) *Elements of Geology* (sixth edition), published in 1873.

By renewing his contract with the Jiangnan Arsenal in 1871 and becoming the head of the new school there, Fryer chose to work for the reform of China. He stayed for twenty-eight years before accepting the Aggasiz Chair in Oriental Languages at Berkeley University and leaving for California in the summer of 1896. The total of Fryer's contributions at the arsenal came to 129 translations, with 77 published by the arsenal. Fourteen were released between 1896 and 1909 when Fryer was in California. The missionary-sponsored School and Textbook Committee and the Chinese Scientific Book Depot published the remaining thirty-eight.

Fifty-seven of Fryer's seventy-seven arsenal translations dealt with the natural sciences. His translations of physics were concentrated in the years between 1885 and 1894. He also completed five works on mathematics in 1887–1888, compared to seven from 1871 to 1879. Forty-eight works dealt with applied science, with eighteen on manufacturing. Because the Chinese government prioritized machinery, Fryer early on stressed Chinese adaptations from *The Engineer and Machinist's Drawing Book*, published in Britain in 1855. Aided by Xu Jianyin, the Arsenal published Fryer's translation in 1872.[22]

Enlightenment through Translation and Terminology

Writing in May 1886 at a symposium titled "The Advisability, or the Reverse, of Endeavoring to Convey Western Knowledge to the Chinese through the Medium of Their Own Language" Fryer noted:

> Next if we examine Chinese secular literature we find astronomy and mathematics with kindred subjects have always been popular among the Chinese. The most highly prized books on these subjects are the translations or compilations made by the Jesuits two or three centuries ago. These are found in the library of every Chinaman who has any pretensions to general scholarship. Coming down to more recent times . . . [t]here is strong demand for whatever useful knowledge foreigners have to impart. The cry on all sides is for more books.[23]

In 1880, Fryer rejected the popular view that Chinese was inadequate for scientific discourse. Moreover, Fryer discarded the notion that English would become a universal language or that China would ever be ruled by foreign powers. He then described the method of translating he and his co-workers employed and noted the translators' efforts to establish a systematic nomenclature based on three linguistic choices: using existing nomenclature by searching through native works on the arts and sciences; coining new terms by creating a new character, inventing a new descriptive term, or phoneticizing a Western term according to the Mandarin dialect; or constructing a general vocabulary of terms and list of proper names.

Earlier plans had not been very successful, according to Fryer, because translators had not appreciated the need to use the same terms throughout a series of publications. Fryer noted that Hobson's pioneering terms, for example, had unfortunately not been followed, which created confusion among Chinese readers. Hence, standardized terms became a key goal of the Jiangnan Arsenal's Translation Bureau. When translating an English work, the foreign employee and Chinese writer collaborated via dictation in Chinese sentence by sentence, which the Chinese then revised. The resulting translation was then printed using traditional woodblocks because of its efficiency for reprints.[24]

To promote modern science beyond the arsenal, Fryer cooperated with other missionaries, such as Martin, Williamson, Calvin Mateer (1836–1908), Allen, and Rudolph Lechler (1824–1908), in the School and Text-Book Series Committee (*Yizhi shuhui*) beginning in 1877. The committee met regularly in Shanghai to approve textbooks on science and other subjects for use in missionary schools. It drew up a plan to prepare a series of elementary and advanced texts covering ten subjects: mathematics, surveying, astronomy, geology, chemistry, zoology, geography, history, language, and music. Although Fryer resigned from the committee for a time, he became the general editor of the series in 1879. At the 1880 meeting, Fryer presented the terms he had used for translation at the Jiangnan Arsenal and compiled the *Translater's Vade Mecum* (*Yizhe zhinan*) based on his experience. By 1886, 104 books were published and Fryer contributed one-quarter of them.[25]

The need for a consensus for systemizing terminology that would become standard was critical for the success of the science textbooks and primers that were produced in the 1870s and 1880s. Justus Doolittle's 1872 *Vocabulary and Handbook of the Chinese Language, Romanized in the Vernacular* (*Ying-Hua cuilin yunfu*) tried to reach a consensus by incorporating translations from the leading translators of the day for specialized vocabularies in eighty-five fields covering over nine thousand terms. Wylie, for instance, prepared a section with 1,016 entries on "Terms Used in Mechanics, With Special Reference to the Steam Engine." Martin presented a list of "Terms Used in Natural Philosophy," and chemical terms were provided by John Kerr (1824–1901).

Doolittle included a section titled "Elements of Natural Science" ("Bowu zhi li"), which borrowed 322 terms from Benjamin Hobson's more complete 1858 *Medical Vocabulary in English and Chinese* (*Yixue Ying-Hua zishi*). Even so, the terminology that Doolittle deployed never became normative. For the terms Doolittle listed in his *Vocabulary*, he rarely took into account earlier translations, many of which later became standard.[26]

Chemical terminology in particular became contentious among the translators. Considerable variations in Chinese terms for the same chemical elements, for example, occurred in five early and influential chemistry translations by Benjamin Hobson in 1855, William Martin in 1868, John Fryer in 1869, John Kerr in 1870–1871, and Anatole Billequin (1837–1894) in 1873, among others (see Appendix 2). Like Martin, Billequin was then teaching chemistry at the Beijing School of Foreign Languages. Fryer and Xu collaborated in the Jiangnan Arsenal's Translation Department, while Hobson and Kerr initially published their translations in Guangzhou. The German missionary Wilhelm Lobscheid developed an earlier nomenclature for chemical elements from 1866 to 1869 for his *English and Chinese Dictionary* (*Ying-Hua zidian*) in Hong Kong, but his translations neglected the phonetic element in Chinese characters and were problematic.[27]

Even the Chinese term for the notion of a chemical element varied among translators, from "original material" (*yuanzhi*) to "original agent" (*yuanxing*). Rival translations created animosities. Fryer and John Kerr began corresponding in November 1869 about their different translations of the same chemical text, namely David Wells's *Principles and Applications of Chemistry* (New York and Chicago, 1858, 1862). In 1895, their enmity over the issue still lingered on when Kerr was criticized by Fryer in the April issue of *The Chinese Recorder*.[28]

Because their translations of fourteen of the chemical elements differed, Fryer charged that Kerr should have delayed publication of his translation on chemistry to take into account Fryer's terms. Kerr replied in the June 1895 issue that before his translation was published in 1870–1871, he had consulted with Fryer. Those exchanges "cannot be called 'negotiations for a compromise,' because the only arrangement that could be made was adoption by me of the terms used by Mr. Fryer." Fryer's self-assurance often stood in the way of the goals he advocated.[29]

When the missionaries created the School and Text-Book Series Committee in 1877 (later reorganized in 1890 as the Educational Association of China) to prepare textbooks for elementary and advanced training in mathematics and science, they made a concerted effort to unify terminology, but the results were still mixed until 1890. By then, they adopted some thirty-six thousand terms. At the second national Missionary Conference of the Series Committee, which convened in Shanghai in 1890, Fryer reiterated his view that rules for terminology should be strenuously applied. Curiously, he blamed his Chinese collaborators for the inadequacies that others pointed to in his translations.[30]

When the 1890 Missionary Committee decided to act, they acknowledged the confusion in the terminology for chemistry. By that time, the Fryer-Xu Shou translation was the most successful in coining Chinese terms for the chemical elements because they had adopted new Chinese characters using the appropriate organizing radicals, whereas the Kerr-He Liaoran version had not used fixed principles in their translations. In 1884, moreover, Fryer published through the Jiangnan Arsenal a *Vocabulary List of Names of Chemical Substances* (*Huaxue cailiao Zhong-Xi mingmu biao*) based on the Fryer-Xu *Mirror of the Origins of Chemistry* (*Huaxue jianyuan*) and its follow-ups. Fryer's terms for organic and inorganic compounds and chemical concepts, however, were less successful. Two of the committee members, Calvin Mateer and W. M. Hayes, complained about Fryer's choices for Chinese terminology:

> If Dr. Fryer's chemical names and terms had been all that the occasion demanded they would no doubt have vindicated their place in the public estimation. They have had ample time and opportunity, and the fact that they have not done so is the patent proof that changes are needed.

Fryer replied to the committee with his usual confidence:

> Your committee ought not to change my terms unless they are radically wrong and impossible to be used. Should any terms of mine be shown to be erroneous, absurd, or otherwise unserviceable and another be . . . without defects I will gladly yield to it and not otherwise.[31]

Similarly, Fryer complained in summer 1891 that Joseph Edkins had not compared the scientific terminology in other works when Edkins prepared his 1886 science primers, which duplicated four of the volumes that Young J. Allen and Zheng Changyan had prepared in 1875 for the arsenal. The latter had used the scientific terminology that Fryer had unified for the Jiangnan Arsenal's Translation Department, but Edkins had ignored those efforts.[32]

Competition among translators was not the only problem, however. In the case of the Chinese term for mechanics, for example, two legitimate translations competed in the 1860s. These terms could be traced back to the Swiss Jesuit Johann Schreck's *Diagrams and Explanations of the Marvelous Devices of the Far West* (*Yuanxi qiqi tushuo luzui*). Schreck's 1627 compilation discussed the principles of weight (*qingzhong zhi litui*) and force (*liyi zhi litui*). Although Schreck's account coined the term for the "study of weight" (*zhongxue*), that is, a pre-Newtonian notion of mechanics, his account also stressed the role of force (*liyi*). The former term likely influenced nineteenth-century translations of mechanics by Wylie and Fryer in Shanghai. The first volume of the *Shanghae Serial* in January 1857, for instance, emphasized that its issues would introduce the Newtonian science of mechanics (translated as *zhongxue*) to its readers.

Wylie and Wang Tao prepared a two-part article in 1858 titled "Popular Mechanics" (*Zhongxue qianshuo*), which presented diagrams of levers for moving things and described the mechanical operation of the wheel and axle, pulleys, the inclined plane, the wedge, and the screw. It appeared in the first volumes of the *Shanghae Serial.* Likewise, Joseph Edkins and Li Shanlan published a translation of William Whewell's *An Elementary Treatise on Mechanics* (Cambridge 1819) in Chinese as the *Study of Weight* in 1867. Justus Doolittle's 1872 *Vocabulary and Hand-book of the Chinese Language* included Wylie's piece titled "Terms used in mechanics, with special reference to the steam engine," which also used "study of weight" as the standard translation for mechanics.[33]

William Martin, however, challenged this translation in 1868 when he published his *Elements of Natural Philosophy and Chemistry* (*Gewu rumen*) for instruction at the Beijing Foreign Language School. Martin included a section on mechanics, which he titled "Introduction to Force" ("Lixue rumen"). His translation of mechanics as "the study of force" replaced the stress on weight. Later in 1883, when challenged about his translation, Martin justified his choice by subsuming the study of weight under the study of force, thus making weight secondary in the study of mechanics.

Fryer countered in 1889, when he used the term for the study of force (*lixue*) as the title of his primer *Dynamics* (*Lixue xuzhi*). Martin's version remained influential enough in China and Japan, however, that the prominent scholar, reformer, and publicist Liang Qichao (1873–1929) introduced Newtonian mechanics as the study of force in his widely read essay on the history of science composed while in exile in Japan in 1902, although at the same time he reserved the study of weight (*zhongxue*) for the mechanics of Archimedes. A similar confusion of terms for mechanics prevailed in Meiji Japan.[34]

Given the potential market for textbooks in the sciences for missionary and

dynastic schools and in the arsenal training programs, a missionary-translator could achieve fame and fortune, as Fryer and Martin both did, through the publication of their works. Hence, the competition over translation terminology since the 1850s was also a claim for priority in the lucrative textbook market. The School and Text-Book Series Committee's 1890s response to the continuing controversy over chemical terminology, for instance, chastised Fryer for not fulfilling his own call for unified rules for nomenclature:

> Conformity to such a diction as this would make it impossible for us to do anything but adopt Dr. Fryer's system *in toto.* The same principle carried out in Mathematics, Physics, Astronomy, Medicine . . . would make short work of the whole business and leave our committee without any reason for their existence. The spirit of Dr. Fryer's remarks is in fact, just what has stopped all progress in the matter of terminology for the past twenty years.

Through the intervention of colleagues, Fryer relented. He became an energetic member of the committee once the controversy had been aired and resolved. In 1898 Mateer issued his *Revised List of the Chemical Elements,* which resolved the differences among the three remaining systems of nomenclature developed by Fryer, Kerr, and Billequin.[35]

Fryer also described the enlightenment project of the Translation Department. His goal was to break up intellectual stagnation in China, which Fryer felt he had in part achieved by 1880. The works the Jiangnan Arsenal had translated were well received, and they were used as textbooks in Beijing at the School of Foreign Languages and in higher-level mission schools. Moreover, bookstores sold translations to provincial civil examination candidates in Nanjing. Fryer also regarded the recent creation of Chinese professorships at Oxford, London, Paris, and Harvard as emblematic of the increasing importance of Chinese language study abroad.

Despite his series of specialized and elementary translations, Fryer remained cautionary in 1880 about the future of the enlightenment project and the popularization of science in China. The "work of supplying useful knowledge to the Chinese by means of their own language" was still needed, Fryer noted, to overturn "the system of ignoring everything but the Four Books and the Five Classics at the Government examinations." In effect, Fryer, Wylie, Macgowan and Kreyer were "spreading intellectual light" within the precincts of the Qing bureaucracy.

Fryer's translations served the gospel of science. Missionaries working for the Qing dynasty interpreted the daily drudgery of translation in light of "bringing about the intellectual and moral regeneration of this great country." Like the Jesuits before them, the Protestants saw the translation of science as a way to spread Western knowledge and Christianity. While visiting the Jiangnan Arsenal in 1877, Zeng Guofan presented Fryer with a fan on which Zeng composed a poem comparing Fryer favorably to Verbiest and Schall, which delighted Fryer.[36]

One major weakness in the School and Text-Book Series Committee's efforts to unify terminology was its deprecation of the contributions made by the Chinese collaborators Fryer and the missionaries worked with. Moreover, Wylie pointed out in 1867 that because the Jesuits had unwittingly translated many things as new, particularly in mathematics, the new nomenclature they used for algebra (i.e., *jiegen fang*), for example, initially replaced an older established terminology (i.e., *tianyuan*). When Qing scholars successfully restored the single-unknown and four-unknowns (*siyuan*) terminology for the native craft of algebra in the eighteenth and nineteenth centuries, however, there were now two systems of terms, which according to Wylie "introduced a looseness and inaccuracy of phraseology, little to the advantage of mathematical studies." This looseness continued in the parallel curriculums for modern and traditional mathematics that Chinese students in the post-Taiping imperial arsenals empirewide were expected to master.[37]

Similarly, other terms, such as tool or implement (*qi*), controlling device (*ji*), and device or weapon (*xie*), were applied to technical machinery in the nineteenth century. The technical name for the Jiangnan Arsenal, for example, was the "Machine Manufacturing General Bureau" (*jiqi zhizao zongju*). When Li Hongzhang proposed establishing new categories for the civil examinations 1867, he included "mathematics and science" (*suanshu gezhi*) and "technology and manufacturing" (*jiqi zhizuo*) as two of the eight categories.[38]

When the Protestant missionary influence peaked in the 1890s, Chinese translators took matters into their own hands and independently translated works in the natural and social sciences from Japanese into Chinese. Unaffected by the natural theology encoded in Christian-inspired textbooks, the Japanese textbooks in the sciences became models after the Sino-Japanese War. Thereafter, the Chinese translators no longer relied on missionary informants. In chemistry, for instance, Japanese books on the subject continued to use earlier Chinese terms for the elements and compounds, but the terms and concepts informing chemical theory had new translations. The same changes occurred in physics, biology, and geology.[39]

Technical Learning in the Jiangnan Arsenal and Fuzhou Navy Yard

Before Fryer joined it, the translation project for the Jiangnan Arsenal was initially very modest. The Chinese and their collaborators planned to produce an encyclopedia that would resemble the *Encyclopedia Britannica*, but this goal was quickly seen as too elementary and perhaps too traditional, that

is, a mimicking of the Ming-Qing encyclopedia tradition. Instead, the core group of Chinese and Western translators hired at the Translation Bureau began producing a series of industrial treatises focused on technology and machinery rather than mathematics and the natural sciences.[40]

From 1863, when the Imperial Court approved its creation, the Shanghai School of Foreign Languages remained an independent school of translation. In 1869, however, the school was moved to the Jiangnan Arsenal and renamed the School for the Diffusion of Languages (*Guang fangyan guan*). The Shanghai Maritime Customs also paid for its new buildings. Fryer's work was narrowly defined to translate Western books on manufacturing for the new Arsenal school. He initially focused on the fields of engineering, navigation, military technology, and naval affairs.[41]

The poetic couplets Feng Guifen and Li Hongzhang wrote to celebrate the unification of the Shanghai school with the arsenal presented the name of the Foreign Language School as the "Hall for Investigating Things and Extending Knowledge" (*Gezhi tang*). Feng and Li were referring to the new industrial sciences, but classical learning and traditional mathematics were also continued in the Jiangnan Arsenal after the Foreign Language School moved in. Teachers in the Foreign Language School stressed study of the Four Books and Five Classics in the hope that the graduates would pass the more prestigious civil examinations. Hence, the school attracted the sons of Shanghai merchants and Christian converts in a more foreign environment, who saw the new learning as an alternate means to access the civil service.

The School made classical and historical studies part of the lower-division curriculum. Texts drawing on Zhu Xi's legacy, such as the *Essential Meanings of Works on Nature and Principles* (*Xingli jingyi*), which the Kangxi emperor had authorized in 1715 as an official reiteration of Cheng-Zhu orthodoxy under Manchu rule, were required. Teachers also drilled students in the eight-legged essay at the same time that mathematics was also given priority. For the latter, the teaching staff used the Ten Mathematical Classics, which had been reconstituted by Qing scholars, and the four-unknowns notational form to tutor the students in traditional Chinese mathematics.[42]

Following the Anglo-American model for training engineers, students also studied Western algebra, geometry, trigonometry, astronomy, and mechanics in the lower-division curriculum. Teachers provided training in international law, geography, and mechanical drawing. The upper-division curriculum for students emphasized seven fields:

1. mineralogy and metallurgy
2. metal casting and forging
3. wood and iron manufacturing
4. machinery design and operation

5. navigation
6. naval and land warfare
7. foreign languages, customs, institutions

It took students three years to complete the two divisions. Outstanding graduates, it was hoped, would then take special provincial examinations in Beijing.[43]

At its crest, the Jiangnan Arsenal contained four institutions: (1) the Translation Department; (2) the Foreign Language School; (3) the School for training skilled workmen; and (4) the Machine Shop. In addition, the Jiangnan Arsenal had thirteen branch factories. By 1892, it occupied seventy-three acres of land, with 1,974 workshops and a total of 2,982 workers. The arsenal acquired 1,037 sets of machines and produced forty-seven kinds of machinery under the watch of foreign technicians, who supervised production.[44]

Shipbuilding in the Jiangnan Arsenal

From 1868 to 1876, according to Meng Yue, shipbuilding in the Jiangnan Arsenal was highly productive. It built eleven ships in eight years. Ten were warships. Five of these had wooden hulls; the other five, iron hulls. All parts of each ship, including the engine, were built at the arsenal. The arsenal also experimented with different designs, from single- to double-screw engines, wooden and iron hulls, and simple warships to turreted vessels. When compared to the warships built following French models at the leading Japanese dockyard in Yokosuka in the 1870s, the level of shipbuilding technology at the Jiangnan Arsenal was actually more advanced.[45]

Founded in 1867 to replace the late Tokugawa regional dockyards in Nagasaki and elsewhere, Yokosuka's dock was designed by the French architect-engineer François-Léonce Verny (1837–1908), who had graduated from the L'École Polytechnique in 1858. Verny worked on shipbuilding projects in Ningbo and Shanghai for two years before coming to Japan in 1865. In the midst of the Meiji Restoration in 1868, his Japanese superiors at Yokosuka thought he should take a short leave to study the Fuzhou Navy Yard, which the Qing government was then building with French technical advice. In 1871, the construction director at Fuzhou visited Verny in Yokosuka, now under the Meiji Public Works Ministry. Verny covetously noted that the Fuzhou Navy Yard's budget was three times his own.[46]

The Yokosuka Dockyard did not produce its largest wooden warships until 1887–1888. They were each armed with twelve guns and boasted 1,622 horsepower. Neither was the match for the largest warship built at the Jiangnan Arsenal in 1872, which had 1,800 horsepower and was armed with

twenty-six guns. The arsenal produced five iron-hulled warships before 1875, while the Japanese did not complete their first iron gunboats until after 1887. In terms of armaments, those manufactured at the Jiangnan Arsenal also were generally superior to those of Japan.[47]

The Chinese fleet of iron and wooden ships quickly fell behind the new ironclad ships of Europe, however. Moreover, the compound engine in Europe had replaced the outmoded single- or double-screw engines in Chinese vessels. The Chinese began to build compound engines only in 1877. An earlier proposal was turned down because of the lack of funds. Hence, China's ships overall were still behind Europe's in the 1870s. Moreover, because Chinese shipyards could not produce enough ships, more warships were built in Europe for the Chinese navy. Although the Qing continued to employ foreign technicians to build large modern warships, Chinese ships were still outmoded by the 1890s because Chinese training did not keep pace with continued Western technological progress. Japanese officers and sailors, in contrast, were better trained to manage their ships and guns by 1894.[48]

Shipbuilding in the Jiangnan Arsenal dramatically slowed after 1876. In 1885, after the arsenal completed its first steel gunboat, it ceased to be a military shipyard. The technological switch toward steel and armored warships in Europe highlighted the difficulty of transporting iron and coal to make steel in coastal China. At the same time, imported steel remained prohibitively expensive. Nevertheless, shipbuilding technology in Jiangnan and the Fuzhou Navy Yard probably remained slightly better than in Japan until 1889, when a French engineer designed new steel and iron warships for the Yokosuka Dockyard. Its first modern warship had more horsepower and a higher top speed than the same type of warship built at the Jiangnan Arsenal.[49]

Once shipbuilding was no longer its major task, the Jiangnan Arsenal adapted its machinery to produce the most advanced foreign guns and small arms for military use. As of 1874, the arsenal had produced a total of 110 cannons and a variety of guns modeled after products from the Armstrong factory in Britain. Three types of large 120 mm, 175 mm, and 200 mm caliber muzzle-loading guns made by the arsenal were deployed at the Wusong fort guarding the mouth of the Yangzi River. In the late 1880s, the arsenal produced large breech-loading guns that initially used black and later brown gunpowder. By 1885, Li Hongzhang favored the German arms industry over the British or French, and the scale of Krupp arms sales to China increased.

Before the Sino-Japanese War commenced in 1894, the Jiangnan Arsenal was producing large breech-loading Armstrong guns with a range from seven thousand to eleven thousand yards. They were capable of firing projectiles from eighty to eight hundred pounds. The arsenal also became known after 1890 for its success in producing the rapid-firing machine gun, which was important in enhancing sea power and coastal defense forts. By 1892 the Jiangnan Arsenal had manufactured ten forty-pound rapid-firing guns. Two years later, the arsenal finished making rapid-firing machine guns capable of launching forty-pound and one-hundred-pound shells. Because annual production in the arsenal was insufficient to supply the Chinese army, the Qing military still had to purchase such arms from abroad. Japan by comparison did not begin its ambitious artillery program until 1905, during the Russo-Japanese War.[50]

The Fuzhou Navy Yard and French Technology in China

Besides the Jiangnan Arsenal in Shanghai, the second major industrial site for shipbuilding and training in the Western sciences, engineering, and technology was the Fuzhou Naval Yard. When Zuo Zongtang submitted his 1866 memorial to establish a complete navy yard at Fuzhou, the expectation was that after five years the need for foreign experts would be eliminated. The estimated start-up costs of 300,000 taels (417,000 silver dollars) and the 600,000 taels (834,000 silver dollars) for annual operations were to come from maritime customs duties and the interprovincial taxes (*lijin*) collected in Fujian, Zhejiang, and Guangdong provinces. In return, those provinces would receive naval protection from the Southern Fleet based at Fuzhou.[51]

In contrast to the hybrid British and French influence at the Jiangnan Arsenal, Zuo and his successor Shen Baozhen from the start relied on French expertise. Once the Navy Yard was established, however, the Fujian maritime customs turned over only 400,000 taels (556,000 silver dollars), with another 50,000 (69,500 silver dollars) per month for operations, leaving the venture in a perpetual financial bind. At its peak the shipyard employed 3,000 workers. When later construction was completed the force dropped to 1,900, with 600 in the dockyard, 800 in workshops, and 500 coolies. Some 500 soldiers guarded the premises. The Navy Yard had more than forty-five buildings on 118 acres set aside for administrative, educational, and production purposes. By comparison, the Jiangnan Arsenal as the largest ordnance enterprise in 1875 had thirty-two such buildings on seventy-three acres.[52]

In terms of scale, the Fuzhou Navy Yard was the leading industrial venture in late Qing China. Designed as a Westernized enterprise based on technical machinery and organizational efficiency, the whole plant was served by a modern tramway with turntables at important workshops and intersections. The Navy Yard's goal was to build a modern Chinese flotilla between 1868 and 1875. Nineteen ships were planned with 80- to 250-horsepower engines. Of these, thirteen would be transport ships with 150-horsepower engines. Sixteen ships were finished during this time. Ten transports with 100-horsepower engines, and one corvette as a showpiece with a 250-horsepower engine, were realized in 1869–1875 while Shen Baozhen was in charge. Nine of the 150-horsepower transports cost over 161,000 taels (224,000 silver dollars) each; five of the 80-horsepower ships cost over 106,000 taels (147,000 silver dollars), with the Yangwu corvette alone requiring 254,000 taels (353,000 silver dollars).[53]

Like the Jiangnan Arsenal, the Fuzhou Navy Yard also compared favorably with the Yokosuka Dockyard. The latter had a budget in 1865 of 1.3 million taels (1.8 million silver dollars) for a four-year period, compared to 4 million taels (5.6 million silver dollars) allotted to Fuzhou over five years. Actual expenditures at Yokosuka doubled the budget, while the Fuzhou Navy Yard expended 5.36 million taels (7.5 million silver dollars) from 1866 to 1874. By 1868, Yokosuka had completed eight ships with eleven more on the way. In comparison, Fuzhou was also at the forefront of naval and technological development. With two major industrial sites in the Yangzi delta and in Fujian province, the Qing was ahead of Japanese modernization efforts in the 1860s and 1870s, but such aggregate advantages in relation to Japan did not translate into organizational superiority when the Fuzhou naval fleet faced the French flotilla alone and unaided in 1884.[54]

The industrial results in Fuzhou were at first gratifying for the Qing dynasty and praised in the December 10, 1875, *North-China Daily News*. Like ships built at the Jiangnan Arsenal, however, those in the Fuzhou Southern Fleet were mainly wooden ships, which were still common in the French navy until 1873, and thus vulnerable to European ironclads after the British began producing them in 1865. They were not equipped with the latest compound engines. When faced with war with France in the 1880s and Japan in the 1890s, some Qing officials unfairly blamed the French, particularly Prosper Giquel (1835–86), a French naval officer, for purposely dumping obsolete equipment and designs on the Chinese navy.[55]

Giquel had joined the Chinese Imperial Maritime Customs as a commissioner of customs at Ningbo in 1861 and later in Hankou until 1866. He signed a contract in 1866 to be the foreign director of the Fuzhou Navy Yard. Zuo Zongtang had also suggested opening a school for technical training called the Hall for the Search for Truth (*Qiushi tang*), an evidential research slogan, which served as the School for Naval Administration. Between 1866 and 1874, almost five hundred Chinese received technical training according to French standards. Twenty became engineers, and another 348 were highly skilled laborers. An additional one thousand men trained as machine and tool workers.[56]

Foreigners taught English, French, mathematics, and drafting. At the same time, just like candidates for the local civil examinations, students were expected to master the *Classic of Filial Piety* and the "Sacred Edict" and "Amplified Instructions" of the Kangxi and Yongzheng emperors. The Qing dynasty's long-term goal for the training that the French engineers and skilled workmen provided in Fuzhou was to create Chinese naval architects and engineers and to generate modern workmen, carpenters, ironworkers, brass workers, ship construction workers, etc., based on the French industrial model.

Giquel reported in 1873 that the Navy Yard set up two divisions of French and English schools. The French division included departments of naval construction, design, and apprentices. A naval academy with departments of theoretical navigation, practical navigation, and engine-room training were in the English division. The naval construction department opened in February 1867 with a curriculum that included French, arithmetic, algebra, descriptive and analytic geometry, trigonometry, calculus, physics, and mechanics. The five-year program suffered a high rate of attrition, however. In the first group of 105 beginning students, only 39 remained at the end of 1873.[57]

To train Chinese officers to operate warships, the English division, headed by John Carroll from England, created a department of theoretical navigation with a curriculum that paralleled that for English and French civil engineers:

Arithmetic: for knowledge of fractions, proportions, interest, etc.
Algebra: for quadratic equations of second degree, ratios, proportions, progressions, etc.
Geography: used Anderson's General Features of the Globe.
Trigonometry: plane and spherical, for solutions of triangles in navigation and nautical astronomy.
Geometry: used Todhunter's edition of Euclid's *Elements* (three books and part of sixth).
Navigation: used Raper's Correction of Compasses, the Sailings, as usually taught, and the Day's Work manuals.
Nautical Astronomy: finding latitude and longitude methods and errors of the compass.

Besides building the dockyard and training personnel, the Navy Yard launched fifteen ships between June 1869 and February 1874. However, only nineteen were completed between 1874 and 1897 due to the lower caliber of administration after Prosper Giquel's departure. During this era the Qing was expected to manage the shipyard on its own. The Navy Yard also faced a curtailment of operating funds due to the decline of interest by Beijing and provincial officials.[58]

A period of Qing self-management commenced in 1874 when operations in the Navy Yard were carried on without foreign technicians, and ended when five new Frenchmen arrived in 1897. The schools attracted native students until the late 1880s. Students in the French division were usually from Fujian; those in the English division were from Guangdong or Hong Kong. After 1874 the Navy Yard sent graduates to Europe, especially England and France, for advanced training to keep up with new technological developments. In 1877 Giquel led a party of twenty-six students. Twelve students from the English division went to England with five attending the Royal Naval College at Greenwich. Nine of the fourteen students from the French division studied hull construction and engine principles in France; the other five studied mining and metallurgy.

A second group of eight graduates was sent out in late 1882 for three years of advanced training. Five studied fortifications, defenses, and gunpowder explosives in France; two studied navigation and naval command in England; and one went to Germany for training in naval mines and torpedoes. A third group of thirty-three graduates was sent in 1886, with ten from the English division, fourteen from the French division, and nine from the Tianjin yard. Thirty completed their training; eighteen studied hydrography, ironclad warship navigation, naval artillery and small arms in England; twelve studied hulls and engines, mathematics and ship construction, river control, bridge and railway construction, and international law in France. A fourth group was scheduled to go to Europe in 1894, but the war with Japan interrupted that.

In 1874, as a twenty-one year-old graduate, Yan Fu, for instance, was acting captain of a small steamer owned by the Fujian-Zhejiang administration but not built by the Fuzhou Navy Yard. As a graduate of the Fuzhou naval division, Yan was eligible to receive advanced training in Europe. On his return to China he became a dean and professor of navigation and mathematics for many years at the Fuzhou Navy Yard. In the early 1880s he became professor of navigation and mathematics in the Tianjin Naval Academy, where he was a teacher and administrator for nearly twenty years.

After the overwhelming defeat by Japan in the Sino-Japanese War, the Navy Yard considered an 1896 recommendation to hire foreign teachers in China rather than sending students to Europe, but the Zongli yamen still wished to send the best naval students to Europe for advanced training. Ten were sent in 1897 for six years of training, but only six went to France. They were recalled in 1900 after three years due to insufficient funds.[59]

Industrial decline at the Fuzhou Navy Yard due to financial troubles had set in by 1876–1877. Expenditures totaled 5.35 million taels (7.4 million silver dollars) for the six and a half years to July 1874. This amount significantly exceeded original estimates, partly due to the high monthly wages per person (371.1 silver dollars) for the forty-five foreign advisors and workmen, which used up 15 to 24 percent of operation costs. By contrast, the total wages for two thousand Chinese craftsmen and nine hundred laborers amounted to only from 12.5 to 20 percent of total operation costs per month, or 4.8 silver dollars monthly per Chinese. Corruption and nepotism ate away at the rest.

The Chinese staff under Shen Baozhen had to work together with Giquel and his Europeans for construction to remain on schedule. Because the Navy Yard was financed as a traditional enterprise with numerous sources of income, traditional Qing budgetary practices did not take into account inflation, growth, or retooling. Long-term planning became impossible. After 1880, the Fujian Maritime Customs failed to turn over regularly the full annual allocation of 600,000 taels (834,000 silver dollars). By the 1890s, the allocation fell to between 200,000 (278,000 silver dollars) and 300,000 (417,000 silver dollars) and under 200,000 taels by 1895. As a result, the schools and dockyard were less active in the 1890s.[60]

Naval Warfare and the Refraction of Qing Reforms into Failure

Europeans and Japanese generally acknowledged that the Jiangnan Arsenal and the Fuzhou Navy Yard were more advanced technically than their chief competitor in Meiji Japan, the Yokosuka Dockyard, until the 1880s. Leaving out the issues of Japanese skills and personal motivations, which were decisive in trumping China's superior numbers in 1895 (see below), David Pong has contended that had the Qing navy engaged the Japanese in a naval battle over Taiwan in 1874–1875, after the Japanese threatened the island in April 1874, Chinese maritime defense preparations would have gained greater support. Perhaps, but due to a failure to reach consensus, the Qing government wavered and sued for peace to avoid hostilities. Subsequently, the budget for the two modern naval fleets in north and south China was cut to 4 million taels (5.56 million silver dollars), much less than was needed. By the late 1870s China's armament industries were mainly producing ammunition. Besides financial difficulties, corruption was also rife among leading officials who competed with each other for the remaining funds.[61]

According to John Rawlinson, only three Japanese ships with about 3,600 hundred men were in the 1874 Japanese expedition to Taiwan. The Japanese naval ministry was established in 1872, and by 1874 it had just seventeen ordinary ships with an aggregate of about fourteen thousand tons. Foreign observers thought China's twenty-one steamers in the one-thousand-ton class could repel the Japanese threat, but, as in 1894–1895, the Chinese ships were not organized into a unified fleet.

Since it would take time to gather a fleet in Taiwan, and because he feared—wrongly—that Japan had two ironclad warships, Shen Baozhen as the director-general of the Fuzhou Navy Yard ended the crisis with a financial payment to Japan. The Qing government also recognized Japanese de facto

control of the Liuqiu (Ryūkyū) Islands. By 1879, China had two ironclad steamships, which had been ordered from the Vulcan factory in the Baltic for the Northern Fleet and were more advanced than anything the Japanese navy had at the time. They were both later sunk in the Sino-Japanese War when the Japanese had caught up technologically. In gunpowder manufacture, moreover, the machinery used in Germany, interestingly, was not as advanced as that in Shanghai at the Jiangnan Arsenal. Japan subsequently caught up with China technically in the 1880s.[62]

The Impact of the Sino-French War

The lack of coordination between the northern and southern navies became the chief weakness of the Qing fleets compared to their counterpart in Japan, which was a unified fleet stationed in Yokosuka under a central command. This disadvantage became clearer after 1874 when the French claimed Vietnam as protectorate, leading to conflict with Qing China in the upper Red River border in northern Vietnam. France began a naval buildup on the China coast that provoked several naval engagements. France did not win all the battles of the Sino-French War in 1884–1885, but it did win the war because of the lack of coordination between the vulnerable Chinese fleet based at the Fuzhou Navy Yard and the Northern Fleet under Li Hongzhang's control. The irony that a French-sponsored navy at anchorage in Fuzhou would be destroyed in a preemptive attack by an invading French flotilla based in Vietnam points to the dangers of relying on European aid in an age of imperialism.[63]

The Qing had over fifty modern naval ships in 1884, with more than half built in China. Among the others, thirteen were British-built Armstrong gunboats, two were Armstrong cruisers, and two more were German-built ships with two eight-inch guns. The latter two pairs were divided equally between the northern commissioner's Beiyang fleet and the southern commissioner's Nanyang fleet. The Qing navy, however, was divided into four fleets: the Northern Fleet at Weihaiwei and Port Arthur, one in Shanghai, another in Fuzhou, and the smallest in Guangzhou. In the 1884–1885 war, the Fuzhou flotilla fought the French nearly alone in the climatic battle.

At its home port of Mawei, the Fuzhou fleet was destroyed in fifteen minutes when French commanders sailed their war vessels uncontested past the Min River defenses protecting the Navy Yard. Because the French had not yet declared war, Qing forces naively allowed the French to exploit the situation. The French fleet thus approached the Fuzhou dockyard on August 23, 1884, unchallenged. The Qing government had not prepared contingencies for the impending war.

The Qing fleet at the Mawei anchorage numbered eleven ships. All were at least nine years old and made of wood. Eight French vessels were anchored near by and were superior, but the Chinese ships had respectable if nonstandard armaments. The Chinese were unable to use the tides to outmaneuver the heavier French vessels, which suggests that the Fuzhou captains were inexperienced. Li Hongzhang sent only two of the ships that the Qing court requested from his Northern Fleet, and he quickly withdrew them by asserting that the Japanese threat in Korea mandated their return north.[64]

The French fleet withdrew to Taiwan, but after a failed landing French forces threw a blockade around the west coast of the island. Negotiations resumed after a Chinese land victory at Lang Són. China's loss, then, was not simply due to French military superiority. French technological superiority in the 1880s was not as great as England's during the Opium War and the Second China War of 1856–1860. China had closed the gap somewhat with Europe technologically. The actual problems were (1) the political and regional disorganization of the empire; and (2) naval personnel were insufficiently trained and had a poor grasp of modern naval strategy.[65]

Except for the lost vessels, the Fuzhou dockyard had survived with little damage. In the postwar period, however, progress at the Fuzhou Navy Yard was limited in scope after its founder, Zuo Zongtang, died in 1885. Li Hongzhang thereafter purchased naval vessels for his Northern Fleet rather than building them at home. Li also had to supply his Anhui land army. After most of the Fuzhou squadron was destroyed by the French in 1884, a foreign-built ship was purchased and used as a training vessel. The Fuzhou Navy Yard also reduced its number of engineers and skilled workmen, but it continued to operate in the 1890s despite neglect. One ship each year was launched in 1891, 1892, and 1895. The war damaged or destroyed books and logistical supplies for the schools, but officials quickly restored them by 1886.[66]

The rise of Beiyang as China's chief fleet after 1885 resulted from what the Chinese called the "Disaster in the South." Although demanded by the court, subsequent efforts to create a single command for a unified naval fleet never succeeded. The new Navy Board and Li's Beiyang fleet competed for financial resources, which were declining due to further naval budget cuts between 1885–1894. The empress dowager's infamous efforts to garner funds to expand the Summer Palace did not bankrupt the imperial treasury, but they didn't help support the Chinese navy either. Inadequate funding and misplaced priorities set limits on Li Hongzhang's plans to expand the Northern Fleet.[67]

The strength of the Beiyang fleet was clear to the Japanese because of stops the Chinese fleet made in Japan in the 1880s after cruises to Vladivostok. Moreover, the inconclusiveness of the Sino-French War, which reporters conveyed to Japan, restored some Chinese prestige in Japanese eyes from the low it had reached after the Opium War. In the Nagasaki Incident of 1886, for instance, four warships of the Northern Fleet anchored in Nagasaki on their return trip from the Russia. Li Hongzhang sought to impress the Japa-nese that China's naval equipment, reinforced by new ships purchased from Germany, was superior to Japan's. Fights between Chinese sailors, who claimed the right of extraterritoriality, and Nagasaki police, who viewed it differently, broke out during the port call, and each side blamed the other.[68]

China's flaunting of its naval superiority aroused Japanese hostility. Similarly, Japanese-Chinese fights provoked the Kobe Incident of 1889, which became a diplomatic dispute after a Chinese port stop there. A reporter for the newspaper *Citizen's Press* (*Kokumin shimbun*) reported another visit by the Chinese fleet in July 1890, presenting it as an instance of Chinese showing off their new ships. Toyama Masakazu (1848–1900), an educator and former president of Tokyo University, visited the flagship of the Chinese fleet and came away impressed with its large-caliber guns and thick steel armor. The Sino-Japanese War put an end to these diplomatic controversies when Japan exploded the notion of Chinese superiority and ended Chinese claims of extraterritoriality.[69]

The Sino-Japanese War and Its Aftermath

When the Sino-Japanese War unexpectedly began on July 24, 1894, the foreign press generally predicted a Chinese victory even after reports of initial losses. At the time, the Qing navy (sixty-five ships) ranked eighth in the world, compared to Japan's (thirty-two ships), which ranked eleventh. China's navy was superior in armor, armaments, and tonnage. Some thought that China's two German-built battleships were more powerful than the *Maine* and the *Texas,* the United States Navy's largest warships. G. A. Ballard, vice admiral in the British Royal Navy, believed the Beiyang fleet in the 1890s was in serviceable condition and ready for action. Some later comparisons of the Qing and Meiji naval fleets have suggested that China could have won the sea war. On land, however, the sixty battalions of the Chinese army in the north had serious organizational weaknesses. Only twenty thousand frontline troops faced Japan's fifty-thousand-man army.[70]

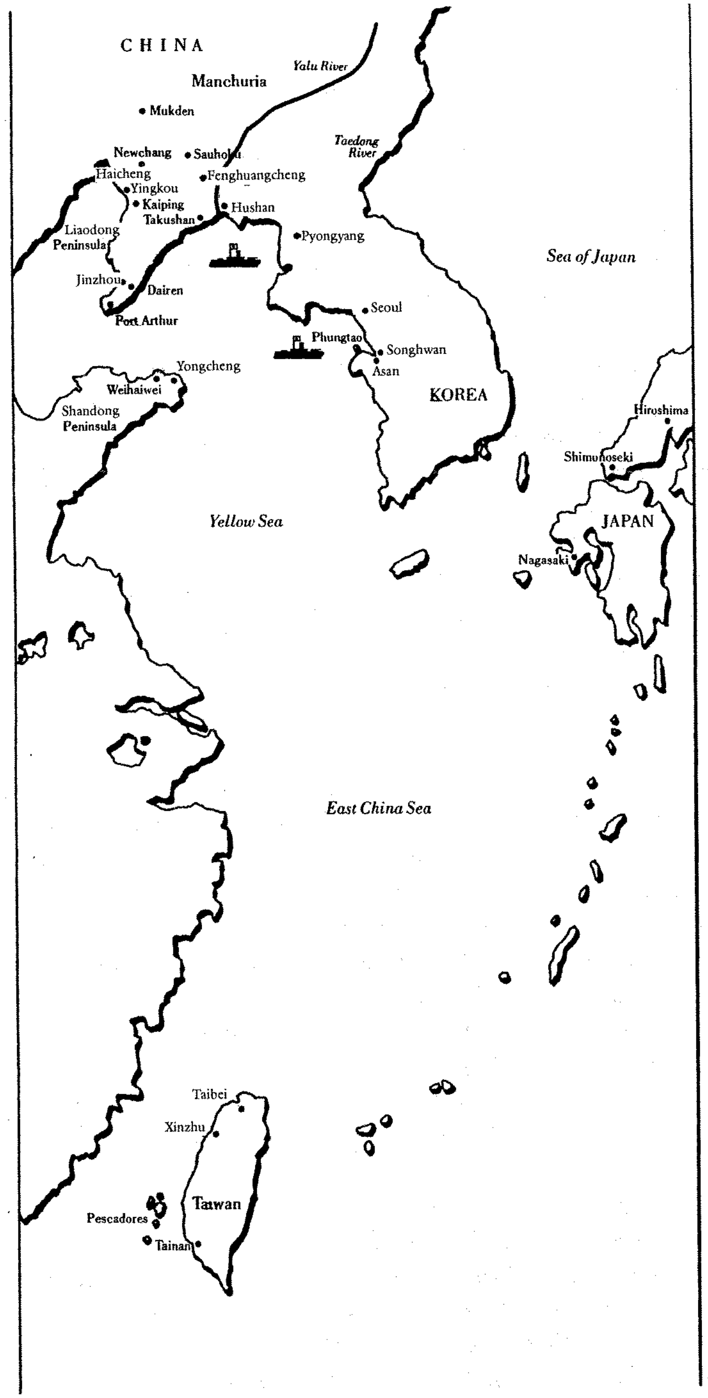
Almost fourteen thousand men manned Japan's naval fleet of thirty-two warships and twenty-three torpedo boats. Ten ships were built in Britain, and two in France. The Yoshino from Britain's Armstrong's shipyard was arguably the fastest vessel of its time when it was timed at twenty-three knots in the 1893 trials. China's navy was still divided into the Beiyang, Nanyang, Fujian, and Guangdong fleets. In 1894, these four combined had about sixty-five large ships and forty-three torpedo boats. The strongest, the Beiyang fleet, more or less equaled Japan's entire fleet. Chinese ships were equipped with more-modern guns, but the navy lacked an adequate supply and transport system to take the offensive. The fleets took a defensive posture, which had contributed to defeat in the Sino-French War a decade earlier.[71]

If general opinion among foreigners favored Li Hongzhang's fleet over Japan's, then Japanese newspapers, magazines, and fiction were marked by exhilaration at the prospect of war with China. Some Japanese were not overly confident of victory, however. The publicist Fukuzawa Yukichi (1835–1901) warned against overconfidence, for instance, although he agreed with Japan's just cause in spreading independence and enlightenment to Korea. The Meiji emperor was reluctant to begin hostilities. He had refused to send messengers to the imperial shrines at Ise or to his father's grave to announce the war until the news of the initial Japanese victories was communicated to him. Japanese Diet members were also surprised at the easy victory.[72]

Another British observer noted that Chinese crews engaged in the war were at half strength, but salaries for full crews were paid. The greatest contrast lay in the fact that Japan's navy was unified. In the end Li Hongzhang's Beiyang navy fought the Japanese principally unaided. Li had kept his fleet out of the Fuzhou battle in 1884, and the Nanyang officers now got their revenge on the Northern Fleet by keeping their fleet for the most part out of war with Japan. So much for a united fleet.

Located between Japan and north China, Korea had historically tilted toward China rather than Japan, particularly after Hideyoshi's disastrous invasions of the peninsula in the late sixteenth century. Two hundred years later, Korea's Chŏson rulers still acknowledged their tributary status in relation to the Qing empire. Korean affairs, particularly Japan's dissatisfaction with Qing influence over Korea's closed-door foreign policies, became a flashpoint between Tokyo and Beijing. With the political and economic opening of Korea as the key dispute, hostilities commenced when Japan seized the Korean king. Li Hongzhang shortly before, in July 1894, had sent Qing troops into Korea to preserve Korea as a Qing ally. The Korean king's regent, an ally of Japan, then declared war on China. The first encounter between Chinese and Japanese ships occurred on July 24 at Fengdao, and China's two warships proved no match against an unprovoked attack. After that sea battle, the Qing Northern Fleet tried to defend the Chinese coast from Weihaiwei and Port Arthur to the mouth of Yalu River and finally declared war on August 1 (see Map 10.1).[73]

Subsequently, the Japanese naval raid at Weihaiwei on August 10 stunned the Qing court, while Li Hongzhang stalled and made excuses. Weihaiwei and Port Arthur controlled the entrance to the Bohai Bay and sea approaches to Beijing. The main Beiyang fleet gathered at the mouth of the Yalu where



Map 10.1. The Chinese coast from Weihaiwei to the mouth of Yalu River during the Sino-Japanese War.

a major naval battle with Japan commenced on September 17. It was arguably the first great naval battle employing steam-powered fleets. Each side had twelve ships in the clash. China had the advantage in armor and weight in a single salvo, while Japan had a decided advantage in speed of ships and total amount of metal thrown in a sustained exchange of salvos. Japan had more quick-firing guns, which could fire three times more weight in shells than China's six- to twelve-inch guns could.[74]

Technology alone was not the key determinant. Japan, for example, could not match China's two major battleships. Japan, however, proved to be superior in naval leadership, ship maneuverability, and the availability of explosive shells. Some observers rushed to scapegoat the Fuzhou-trained officers as cowards because they were the dominant Chinese group and had more experience and training than the Tianjin-trained officers. In 1892, for example, most engine-room appointments still went to Fuzhou graduates. Nine of the twelve captains of the Beiyang ships that fought Japan at the mouth of the Yalu were Fuzhou graduates. Rawlinson, however, has contended that cowardice was not the decisive factor. China fired 197 twelve-inch projectiles at the decisive naval battle of Yalu, with half of them being only solid shot rather than explosive shell. They scored ten hits, only four filled with explosives.[75]

From smaller guns, Chinese fired 482 shots and registered fifty-eight hits, twenty-two on one ship. They also launched five torpedoes without hits. China scored about 10 percent of her tries. The Japanese, on the other hand, with their rapid-firers scored about 15 percent of their tries. In addition, the Chinese were hampered by shortages of ammunition, especially for their bigger guns. Some were filled with cement, for example, the one that struck the Matsushima and the two that passed through the Saikyo. This suggests that there were serious corruption problems in Li Hongzhang's supply command. With hindsight, assuming that Qing and Meiji strategic decisions remained the same, it was clear that the speed and rapidity of fire of Japan's ships were more important at Yalu than the weight of the Qing vessels and their superior armor.

Shore engagements continued after the battle at the Yalu as the Japanese took advantage of their unexpectedly decisive victory at sea to launch a land war that allowed the Japanese First Army to occupy Pyongyang and then cross the Yalu to enter China at the Manchurian border. In addition, Japanese cryptographers had since June 1894 decoded Li Hongzhang's military communications. The Japanese Second Army, formed in September 1894, landed on the Liaodong Peninsula and took Port Arthur. The poor command structure of the Beiyang Fleet and the lack of a court-martial system made it impossible to place blame on any Qing officers or allocate reward

properly. Moreover, the Qing personnel system was unpredictable and far from impartial. Many Chinese captains and officers simply committed suicide. No one dared to question the command structure or demand a board of review independent of the navy.[76]

The Sino-Japanese War generated intense Japanese self-confidence after 1895. The Japanese navy was enhanced by the capture of twelve Chinese warships and seven torpedo boats during hostilities, which added significant tonnage to the Meiji fleet. Moreover, Japanese industrialization accelerated after the Qing dynasty was forced to pay a considerable indemnity to the Meiji regime. The Japanese government used the indemnity as a windfall to bankroll a massive rearmament program to address the Russian expansion on the borders of northeast China. Korea and Taiwan were ceded to Japan and became colonies.

The indemnity also meant that China's huge payments to Japan could not be used to augment the Qing dynasty's reconstruction projects. The Jiangnan Arsenal and Fuzhou Shipyard in particular never recovered from the indemnities. If the Qing government was unable to integrate development so that innovative institutions reinforced each other before this, the added weight of Japanese and European imperialism after 1895 tipped the scales. The Qing reforms initiated in 1865 had even less chance of success under such political conditions.[77]

Wider Western notice of the small island kingdom that had defeated the Qing empire also ensued. The Japanese victory, however, angered the Russians, who feared Japanese expansion on the Asian continent. In concert with Germany and France, the Russians joined in a Triple Intervention after the Treaty of Shimonoseki was signed in April 1895, which forced the Japanese to withdraw from the key Liaodong Peninsula in exchange for an additional payment from the Qing government. Subsequently, in June 1896 Russia and the Qing government signed a secret alliance against Japan in which Russia was granted a railroad concession in the northeastern provinces that were increasingly referred to as Manchuria.[78]

For the Japanese public, the victory developed into the key event that energized the newly emergent Meiji press, and drowned out editorial debate over Japan's military role in Korea (see Figure 10.2). Public rage was also directed at the European powers for intervening on the side of China. When Russia later forced the Qing to lease the Liaodong Peninsula to them, the Japanese were primed for war with Moscow over the fate of China. Public enthusiasm for military adventures became a common feature when the dissemination of the national news became a central feature of the Japanese press after 1895. There were by then 600,000 newspaper subscribers in Tokyo and Osaka alone. The Japanese victory over China reverberated throughout the country and demonstrated the preeminence of Meiji Japan in east Asia. The Japanese naval victory over Russia in 1904–1905 cemented such national exuberance.

The shift from a controlled to an information press in Meiji Japan grew out of news accounts of the Sino-Japanese War, which stimulated the demand for news and information in a new, unified Japanese language. The Hakubunkai Publishing House, for example, took advantage of the outbreak of war and quickly published a trimonthly illustrated record in September 1894 titled the *Diary of the War Between Japan and Qing China* (*Nisshin sensō jikki*), which was enormously popular and helped create a cult of Japanese war heroes. Other publishers quickly followed suit, and novels, plays, and woodblock posters about the war became best sellers. The *Yomiuri shimbun* newspaper initiated a prize competition for the "best" anti-Chinese war songs.[79]

In a completely opposite way, the naval disaster at the Yalu River and the decisive Qing defeat in the Sino-Japanese War energized public criticism of the dynasty's inadequate policies and enervated the staunch conservatives at court and reformers in the provinces who had opposed westernization. The unexpected naval disaster at the hands of Japan and the way it was presented as a technological victory had shocked many literati and officials and now led to a new respect for Western studies in literati circles (see Figure 10.3). The

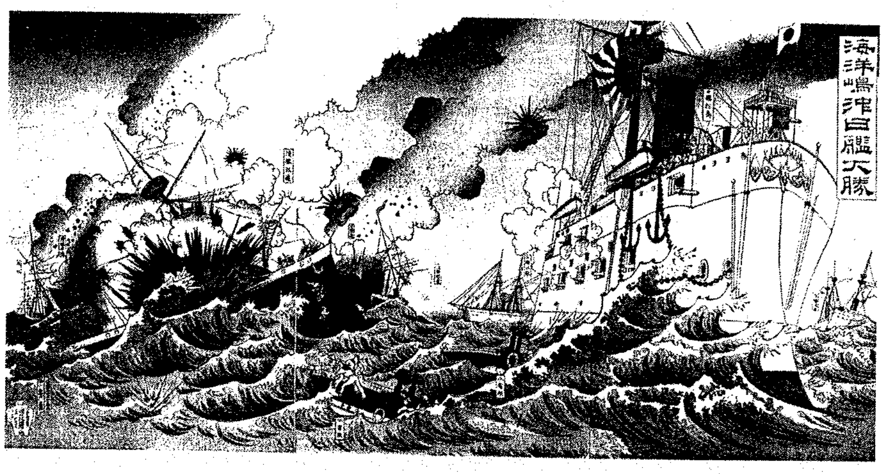


Figure 10.2. Nakamura Shūkō, "The Great Victory of Japanese Warships off Haiyang Island, 1894."

Source: Reprinted from *Japan at the Dawn of the Modern Age: Woodblock Prints from the Meiji Period,* Catalogue by Louise E. Virgin, with the permission of the publishers, Museum of Fine Arts, Boston. Copyright 2001.

renewed success of the Shanghai Polytechnic in 1896, for example, was tied to this event. John Fryer now reported, "The book business is advancing with rapid strides all over China, and the printers cannot keep pace with it. China is awakening at last."[80]

Unfortunately for Fryer and the missionaries, China increasingly imported science books that were translated or edited in Japan after the Sino-Japanese War. Accordingly, there was a sea change from missionary-based Chinese terminology for science from the 1840s to Japan-based Chinese terminology from 1900 with the Sino-Japanese War as key point of change. During the last decade of the Qing dynasty, the terminology in science journals in China shifted dramatically away from terminology associated with investigating things and extending knowledge (*gezhi xue*) to Japanese terms in science texts such as *World of Science* (*Kexue shijie,* 1903–1904); *First Level in Science* (*Kexue yiban,* 1907); *Science Journal* (*Lixue zazhi,* 1906–1907); and *Science* (*Kexue,* 1908–1910).[81]

The period after the Sino-Japanese War in Shanghai also saw the more-active involvement of Catholic missionaries in a new enlightenment project (*weixin*) that drew on the image of Meiji Japan as a model for the 1898 reform movement in China. It was ironic that as Japanese influence in the sci-

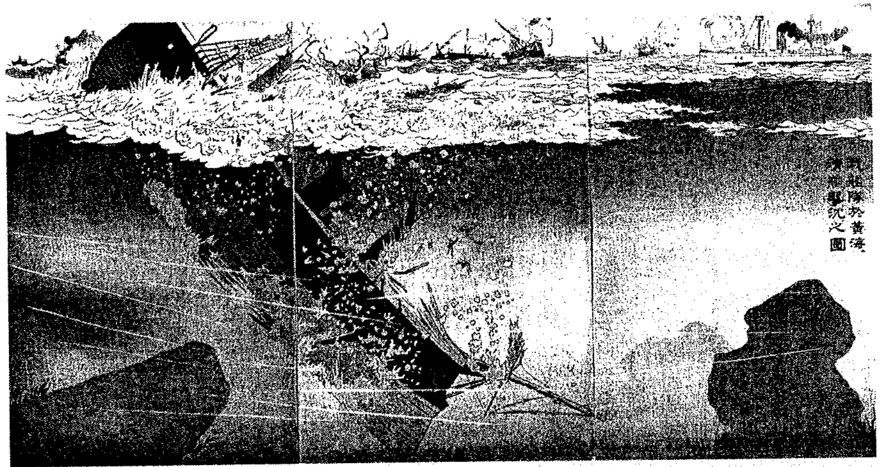


Figure 10.3. Kobayashi Kiyochika, "Illustration of our Naval Forces in the Yellow Sea Firing at and Sinking Chinese Warships, 1894."

Source: Reprinted from *Japan at the Dawn of the Modern Age: Woodblock Prints from the Meiji Period,* Catalogue by Louise E. Virgin, with the permission of the publishers, Museum of Fine Arts, Boston. Copyright 2001.

ences replaced the Protestant era of translations, the French Catholic community renewed the Jesuit effort to enlighten China through science.[82]

For example, the *Revue Scientifique* (*Gezhi xinbao,* also called the *Scientific Review*) was published monthly by the Commercial Press from March to August 1898 and was tied to the French Catholic community in Shanghai. Founded by Zhu Zhiyao (1873–1955) and Zhu Yunzuo (d. 1898), both converts, with the editorial assistance of Wang Xianli and French missionaries, it represented a clone of *The Chinese Scientific and Industrial Magazine.* On the same model, the *I-Wen-Lou et Revue Scientifique* (*Gezhi yiwen huibao*) was published as a Catholic journal in Shanghai from 1898 to 1899, which combined two earlier periodicals into a single journal. The stated goal was to introduce Western learning and practical affairs to the Chinese, as if they had not mastered their earlier lessons properly. Chinese awareness of modern science was deepened by these new journals, but they were soon superseded.[83]

Reconsidering the Foreign Affairs Movement

Chinese naval defeats contributed to the transformation of official, elite, and popular perceptions of the Self-Strengthening era. New public opinions appeared in the Chinese and missionary press that shaped the emerging national identity and sense of crisis among Han Chinese, who increasingly opposed the Manchu regime in power. Disappointment with the military losses convinced many Chinese that the foreign affairs movement had failed and that more radical political, educational, and cultural changes were required to follow Japan's lead in modernizing and coping with foreign imperialism. Earlier adaptation of new technological and scientific learning before 1895 was forgotten and repressed. Euro-American missionaries and experts who had aided in the Qing dynasty's scientific translation projects, which were used as textbooks in the arsenals and technical schools, now also thought that the Chinese nation, language, and culture were doomed.[84]

Allen Fung has recently reconsidered the "witch-hunt for the inadequacies of the Chinese army and navy" that ensued after 1895. Fung focuses on the defeat of the Chinese army in the Sino-Japanese War because Japanese land victories gave them a clear path to march on Beijing. This threat to the capital forced the Qing court to seek an immediate settlement of the war. In contrast to accounts in China that still accuse the key Qing minister, Li Hongzhang, of cowardice for his peace-at-any-cost policy, Fung maintains that Chinese armies were well equipped during the early stage of the war with Japan and that the Chinese field commanders were not incompetent. He refutes earlier claims that China's land defeats in the Sino-Japanese War were due to the failure of the Chinese ordnance industry.

Fung concludes that the primary explanations for China's losses in the land war are (1) the better military training Japanese troops and officers received compared to their Chinese counterparts; and (2) the fact that Qing troops were outnumbered by the Japanese at the major battles. I would add that the Qing court and its regional leaders underestimated the dangers of relying on European aid in an age of imperialism.[85]

We have assessed above the naval wars that the Qing dynasty lost in the late nineteenth century. Along with the Sino-Japanese War, the Sino-French naval battles have also been used as a litmus test for measuring the failure of the Self-Strengthening reforms initiated after the Taiping Rebellion. The rise of the new arsenals, shipyards, technical schools, and translation bureaus, which are usually undervalued in such "failure narratives," should also be reconsidered in light of the increased training in military technology and education in Western science available to the Chinese after 1865. Long-standing claims made by contemporaries of the Sino-Japanese War that China's defeat demonstrated the failure of the foreign affairs movement to introduce Western science and technology successfully will be reconsidered below.[86]

From "Computists" (Chouren) to "Scientists" (Gewu zhe)

We have focused above on the schools and factories launched within the Jiangnan Arsenal in Shanghai and the Fuzhou Navy Yard. John Fryer wrote in 1880, for instance, that the Jiangnan Arsenal had commenced publishing translations of Western works in 1871. By June 30, 1879, some ninety-eight works were published in 235 volumes (*juan*). Of these, twenty-two dealt with mathematics, fifteen were on naval and military science, thirteen covered the arts and manufactures. Fryer reported that another forty-five works in 142 volumes were translated but not yet published, and thirteen other works were in process with 34 volumes already completed.

Altogether, the Translation Office in the Jiangnan Arsenal had by 1880 sold 31,111 copies representing 83,454 volumes, and this had been accomplished without advertisements or postal arrangements. A work on the German Krupp guns translated in 1872 sold 904 copies in eight years, for example. Another work on coastal defense published in 1871 sold 1,114 copies in nine years. *A Treatise on Practical Geometry* (1871) sold 1,000 copies in eight years; *A Treatise on Algebra* (1873) sold 781 copies in seven years. Fryer's work on coal mining published in 1871 sold 840 copies in nine years. Publicizing these works beyond Shanghai, Beijing, and the treaty ports was difficult, but even for the latter venues such numbers were disappointing.[87]

Nevertheless, the controversial political reformer cum New Text iconoclast Kang Youwei (1858–1927) purchased all the arsenal works when he was in

Shanghai in 1882. Between 1890 and 1892, his disciple Liang Qichao purchased many of the arsenal's translations and *The Chinese Scientific Magazine*. Liang developed an influential reading list based on these materials known as the "Bibliography of Western Learning" (*Xixue shumu biao*), which was revised and published in 1896. Of these 329 published works in twenty-eight categories, 119 (36 percent) were translated by Fryer and his Chinese collaborators.

Tan Sitong (1865–1898) wrote in 1894 on scientific topics and mentioned *The Chinese Scientific Magazine* as one of his sources of scientific learning. Tan had visited Shanghai in 1893 and bought many of the arsenal's science translations, as well as works on history, politics, geography, and religion that were published by the Society for the Study of National Strengthening (*Qiangxue hui*).[88]

Besides their use as textbooks in the increasing number of missionary schools, a regional matrix of arsenals, factories, and technical schools that formed the nineteenth-century roots of the twentieth-century industrial revolution in China also used them (see Map 10.2). Hence, we should also acknowledge the scope and scale of scientific translation and military arsenals elsewhere in China after 1860. Not all of them were based on British or French models, although our two examples of the arsenal in Shanghai and navy yard in Fuzhou largely were. A list of these empirewide venues is included in Appendix 4.[89]

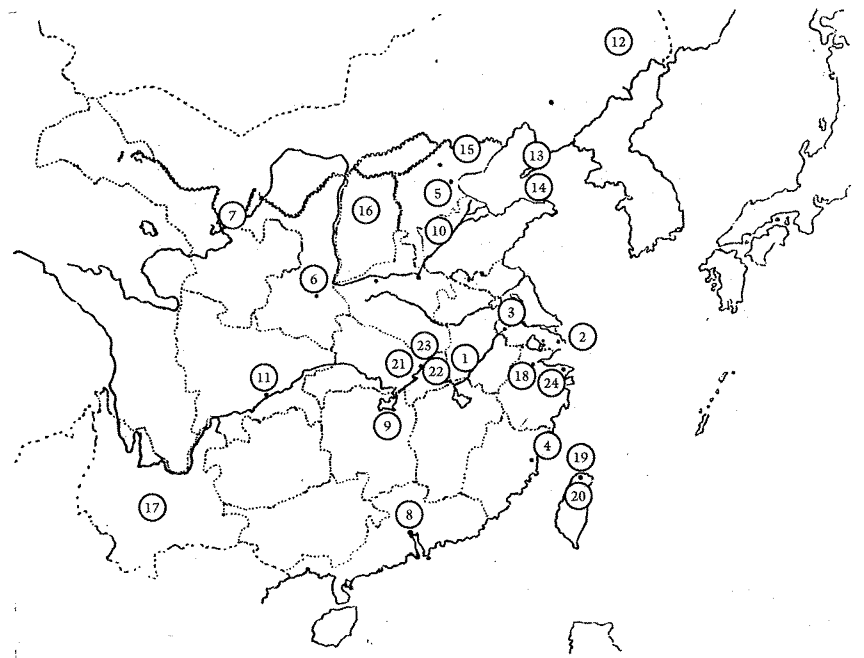
Once the attack on the Fuzhou Shipyard during the Sino-French War demonstrated the vulnerability of the factories and fleets to foreign naval blockade, Zhang Zhidong (1837–1909), then governor-general in Hubei and Hunan provinces in the middle Yangzi region, recognized the need for the Hanyang Ironworks (1890) and Hanyang Arsenal (1892) as protected, inland industrial sites. Not funded until 1891–1895, however, and then subject to the competing interests of Li Hongzhang's Northern Fleet and the military threat from the Japanese in Korea, the Hanyang Arsenal found that its funds were inadequate for simultaneous development of the ironworks and the arsenal. This problem lead to a slowdown in the arsenal, which failed to produce weapons or ordnance in time for the Sino-Japanese War.

Other delays in plant building and a damaging fire in summer 1894 kept the Hanyang project from achieving success before the twentieth century. Zhang wrestled with the twin goals of strategic industrialization and modern military production in the midst of the court's emergency diversion of funds and resources to deal with the Russian and Japanese threats. He chose to fund the ironworks for raw material rather than the arsenal for military arms. Hence, the Hanyang Ironworks became the hub of China's iron and steel industry during the first half of the twentieth century.[90]

If we repopulate this impressive list of factories with the human lives and literati careers they contained, then we can trace more clearly the post-Taiping

successors to the native mathematical astronomers (*chouren*) that Ruan Yuan's compilation of the *Biographies of Astronomers and Mathematicians* had adumbrated circa 1800. A new group of artisans, technicians, and engineers emerged between 1865 and 1895 whose expertise no longer depended on

Partial Chronological List of Arsenals, etc., in China, 1861–1892



1. Anqing Arsenal, 1861
2. Jiangnan Arsenal, 1865
3. Jinling Arsenal, 1865
4. Fuzhou Shipyard, 1866
5. Tianjin Arsenal, 1867
6. Xi'an Arsenal, 1869
7. Lanzhou Arsenal, 1871–1872
8. Guangzhou Arsenal, 1874
9. Hunan Arsenal, 1875
10. Shandong Arsenal, 1875
11. Sichuan Arsenal, 1877
12. Jilin Arsenal,1881
13. Lüshun, Port Arthur Naval Station, 1881–1882
14. Weihaiwei Shipyard, 1882
15. Beijing Field Force Arsenal, 1883
16. Shanxi Machine Shop, 1884
17. Yunnan Arsenal, 1884
18. Hangzhou Arsenal, 1885
19. Taiwan Machine Shop, 1885
20. Taiwan Arsenal, 1885
21. Daye Iron Mine, 1890
22. Hanyang Ironworks, in Hubei, 1890
23. Hanyang Arsenal, 1892
24. Zhejiang Machine Shop, 1893

Map 10.2. Location of key arsenals, shipyards, and factories during the Self-Strengthening period. (See also Appendix 4).

the fields of classical learning monopolized by the customary scholar-officials. Increasingly, they were no longer subsidiary to the dynastic orthodoxy or its official representatives.[91]

Still a necessary part of the cultural, political, and social hierarchies, the new students of the sciences in the arsenals and missionary schools emerged from the older categories of the myriad elite aspirants for official status. The scientist (*gewu zhe*) was "one who investigated things," and he now coexisted with the orthodox classical scholar in the bureaucratic apparatus but at lower levels of political rank, cultural distinction, and social esteem. The self-taught students of modern science and technology in the 1850s, such as Xu Shou, Hua Hengfang, Xu Jianyin, and Li Shanlan, were successors of the Yangzi delta mathematical astronomers who had emerged during the rise of mathematics in the age of evidential research.

Before he began work in the Jiangnan Arsenal, for instance, Xu Shou was expert in mathematics and physics, but he remained unsuccessful in the civil service competition. His classical and mathematical expertise enabled him to master the technical knowledge needed for shipbuilding and other industrial projects at the arsenal. In one curious overlap between evidential studies and modern physics, for example, Xu Shou, who was a skilled maker of replicas of ancient musical instruments, revised the findings in the English physicist John Tyndall's (1820–1893) book *Sound,* whose second edition (London, 1869) was translated by Fryer and Xu Jianyin.

Seeking to restore a mathematically accurate musical pitch pipe series for ancient harmonics, Xu Shou published an article titled "Evidential Investigation into Mathematical Harmonics" ("Kaozheng lülü shuo") in an 1880 issue of *The Chinese Scientific Magazine,* in which he noted that the ratio of the length of a pitch pipe to another one an octave higher was 9:4 and not 2:1 as Tyndall had claimed. Fryer then submitted a letter to *Nature* in 1881 that demonstrated why Tyndall's finding was in error. Seeing a scientific basis in Xu Shou's experimental critique of Tyndall's error, the editor of *Nature* noted, "It will be seen that a really scientific modern correction of an old law has most singularly turned up from China and has been substantiated with the most primitive apparatus." Tyndall initially corresponded with Fryer about the translation of his book into Chinese, but after the Xu critique of his work appeared in *Nature,* Tyndall made no effort to alter the mistake in later editions of his book.[92]

Xu Shou's training in evidential research was coupled to a rejection of the key concepts of traditional Chinese natural studies. We have seen in Chapter 8 that he also attacked traditional Chinese medicine because of its use of yin-yang and the five phases. In Xu's case, evidential research also prepared him for mastering Western science. Xu Shou, Li Shanlan, and others were in turn

succeeded by those like Yan Fu and Lu Xun who were drawn to the Fuzhou Navy Yard and the Jiangnan Arsenal for formal training in science, mathematics, and engineering.[93]

By going outside the orthodox curriculum of the civil service examination, the newly educated in science, mathematics, and engineering inhabited the unprecedented arsenals, shipyards, and factories that offered non-degree-oriented engineering, mathematical, and science training. By linking science and technology, late Qing reformers produced an early version of twentieth-century Chinese techno-science (*keji*). The regional leaders of the foreign affairs movement emphasized technical expertise in engineering and mechanics and specialized knowledge of the modern sciences.[94]

Those who were drawn to scholarly work in the new industrial arsenals in Fuzhou, Shanghai, and elsewhere or translation positions in the three Foreign Language Schools in Beijing, Shanghai, and Guangzhou still tended to be Manchu bannermen or Han Chinese literati such as Xu Shou and Li Shanlan, men who failed the civil examinations several times and saw Western learning and the sciences as an alternative route to an official career. Yan Fu and Lu Xun were famous examples of this group of outsiders from the civil examinations that initially served as the pool of highly educated men who filled the promising world of late Qing institutions oriented toward science.[95]

Lu Xun's grandfather, Zhou Fuqing, a Hanlin academician and the first important scholar in the Zhou family from Shaoxing in Zhejiang province, was jailed for attempting to bribe an examiner assigned to the 1893 Zhejiang provincial examination. The scandal forced Lu to leave his lineage school where he had prepared for the civil examinations. Before turning to literature, Lu Xun was first trained at the Jiangnan Arsenal, and he later traveled to Japan to study modern medicine at Sendai just before the 1904–1905 Russo-Japanese War.[96] Better known as a translator and publicist who was critical of late Qing reform efforts, Yan Fu, we have seen, was a graduate of the Fuzhou naval division and later received advanced training in Europe. In 1902 he was appointed chief editor for the new official Translation Bureau in Beijing after the fame he received for his translations of John Stuart Mills's *On Liberty* and Herbert Spencer's account of social Darwinism.[97]

Eventually, thousands of administrative experts, translators, and advisors—including hundreds of foreigners—served in provincial schools and arsenals under the chief provincial ministers of the late Qing. Zeng, Li, Zuo, and Zhang were the leaders of the post-Taiping turn toward foreign studies focusing on science and industry. Literati associated with statecraft and evidential studies after the Taiping Rebellion legitimated literati study of natural studies and mathematics within the framework of "Chinese studies as fundamental, Western learning as useful" (*Zhongxue wei ti Xixue wei yong*).[98]

The promising start made in missionary schools and the empirewide arsenals accelerated in the 1880s when Shanghai and Beijing took the lead in promoting the new fields associated with the foreign studies movement. In particular, the shipbuilding industry played an indispensable role in the emergence of late Qing industrial enterprises. At Jiangnan and Fuzhou the first lathes and furnaces in China to produce molten steel emerged. During the last years of the First World War, more than two hundred skilled workers at the Fuzhou Shipyard manufactured the first Chinese airplane. The arsenals, machine shops, and shipyards provided the institutional venues for an education in science and engineering. They also trained the architects, engineers, and technicians in the shipyards and arsenals who later provided the manpower for China's increasing number of public and private industries in the early twentieth century.[99]

China's defeats in the Sino-French and Sino-Japanese wars produced a pessimistic intellectual climate among both foreigners and reformers in China. Chinese literati increasingly believed that China was doomed unless more radical political initiatives were carried out. In the process, rhetoric favoring modern science became a key theme of revolutionaries in their political discourses. Earlier efforts to complement traditional Chinese natural studies and mathematics with modern science were gainsaid and deemed ludicrous. This perspective informed elite discourse about premodern natural studies and traditional Chinese medicine for much of the twentieth century.

The Construction of China's Backwardness after the Sino-Japanese War

The Sino-Japanese War provoked a striking switch in Protestant confidence about the future of Qing China. Chinese frequently pirated Young J. Allen's account of the Chinese defeat, after it was translated into Chinese. It was required reading for the 1896 Hunan provincial examination in Changsha. One of the leading Protestant missionaries and translators in Beijing, Allen outlined needed reforms in China. Allen had published an extended essay titled "Precis of Sino-Western Relations" (*Zhongxi guanxi luelun*), in the September 1875 to April 1876 issues of the *Review of the Times* (*Wan'guo gongbao*). The *Review*'s accounts of the war with Japan were republished in 1898 as a massive tome and immediately sold out its three thousand copies.[100]

Such missionary assessments were no longer gradualist, however. In the essay, Allen traced China's backwardness to three root causes: (1) superstition (*mixin*); (2) opium; and (3) civil examinations. In this series, he also stressed the importance of science (*gezhi*) as a corrective for the causes of China's backwardness. Native studies had, according to Allen, failed to grasp the universal lessons of modern science. In particular, China's assimilation of Western science missed the importance of the "study of the principles of things" (*wuli zhi xue*), that is, natural science. After 1900 this term would increasingly refer to physics, based on Japanese translations of Western scientific texts. Moreover, Allen used superstition as a modern cultural category to pigeonhole the entire Chinese classical tradition, a reduction that would become de rigueur among many Chinese radicals in the twentieth century.[101]

One of the institutional products of the political iconoclasm in China after the Sino-Japanese War, which survived the empress dowager's counter-coup against the Reform Movement in 1898, was the Imperial University of Beijing (*Jingshi daxue*). The Qing government established it at the pinnacle of an empirewide network of schools that would expand on the Foreign Language Schools in Beijing, Shanghai, and Guangzhou. Like the Translation College, the new university trained civil degree holders in Western subjects suitable for government service. The court chose William Martin, a distinguished missionary who had worked in the Beijing School, as the dean of the Western faculty in 1895.[102]

The curriculum at the Imperial University comprised eight fields: classical studies, politics, literature, medicine, science (*gezhi*), agriculture, engineering, and commerce. Six courses defined the science field: mathematics, astronomy, physics, zoology, botany, and geology. The Imperial University still referred to science courses in light of the investigation of things, although the facilities included modern laboratories equipped with the latest instruments for physics, geometry, and chemistry. This promising development was short-lived, however, because north China rebels associated with the Boxer Rebellion smashed everything in sight at the university in the summer of 1900. European armies were not any kinder during their occupation of Beijing after the Boxer siege of the foreign legations was lifted.[103]

The Qing race to establish Chinese institutions of higher learning that would stress modern science accelerated after the occupation of the capital by Western and Japanese troops in 1900. The Boxer popular rebellion in north China and the response of the Western powers and Japan to it unbalanced the power structure in the capital so much that foreigners were able to put considerable pressure on provincial and metropolitan leaders such as Li Hongzhang. Foreign support of reform and Western education thus strengthened the political fortunes of provincial reformers such as Yuan Shikai (1859–1916) and Zhang Zhidong, who had opposed the Boxers.[104]

Fryer and the Missionary Response to the Sino-Japanese War

In a May 22, 1895, letter to President Kellogg concerning the chair of Oriental Languages at Berkeley University, which he would be offered in July, John Fryer explained that his position in China had been strengthened because of China's defeat in the war. A "strong tide of demand for Western learning" was now evident among Chinese literati, who were "becoming aware of their own gross ignorance of modern arts and sciences." He added to Kellogg:

> My translations are being bought up as fast as they can be printed, and education conducted on Western principles is becoming the order of the day. It is for this tide that I have waited patiently year after year, and now that it has begun to flow it would seem almost wrong to absent myself from the country that has so long afforded me a home and for those whose enlightenment I have so long been working.

Why then entertain a teaching position at Berkeley University at this promising time? We have seen that Fryer in 1880 had rejected the possibility that English would become a universal language or that China would be ruled by foreign powers. In his 1895 letter to President Kellogg, however, Fryer explained why he now entertained accepting the Berkeley position:

> However necessary it may be for China to have the arts and sciences of the West translated into the native language and disseminated throughout the country in the first instance, it stands to reason that this will only succeed up to a point. Beyond that point no amount of translation can keep pace with the requirements of this age of progress.

The "complete education of China" had begun through translation, Fryer quipped, but that was only a first step.

The man who had tirelessly translated several score of works on science and technology into Chinese now assumed a more strident tone in his private letters. The war had proven to him and the Chinese that their efforts since 1865 had been a failure. Fryer now became a voice of doom for China's future:

> Of course this looks to the gradual decay of the Chinese language and literature, and with them the comparative uselessness of my many years of labor. Their doom seems to be inevitable, for only the fittest can survive. It may take many generations to accomplish, but sooner or later the end must come, and English be the learned language of the Empire.[105]

This intriguingly timed Spencerian perspective belied the religious message of a natural theology that informed earlier missionary translations of botany and biology for the Chinese.

On the eve of his departure for California, however, Fryer remained involved in China's affairs. He also gave the impression that his move to Berkeley might not be permanent. For instance, he publicly announced a competition for new-age novels (*xin xiaoshuo*) in Chinese that would enhance the morals of China and eviscerate the triple evils of opium, stereotypical examination

essays, and footbinding. This appeal for a new literature written in "easy and clear language with meaningful implications and graceful style" attracted the interest of Liang Qichao and other reformers who called for a new culture in China, premised on the failure of traditional Chinese civilization. The bound feet of Chinese women symbolized this failure. In the 1890s, Qing radicals and revolutionaries increasingly adapted the three evils campaigns to discredit the Manchu regime.

The Boxer Rebellion of 1900 confirmed the fears of many missionaries, such as the devoted William Martin. In the 1868 preface for his *Elements of Natural Philosophy and Chemistry,* Martin had hoped to rescue "the intellect of the Chinese" from the "barren field" of belles lettres. Now he sounded more shrill: "Let this pagan empire be partitioned among Christian powers." Unlike Fryer, Martin stayed on in China and continued his educational work. In a peculiar manner, China's "defeat" in the Sino-Japanese War also represented John Fryer's and William Martin's failure "to change China."[106]

In our concluding chapter, we address the remaining steps in the Chinese construction of modern science in late imperial China. After the debacle of the Sino-Japanese War, that construction increasingly denigrated traditional natural studies and classical medicine. When we look at the changes in scientific terminology that occurred in fields such as botany and chemistry after 1900, we find that Japanese scientific terminology decisively replaced Protestant terms in China. Although the role of Chinese students who studied science in the United States and Europe should not be underestimated, a sea change in favor of Japanese science and technology took hold during the last years of the Qing dynasty. We tend to underestimate what the Japanese wave left in its wake, namely the hundreds of translations that Protestants such as Fryer, Martin, and others had labored on since 1865, which had also made their way to Yokosuka and to virtually every prefectural library in Meiji Japan.[107]