History of Science and Technology in Japan*

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1. Introduction

Japan took her first step towards modernization with the Meiji Restoration of 1868. *Nihon Kagaku-Gijutsu-shi Taikei* (*History of Science and Technology in Japan*) covers the period 1853–1960. It is a fact worthy of special attention in modern world history that Japan, having become conscious of her status as a non-European nation during the latter part of the 19th century, groped to find a way of self-modernization and began to tread the road to industrialization.

In 1960, the History of Science Society of Japan planned to publish as its twenty year commemoration publication a series of source books on the history of science and technology in Japan since 1853. Entitled *Nihon Kagaku-Gijutsu-shi Taikei*, this series consists of historical surveys, sources, documents with commentaries, together with many illustrations. (The proportion is approximately 80% historical materials and 20% explanatory descriptions.)

The following gives the translated title of each volume:

Vol. 1	Outline History I	(Chief Editor,	M. Yuasa)
2	Outline History II	("	M. Yoshida)
3	Outline History III	("	K. Oka)
4	Outline History IV	("	C. Kamatani, T. Tsuji, T. Hirosige)
5	Outline History V	("	C. Kamatani, T. Tsuji, T. Hirosige)
6	Philosophy	("	T. Tsuji)
7	International	("	C. Kamatani, S. Nakayama, E. Yagi)
8	Education I	("	K. Itakura)
9	Education II	("	S. Ooya, M. Hara)
10	Education III	("	K. Itakura, J. Hasegawa)

* This paper was originally prepared for the "Index" (supplementary volume) to the whole twenty-five volumes of *Nihon Kagaku-Gijutsu-shi Taikei*.

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11	Natural Environment	(Chief Editor,	J. Nemoto)
12	Mathematical Science	(”	T. Shimizu, Z. Murata)
13	Physical Science	(”	J. Sugai, M. Tanaka)
14	Astronomy & Earth Science	(”	Y. Ishiyama, F. Shimamura, S. Nakayama, J. Nemoto)
15	Biological Science	(”	H. Sato, Y. Susuki, T. Nakamura)
16	Civil Engineering	(”	Y. Kaneseki)
17	Architecture	(”	T. Muramatsu)
18	Mechanical Engineering	(”	H. Kato, T. Susuki, T. Yamazaki)
19	Electrical Engineering	(”	S. Nojima)
20	Mining & Metallurgy	(”	K. Iida, T. Kuroiwa)
21	Chemical Engineering	(”	M. Tanaka, T. Yamazaki)
22	Agriculture I	(”	T. Furushima)
23	Agriculture II	(”	T. Furushima)
24	Medicine I	(”	Y. Nakagawa, H. Maruyama)
25	Medicine II	(”	Y. Nakagawa, H. Maruyama)
	Index.	(”	M. Yuasa)

All volumes (25.7 cm × 18.2 cm, about 600 pp. each) were completed by 1972.

2. Before the Meiji Era

The titles of the first and second chapters of **Outline History I** (Vol. 1) are "The Opening of Japan to Western Countries" and "Western Learning in the Latter Days of the Tokugawa Shogunate", respectively. In each of the twenty-five volumes, statements begin, as a rule, with the opening of the country—or, rather, with Commodore Perry's visit to Japan in 1853—but there are some exceptions. The purpose of this chapter is to summarise those exceptions.

The first chapter of **Philosophy** (Vol. 6), entitled "The Traditional Culture and the Opening of the Country", opens with the essay *Gengo* (1775), a masterpiece written by Baien Miura (1723–1789), one of the representative thinkers of the middle of the Tokugawa era; the manuscript is said to have been rewritten twenty-three times during the twenty-three years before its completion in 1775. Next we find Atsutane Hirata's *Kodōtaii* (1813) and Nobuhiro Sato's *Tenchūki* (1822), both of which illustrate the scientific thought cultivated in the traditional atmosphere.

The first translation of a genuine European scientific book had appeared much earlier, in August, 1774, when Suharaya, a publisher in Edo (Tokyo), published the five volumes of *Kaitaishinsho* (four volumes devoted of text and one of preface and charts). This had marked the starting-point of Japanese studies to Western science by means of Dutch Learning. It was, however, not until the 1820's, about fifty years after the publication of *Kaitaishinsho*, that technical books on such basic sciences as physics, chemistry and biology were published. In 1822 Yōan Udagawa (1798–1846) published *Botanica*, and later, in 1833, wrote *Shokugakukeigen*, in which he introduced botanical scientific methods, including the Linnaean system of classification. In 1837 he published *Seimikaisō*, the first book on chemical science. The first Japanese physics text was *Kikaikanran*, writhen in Chinese by Rinsō Aochi in 1825; and the second was *Kikaikanrankōgi* written in Japanese by Kōmin Kawamoto in 1851, the fourth year of Kaei, only two years before the coming of Commodore Perry. *Kyūritsū*, an eight volume work written by Banri Hoashi (1778–1852) in 1836, is a monument in the history of science in Japan, for it provides accounts of physics, astronomy, chemistry, geography, botany, physiology, and hygienics. As will be pointed out below, the first publication on Western mathematics did not appear until 1857, some years after the publications on physics, chemistry and biology, and after Perry's visit to Japan. In this year Shunzō Yanagawa's *Yōzanyōhō* and Riken Fukuda's *Seizansokuchi* were also made public.

The first chapter of **Education I** (Vol. 8), "Establishment of Educational Instiutions of Science and Technology in the Closing Years of the Tokugawa Shogunate", contains much data (index nos. 2901–2933), and gives, from the educational point of view, vivid descriptions of science and technology at the end of the Tokugawa regime. *Nagasaki-Kaigun-Denshūsho* and *Bansho-Shirabe-Sho*, established as government institutes immediately after the coming of Perry, played a key role in transplanting European science and technology in Japan. *Nagasaki-Igaku-Denshūsho* and *Edo-Igaku-Denshūsho* became centers of learning, not only for medicine but also for Western science in general. Tokyo University, founded in 1877 with departments of law, science, literature and medicine, originated in the above-mentioned *Bansho-Shirabe-Sho* (established in 1857) and *Edo-Igaku-Denshūsho*.

"An outline of Japanese Mathematics", the first chapter of **Mathematical Science** (Vol. 12), begins with an explanation of *Jingōki* written by Mitsuyoshi Yoshida (1598–1672), and goes on to describe representative Japanese books on mathematics, for example, *Kokonsampōki*, *Katsuyōzampō*, *Teijutsusankei* and *Kohaijutsukai*. It was in 1855, two years after the visit of Perry to Japan, that the Japanese began to learn Western mathematics directly from foreign teachers. *Nagasaki-Kaigun-Denshūsho* was founded in that year, and there Dutch officers taught mathematics, physics and chemistry as foundation subjects in the study of navigation. As mentioned above, the first Japanese book on Western mathematics was published in 1857.

For better understanding of "Astronomy and Geology in the Latter Days of the Tokugawa Shogunate", the first chapter of **Astronomy & Earth Science** (Vol. 14), we should read the first chapter of **Natural Environment** (Vol. 11), "Understanding and Description of Nature at the End of the Tokugawa Era and the Beginning of the Meiji Era." With regard to the gradual modernization of the Japanese attitude toward nature, the first chapter of **Biological Science** (Vol. 15), "From *Honzōgaku* to Biology", offers important data. The beginning of this first chapter (p. 17) of **Biological Science** describes the origin of biology in Japan in the following words: "The origin of biology in our country can be traced to *'honzōgaku'* introduced from China in olden days. The advent of *'honzō'*, the Chinese pharmacopoeia, dates back to the sixth century, and from that time new knowledge was transmitted to Japan as it developed in China. But it was during the Edo era, after the introduction of *Honzōkōmoku* by Ri Jichin, that Chinese pharmacopoeia developed into the branch of study known as *'honzōgaku'*. Ri's book not only served as a source book of pharmacology, but also stimulated, first, the study of plants and animals for medical purposes and, secondly, the study of plants and animals for their own sakes, regardless of their utility. Hence, as well as *'Honzōgaku'*, natural history studies were also advanced. In this chapter, though the term *'honzōgaku'* is used in its broad sense, the main objective is to describe the growth of natural history (from which biology developed) in Japan during the latter part of the Edo era and the early years of Meiji." It is interesting to observe the way in which such Japanese scholarship, for example *'wasan'* (mathematics developed in Japan) and *'honzōgaku'* (based on the Chinese school), were brought face to face with European science and were influenced by the latter. The change from Chinese to Western medicine is clearly described in the opening chapter (pp. 9–12) of **Medicine** I (Vol. 24).

Turning now to Technology (in six volumes), though there is no description of pre-Meiji conditions in **Civil Engineering** (Vol. 16), the first chapter of **Architecture** (Vol. 17), entitled "Introduction of Western Architectural Technique by the Tokugawa Government and Powerful Clan Governments", provides an excellent explanation, based on abundant data, under the following five headings:

1. *Goryōkaku, Matsumae-jinya,* and *Shinagawa-daiba*
2. *Nagasaki-seitetsusho*
3. *Shōkoshūseikan* and *Kagoshima-bōsekisho*
4. *Yokosuka-seitetsusho*
5. A hoist-cottage at Kosuga Dockyard

Chapter one of **Mechanical Engineering** (Vol. 18), "Western-style Shipbuilding at the End of the Tokugawa Era", describes the factory equipment at *Nagasaki-seitetsusho*; the establishment of shipyards at Yokohama and Yokosuka; and the shipbuilding of Satsuma and Saga Clans. This chapter will be more meaningful if read together with the first chapter of Architecture (sections 2–5). (Here, *'seitetsusho'* means shipyard).

The first chapter of **Electrical Engineering** (Vol. 19) is entitled "The Dawn of Electrical Engineering—Telegraphic Technique at the End of the Tokugawa Era", while that of **Mining and Metallurgy** (Vol. 20) is headed "The Dawn of Modern Mining Technique." The introductory chapter of **Mining and Metallurgy,** "The History of Mining Technique in our Country", has the sub-heading, "The Foundations of the Acceptance of Modern European Techniques". It is a long chapter, consisting of three sections: 1. Birth, 2. Growth, and 3. Maturity, and provides the information essential for an understanding of the technical situation of Japan before the Meiji era.

The first chapter of **Chemical Engineering** (Vol. 21), "From *Seirengaku* to Practical Chemistry", contains the description of chemistry before the Meiji era which is omitted in **Physical Science** (Vol. 13). The first three sections in chapter one of Chemical Engineering, "Activities of Scholars of Western Learning in Developing Chemical Techniques at the End of the Tokugawa Era", "Chemistry at the Chemistry Department of *Bansho-Shirabe-Sho*", and "The Study of Chemistry by Various Clan Governments", constitute the introductory part of the 'Chemistry' division of *Physical Sciences.* The term 'Various Clan Governments,' used in section three, refers to Shimazu (Satsuma) and Fukuoka. It is worthy of note that the powerful clans in Kyūshū were progressive not only in chemistry, but also in the fields of architecture, mechanics, electricity, mining and metallurgy. The first Japanese modern spinning factory (operated by steam engine) was built in Kagoshima in the third year of Keio (1867). Two years prior to this, the Kagoshima government had sent Tomoatsu Godai and others to England and imported spinning machines from Platto Co. At the same time, it had invited British engineers to assist in the building of the factory. Work was begun in the following year and completed by May, 1867 (Vol. 18 **Mechanical Engineering**, p. 120).

In **Agriculture I** (Vol. 22), as explained in the editing plan (2) included at the beginning of the book, "Even data relating to the Edo era are furnished, so that the level of agricultural development and the methods of arriving at new techniques in the period before the introduction of Western-style agriculture may be ascertained." In the first chapter, entitled "Agriculture at the End of the Tokugawa Era", section one, 'Various Stages of Ploughing and Sowing Technique', and section two, 'Development of Sericulture', include data from the middle of the eighteenth century to the beginning of the nineteenth, thus providing us with a complete picture of tilling and sowing techniques as well as silkworm production during the Edo period. After the opening of Yokohama Port for foreign trade in 1859, silk quickly become the most important export item. This was chiefly owing to the advanced level of silkworm raising techniques in Japan.

3. The Meiji Era (1868–1912)

Volumes one and two of **Outline History** are devoted to a general scientific history of the Meiji era, or, more precisely, to the period from 1853 (the year of

Perry's visit to Japan) to 1914 (the third year of Taisho, when World War 1 broke out). The dividing point between volumes one and two is the twenty-second year of Meiji (1889), the year in which the Constitution of Japan was proclaimed. In the nineteenth year of Meiji (1886), the Imperial University Law was enacted, and the postgraduate course, which is still in operation today, was set up. The next year, the law regulating the awarding of degrees was issued, and on the seventh of May, 1888, twenty-five scholars (five in each field of law, literature, science, engineering and medicine) were awarded doctor's degrees. Another twenty-five doctor's degrees (again five in each field) were granted on the seventh of June of the same year. On page 392 of **Education I** (Vol. 8), we find the names of the twenty-six doctors of science who were awarded doctoral degrees before the twenty-fourth year of Meiji (1891). In the list are indicated each person's year of birth, alma mater, term of study abroad, and the country where he studied. In surveying the years of birth, we notice that, excepting for the first three (Keisuke Itō (born in 1803), Nagayoshi Nagai (born in 1845), and Ryōkichi Yatabe (born in 1851)), all were born in the years of disturbance between 1854 and 1862, that is, the years after the coming of Perry but before the Meiji Restoration. The same is true of almost all of the doctors of engineering and medicine. Most of the top leaders of science and technology during the mid-Meiji period were men who were born in the 1850's and educated in foreign countries. Around 1890, achievements of an internationally high level were performed by such scholars as Jirō Kitaō, Shōhei Tanaka, and Shibasaburō Kitazato.

Chapters three to fourteen of **Outline History I** (Vol. 1) present important events of the first half of the Meiji era in a roughly chronological order: 3. Civilization and Enlightenment, 4. Institutionalization of Science, 5. Government Policy for Fostering Industry and Enterprise, 6. The Age of Exhibitions, 7. The Achievements of the Colonization Commission, 8. The Systems of Patents, Weights and Measures, and Statistics, 9. Science and Technology to Provide for a Powerful Army, 10. Consolidation of Organizations for Research, Investigation and Administration, 11. Quickening of the New Industrial Society, 12. Europeanization and Reaction, 13. The Standardization of Technical Terms, 14. The Encouragement of Basic Sciences. The editing plan of *Outline History I* is explained in section two as follows: "This volume aims to provide a synthesis of general and scientific histories, giving weight to the description of political institutions. It is, so to speak, a sociological history of science." The editing policy of **Outline History II** is: "Because this is a general view, individual topics are not dealt with, no matter how conspicuous. Emphasis is placed on the description of science and technology as an element in the organization of the state, and of its relation to the people."

Scientific research in the Meiji era is treated in the following books and chapters in the series:

In **Mathematical Science** (Vol. 12), four chapters are devoted to the description of mathematical study in the Meiji period: 2. The Adoption of Western Mathematics, 3. The Foundation of Tokyo University, 4. The Mathematical Department of Kyoto Imperial University, 5. Tōhoku Imperial University and the *Tōhoku Sūgaku Zasshi,* 6. Mathematical Thought and the Enlightenment Movement—1. **Physical Science** (Vol. 13) contains separate chapters on physics and chemistry. Two chapters, assigned to physics, are: 1. Physics under the Guidance of Foreign Teachers (1882–1896), and 3. The Fixation of Physics in Japan (1897–1910). The two chapters allotted to chemistry, are: 2. The Basis of Chemical Study (1878–1900), and 4. The Formation of a Tradition of Chemical Research (1901–1916). For a deeper understanding of the development of chemistry in this period, these two chapters should be read in conjunction with the first chapter of **Chemical Engineering** (Vol. 21), especially with the following sections: 4. Educational and Industrial Institutions during the Early Years of the Meiji Era; 5. Modernization of Industrial Education and the Establishment of Governmental Factories; 6. A Glance at the Early Years of the Chemical Industry; and 7. The Establishment of Factories. Relevant also are chapter two, Technical Advances made possible by the Independence of Applied Chemistry (1884–1897); and chapter three, The Transitional Stage in Modern Chemical Technique (1898–1913)." With regard to physics, closely connected with the above two chapters are the following ones in **Astronomy & Earth Science** (Vol. 14): The Establishment of Investigation and Research Organizations to Protect Natural Resources from Disaster, 4. The Process of Development of Scientific Geology, 5. Projects and Study relating to Weather and Ocean Conditions.

The chapters devoted to the Meiji era in **Biological Science** (Vol. 15), are: 2. The Consolidation of the Research System; 3. From Enlightenment to Original Work; and 4. Evolution Theory and Thought. Chapter five, Agricultural Biology, describes mainly the Meiji era, but also devotes some pages to the first half of the Taisho era. The development of biology has a close connection with that of agriculture (see **Agriculture I**, Vol. 22).

We are informed of the development of technology in the Meiji period in the following chapters: 1, 2, 3 and 4 in **Civil Engineering** (Vol. 16); 2, 3, 4, 5 and 6 in **Architecture** (Vol. 17); 2, 3, 4, 5 and 6 in **Mechanical Engineering** (Vol. 18); 2, 3, 4, 5 and 6 in **Electrical Engineering** (Vol. 19); 2, 3, 4 and 5 in **Mining and Metallurgy** (Vol. 20); and 1, 2 and 3 in **Chemical Engineering** (Vol. 21).

Throughout the Meiji era, a pivotal role in the development of Western science was played by Tokyo University. However, during the first half of the same era, a no less important role was played by the Ministry of Engineering (1870–1885) in introducing Western technology into Japan. We are given a detailed description of the Ministry of Engineering in the fifth chapter of **Outline History I** (Vol. 1), entitled "Government Policy for Fostering Industry and Enterprise (pp. 179–257)":

"The idea of establishing the Ministry of Engineering was first suggested by Edmund Morell in a letter to Finance Minister Hirobumi Ito. (Morell was then in Japan as chief engineer in the construction of a railway between Yokohama and

Tokyo.) 'After thinking carefully over that matter of great importance you asked me about, I have come to the following conclusion. I am afraid, however, that my answer might sound strange and not to the point, since I am an outsider and quite ignorant of Japanese customs and institutions. All the countries in Europe, except England, have government institutions which control construction work. These institutions are prosperous and serve the immediate needs of the people by utilizing the materials produced in the country. Therefore, the possibility of setting up the same kind of institution in Japan should be discussed before any action is taken.' This is the opening part of his letter. He then presented his "Plan for Establishing the Institution", in which he emphasised the importance of standardization in industrial administration and the education of engineers (p. 179)." A government notice handed to the Ministry in January of the fifth year of Meiji and entitled, The Public Service Regulations, reads: "The Ministry of Engineering should be responsible for all matters concerning industry. Its principal duties are: 1. to develop technology; 2. to encourage all kinds of industry and to increase production; 3. to control mines and supervise all mining products; 4. to build and repair railways, telegraph stations, lighthouses, and signs notifying sunken rocks; 5. to build and repair ships; 6. to refine and cast copper, iron, and lead for general use; to make various machines; and 7. to measure land and sea."

The Ministry of Engineering (*Kōbu-shō*) was established in the third year of Meiji (1870), and, in August of the following year, ten bureaus were formed: technology; industry encouragement; mining; railways; civil engineering; lighthouses; shipbuilding; telegraph; iron manufacture; machine making; and surveying. Many foreigners were employed to introduce foreign technology. Volume one of **Outline History** states: "The numbers of foreigners employed by the Ministry of Engineering are listed in table 3 (Note: shown here in this essay).

Railways	256	Construction	81
Mines	78	Telegraph	59
Lighthouses	52	Building and repairs	13
Schools of technology		Others	2
(advanced)	21		
(elementary)	7		

The largest number were employed in the railway service, and the second largest in construction work. This was because the dockyards in Yokosuka, Nagasaki, and Hyogo; the machine shops in Akabane; and the glass factories in Shinagawa all needed many foreign engineers. With regard to the mining industry, foreigners were attached to each type of mine (gold, silver, copper, iron, and coal) and to locations all over the country (Sado, Ikuno, Miike, Takashima, Ani, Innai, Kamaishi, Nakakosaka, Okuzu, Magane, Yudo and Kosaka). Telegraph stations and lighthouses were built under the guidance of foreign technicians. When was the largest number of foreign experts employed? The answer can be obtained by counting the number of foreigners living in Japan for each year, and this figure can be calculated from the numbers of arrivals and departures for each year. (The latter are available in *The Historical Records of the Ministry of Engineering*.) The result is shown in figure 3 (Vol. I, p. 19). The highest peak was reached in 1874 (the seventh year of Meiji) with 255 persons; and a high level of more than 130 persons was maintained from 1871 to 1879 (from the fourth to twelfth year of Meiji). After the peak, graduates of Tokyo University and Tokyo Technical College began to replace the foreigners."

Chapter four of **Outline History II** (Vol. 2), "The Primary Functional Differentiation", deals with the second half of the Meiji era (1889–1912), and contains much data, for example: 'The Higher Council of Agriculture, Commerce, and Industry' (the twenty-nineth year of Meiji; 1896); 'Some Suggestions on Marine Transportation after the Sino-Japanese War' (the twenty-eighth year of Meiji; 1895); and 'Proposal to set up Educational and Research Organizations' (the thirtieth year of Meiji). In Chapter 9, entitled "The Second Functional Differentiation", we find the following documents: 'The Process of Enacting the Law Regulating Electrical Enterprises' (the fourty-third year of Meiji; 1910); 'The Process of Enacting the Law Regulating Electrical Measurement' (the fourty-third year of Meiji); 'The Process of Enacting the Railway Nationalization Law' (the thirty-nineth year of Meiji; 1906); and 'Proposals for Harbor Improvement' (the thirty-nineth year of Meiji). These data provide insights into the development of industrial techniques in Japan before the promulgation of the Factory Law in the fourth-fourth year of Meiji (1911).

4. The Taisho Era (1912–1926)

Outline History III (Vol. 3) takes up from the early years of Taisho and covers the period ending with the 4th year of Showa (from 1912 to 1929). In the preface of this volume, Kunio Oka defines the age as one of "public unrest, beginning and ending with wars. Government, economy, and other agencies were directly or indirectly controlled by militarism, and the people's life was extremely uneasy. Besides, there was an apprehension that the future might be even more tightly controlled. In spite of these restrictions, however, science and technology continued to develop, following their own laws of growth." The editing policy of **Outline History** III (Vol. 3) is stated under item 4: "Various kinds of data are arranged chronologically in each chapter: regulations, political documents, comments, records of conferences, articles in newspapers and magazines. This volume has been compiled with the idea of demonstrating the way in which this period, despite contradictions, tended towards increased control and rationalization, with the ultimate aim of militalizing the nation's economy". This trend is reflected in the table of contents: 'The Change in Policy towards Technology and Society'; 'Transformation of the Industrial Structure', 'The Rationalization Movement', and so on. The titles of chapters 1 through 11 are; 1. World War I and the Heavy Chemical Industry; 2. Transformation of Industrial Structure and Technical Policy; 3. Consolidation of Research Organizations in Science and Technology; 4. The

Rice Riots and Agriculture; 5. Technical Policy after the World War I; 6. Development in the Industrial Sector and Social Policy; 7. The Great Earthquake of 1923 and Its Aftermath; 8. Armament Reduction and Its Contradiction; 9. International Communication and the Awakening of the Scientist to His Profession; 10. Democracy in the Taisho Era and Science and Technology; 11. The Beginning of the Rationalization Movement. These significant events of the Taisho era, listed in a roughly chronological order, are treated in connection with developments in science and technology.

The first major event of the Taisho period, World War I, divided in half the one hundred years of Meiji, Taisho, and Showa, and marked the real beginning of the consolidation of scientific and technological organizations. Just as the introduction of modern science and technology at the end of the Tokugawa era had been begun under the impact of Perry's visit to Japan, so the consolidation of scientific and technological organizations, was brought about by an external cause, the separation of Japan from European countries by World War I (1914–1918). The first chapter of **Outline History** III (Vol. 3) explains the background: "During World War I, the Japanese chemical industry made unique progress. Because Japan had depended almost entirely upon countries overseas for chemical products, domestic production became absolutely necessary when the outbreak of the war caused a stoppage of imports. In November of the 3rd year of Taisho (1914), a chemical industry investigation committee was organized within the Ministry of Agriculture and Commerce. In addition to this, an experimental station was founded, and a law concerning the encouragement of dyestuff and medicine production was proposed. As the result, in the 4th year of Taisho, Hodogaya Sōda Co. began to produce electrolysis soda, Akita Refinery of Japan Oil Co. built a successive distillatory apparatus, and the Shinagawa Branch of Mitsui & Co., Ltd. began the production of bakelite. In the 5th year of Taisho (1916), Kyota Hisamura of Azuma Industry Co. succeeded in making byssus artificial silk; in the next year, Asahi Glass Co. began to produce soda by a process using ammonia; Nihon-Senryō Co. manufactured artificial dyes; and Nihon-Kōgaku Co. produced optical glass. Thus the cornerstone in the foundation of the chemical industry in Japan was laid." With regard to civil engineering, architecture, mechanics, electrical engineering, mining, metallurgy and chemical techniques of the Taisho period, explanations are found in volumes 16 through 21.

A speech made by Jōkichi Takamine in June of the 2nd Year of Taisho (1913), entitled "On the National Research Center of Science," marked the beginning of the movement to consolidate research organizations during the Taisho era. Jōkichi Takamine was well-known even in Europe and America as the inventor of adrenalin and *takajiastaze*. The first World War broke out on the 28th of June in the 3rd year of Taisho (1914); and in less than a month, Eiichi Shibuzawa (then president of three banks: The First Bank, The Tokyo Bank, and The Tokyo Saving Bank) contributed an article entitled "On the Establishment of a Chemical Research

Institute" to *the Yomiuri Newspaper* of July 15 (No. 13368): "We have very few chemical inventions in Japan, so a large amount of gold flows out every year in the purchase of expensive inventions from abroad. I have long thought that, in order to decrease imports and increase exports, we should encourage fundamental chemical research. Dr. Jōkichi Takamine has just returned from America. He has often advocated the establishment of a chemical research institute. Once he invited about 150 persons (intellectuals, technicians, and us businessmen) to the *Seiyōkan*, and held a conference in which he discussed the establishment of such an institute. In that very place, he declared, 'In order to commemorate the grand coronation ceremony held this year, we would like, with the help of the government and the general public, to set up a chemical research institute as an indispensable and basic means of advancing chemical research in Japan. In order to achieve our end, we should make the establishment of the institute a great national project, just as Prince Katsura founded *Saiseikai* (The Society for Public Welfare) in accordance with His Majesty's wishes. We sincerely hope that the government, businessmen and scholars will help us.' I was the first to approve his proposal, declaring that I would try to help him, regardless of the outcome. I consulted with Mr. Buei Nakano and appointed about twenty committee members on the spot. . . ." The plan thus proposed reached fruition in the Institute of the Physical and Chemical Research. In the first part of "A Prospectus for the Establishment of the Physical and Chemical Research Institute", published in April of the 4th year of Taisho (1915), we find the following statement on the defective condition of science and technology in Japan: "Since the Meiji Restoration, Japanese civilization has made remarkable progress, but this was brought about chiefly through our imitation of European and American civilizations. This is especially true of chemistry and its application. It is most regrettable that we have been responsible for very few original inventions at the international level, our scientists simply using the results of researches done in Western countries. Though some try to produce original work, they cannot attain their aims for want of suitable facilities and financial support. We must not remain in this situation, but should establish a proper institute to encourage this type of research, and to accelerate the general industry progress from its foundation. Finally, we hope to contribute our investigations to the cultural development of the world, and to repay to Western countries the intellectual debts which have been ours for such a long time." We find many institutes of this sort in Western countries, for example, the National Physical Laboratory (in England), the Physikalisch Technische Reichsanstalt (in Germany), and the National Bureau of Standards (in America).

The Institute of the Physical and Chemical Research was thus established and it did accomplish many of the tasks expected of it. This fact is demonstrated in the list of "Prize Achievements at the Institute" conducted from the 10th year of Taisho to the 4th year of Showa (1921–1929).

However, while the establishment of the Institute of Physical and Chemical

Research was no doubt an epoch-making event in consolidating research organizations of science and technology, it was not the only one. The foundation of the Aviation Laboratory attached to Tokyo Imperial University is also noteworthy, since it was the first laboratory attached to a national university. "President Yamakawa decided, after much deliberation, to set up a research laboratory on the campus for basic study on aviation. In the 3rd year of Taisho (1914), when the Great War broke out in Europe, he began to put his idea into practice. He asked Marquis Okuma, Prime Minister and President of the Aviation Society, to introduce a bill in the cabinet meeting in May requesting the establishment of an aviation laboratory attached to a university. He succeeded, moreover, in getting the cabinet to make provision for this expenditure in the budget for the fiscal year of the 5th and 6th years of Taisho." Thus, in December of the 7th year of Taisho (1918), the Aviation Laboratory was founded. Next, the Iron and Steel Laboratory attached to Tōhoku Imperial University was founded in May of the 8th year of Taisho (1919). Following this, non-governmental research organizations were also established: for example, the Chemical Laboratory attached to Marumiya-shōten, the Laboratory at Tokyo Electric Co., the Laboratory at Shibaura-seisakusho and that of Mitsubishi Paper Manufacturing Co. As many as 162 private research laboratories are reported in Vol. 2 (**Outline History** II), No. 2, of the *Kogyō-chosa-ihō* (October, the 13th year of Taisho; 1924), and there were 3 others which were not reported.

Scientific studies in mathematics, physics, chemistry, biology, *etc.* made during the Taisho era (1912–1926), are described in the following volumes as follows: In **Mathematical Science** (Vol. 12), two chapters are allotted to this period: 7. "*Ruitairon* by Teiji Takagi", and 8. "Expansion of Colleges and Higher Technical Schools." In **Physical Science** (Vol. 13), chapter 4, "The Formation of a Chemical Tradition (1901–1916)", takes up from the 2nd half of the Meiji era and continues until the beginning of the Taisho era; then follow the next chapters: 5. "Physics in Japan in the Transistory Stage of Physical Science (1911–1917)"; 6. "Chemical Study After World War I (1917–1930)"; and 7. "Physics as Applied to the Outside World (1918–1927)." In **Biological Science** (Vol. 15) two chapters are assigned to this period: 6. "Development of the Research System"; and 7. "The Appearance of Original Research." The Taisho era saw many achievements which brought international fame to Japanese scientists and caused sensations in the scientific world; for example, *Ruitairon* by Teiji Takagi; Jun Ishihara's theory of relativity; the cytological theory of Kenjiro Fujii; the theory of non-decrement propagation of nerve outlined by Genichi Kato; and the discovery of small planet families by Seiji Hirayama.

Formal scientific relations with other countries were begun in the 39th year of Meiji (1906), when the Tokyo Academy (founded in the 12th year of Meiji; 1879), adopted the name of Imperial Academy and joined the World Academic Association. International conferences were first held in Japan in the Taisho era. From early in the Meiji era Japanese scientists had often attended international scientific conferences, but no international conferences were held in Japan. During the Taisho period, however, Japan hosted such international conferences as the Conference of the Heads of the Weather Stations of Eastern Asia (from the 12th to 18th of May in the 2nd year of Taisho; 1913); the 6th Far Eastern Convention of Tropical Diseases (from the 12th to 16th of October in the 14th year of Taisho; 1925); the International Communication Congress of Hygiene Specialists (the 19th of October in the 14th year of Taisho); the 3rd Pan-Pacific Scientific Conference (from the 30th of October to the 11th of November in the 15th year of Taisho; 1926); the International Meeting on Technology and World Assembly on Motive Power (from the 29th of October to the 7th of November in the 4th year of Showa; 1929). It is also a notable event in the history of science in Japan that the Mizusawa Latitude Observatory was designated as the central office of the Department of Latitude Change in the International League of Astronomy, and Sakae Kikura was appointed its head.

Agricultural development in Japan in the Taisho era is described in the first half of **Agriculture II** (Vol. 23); and the medical situation of that period is explained in the first half of **Medicine II** (Vol. 25).

5. The Showa Era (1926–1960)

The year dividing the period 1926–1960 in half is the 20th year of Showa (1945), the year in which the Pacific War came to an end and a new Japan was organized according to American occupation policy. The first half of this period is dealt with in *Outline History* IV (Vol. 4), the chapters being: 1. "Resource Policy and Industrial Control"; 2. "The Attempt to Realize a High-pitched Industry"; 3. "Cultural Control and the Encouragement of Science"; 4. "National Mobilization and the Expansion of Productivity; 5. "National Defense and the Transfiguration of Industrial Structure"; 6. "War and Scientific Mobilization"; 7. "The National Wartime Organization and the Reinforcement of Industry"; 8. "Science during the Final Stages of the War"; 9. "The Industrial System during the Final Stages"; 10. "Desolation, Atomic Bomb and Defeat." According to *The Stages of Economic Growth*, a publication by W. W. Rostow, an American economist, the development of a capitalistic economy in Japan may be divided into five stages: traditional society (the Edo era); a transitional period, take-off (1878–1900); maturity (around 1940); and high-level mass consumption (around 1955), which Rostow sees as the final stage. Rostow's work is a type of anti-communist manifesto, and thus has not received wide support. It is a matter of common knowledge, however, that the Japanese economy of the Meiji, Taisho, and Showa periods, though stricken by frequent panics (the first one in the 23rd year of Meiji; 1890), made steady and smooth progress from the feudalistic economy of the Edo era to capitalism. A high level of capitalism had already been reached when Japan began the Pacific War (1941–1945). This economic development could not have been achieved without the introduction of European science and technology.

The first half of the Showa era (1926–1945) opened the age of world panic, and comprised fifteen war years. For us who live in the 1970's it is difficult to understand these fifteen years from the outbreak of the Manchurian Incident (the 18th day of September in the 6th year of Showa; 1931) to the termination of the Pacific War, World War II (the 15th of August in the 20th year of Showa; 1945). The interpretation of the editor of **Outline History** IV (Vol. 4) is presented in the introductory section as follows: "It is true that Japan, having striven since the Meiji Restoration to become a military state by means of a policy of wealth and armament and the encouragement of industries, encountered a serious breakdown in the course of her development. Such a breakdown, however, can be interpreted as a historical necessity, something which might happen to any growing country. This interpretation is by no means intended to justify the war, but at the same time, one must not disregard the fact that, Japan, as a developing country, had to resort to independent exploitation, even if this meant war. In other words, the breakdown of modern Japanese society by its war policy was, in view of the result, a phenomenon which promoted the modernization of the country. With regard to our chief concern, that is, the development of science and technology, we must stress the fact of its subordination to the war policy. In the first half of the Showa era, the period treated in this volume, science and technology in Japan became part of the wartime organization, and began, for the first time, to be so stimulated and modernized as to become part of the social organization."

In the first half of the Showa era (1926–1945), the most significant role in the modernization of Japanese science was played by the Japan Association for the Advancement of Science, established on the 28th of December in the 7th year of Showa (1932). The association was a judicial one, having H. H. Prince Chichibu (the Emperor's brother) as honorary president, and the director of the Japan Academy (Jōji Sakurai, 1932–39; Hantaro Nagaoka, 1939–1947) as chairman. It was a semi-governmental, semi-private organization, and its expenses were largely met by the government. A prospectus for the establishment of the Japan Association for the Advancement of Science, finally drawn up on the 6th of December in the 7th year of Showa (1932), describes the condition of science and technology in those days as follows: "Now turing to our country, we can see that the nation still lacks an understanding of the importance of scientific research, and has very little interest in its practical application. Thus we have few efficient institutions to promote and encourage scientific research, and competent researchers cannot achieve anything for want of financial help. We have almost no research institutions in which scientific studies can be undertaken for later application to industry. Moreover, there is little communication between institutes and laboratories, and researchers are often unable to make effective progress because of their isolation. Japan, therefore, has produced only a very small number of first-rate, creative scientists, and in the industrial world, almost all important developments have been made possible through importation or imitation. We can cite no instance of an invention of ours being adopted in a foreign country and opening up a new industry there. In Japan, the results of scientific research are not given practical application as they are in Western countries, and a new invention or discovery is not utilized to promote further cultural development. It bodes ill for the future prosperity of the country that research expense is regarded as unnecessary, and, in time of depression, it is a common practise to curtail it before other expenses or not to pay it at all." It is surprising to notice that this prospectus, written in the 7th year of Showa (1932), is strikingly similar to the earlier document, "A Prospectus for the Establishment of the Physical and Chemical Research Institute" (1915), referred to in chapter 4. The growth of Japanese science and technology was very slow as compared with that of European countries.

Developments of the 2nd half of the Showa era (1945–1960), the period after World War II (the Pacific War), are taken up in **Outline History** V (Vol. 5). The titles of chapters 1 through 13 are: 1. A New Beginning under Occupation; 2. Economic Crisis and Scientific Technology; 3. Democratization in the Sphere of Science and Technology; 4. Innovation in the Scientific System; 5. Economic Reconstruction: Plan and Dodge-line; 6. Problems in Research Organization; 7. The Search for Economic Independence; 8. From Reconstruction to Rationalization; 9. War, Peace, and Colonization; 10. Measures for the Promotion of Science and Technology; 11. Reorganization of Technical Administration; 12. The Development of a Policy for a Heavy Chemical Industry; and 13. Signs of New Conditions.

Descriptions of particular scientific fields after World War II are given in each volume as follows: **Education** III (Vol. 10), chapters 7 through 14 (until the first part of the 40th year of Showa); **Agriculture** II (Vol. 23), the latter half of the volume (until the 20th of Showa); and **Medicine** II (Vol. 25), the latter half of the volume (until the 40th year of Showa). The chapters allotted to this period in **Mathematical Science** (Vol. 12) are: 12. Pure Mathematics After the War; 13. The Development of Statistical Science; 14. The Electronic Computer; 15. Mathematical Thought and the Enlightenment Movement; and 16. Various Aspects of Internationalization. The chapters in **Physical Science** (Vol. 13) are: 11. Physics After the War (from 1946); 12. Chemistry After the World War II (1946–1969). The chapters in **Astronomy and Earth Science** (Vol. 14) are: 12. The Development of Meteorology and Meteorological Activity; 13. Reorganization in the Earth Sciences; and 14. The Emergence of the Space Age. The chapters in **Biological Science** (Vol. 15) are: 9. A New Start under Difficulties; and 10. The Front Line of Modern Biology. The chapters in **Natural Environment** (Vol. 11) are: 13. Exploitation and Natural Disasters; 14. Isewan Typhoon; 15. Endemic and Epidemic Diseases; 16. The Protection of Nature; and 17. Local Cultivation, Natural Resources and Disaster. **Civil Engineering** (Vol. 16) assigns three chapters to the description of technology in the second half of the Showa era (1945–1960): 8. From Control to Management in Cities; 9. Reconstruction Work After the War; and 10. Highly

Developed Construction Work. In **Mechanical Engineering** (Vol. 18) the chapters are: 16. Automobile Industry After the War; 17. Post-war Transporation and Machinery; 18. Material Science and the Automatization of Machine Tools; and 19. A Perspective. **Electrical Engineering** (Vol. 19): 11. Electric Communication After the War; 12. Reconstruction, Technical Revolution and Wide-Area Operation; 13. The Development of Information Processing Techniques; and 14. Atomic Generation of Electric Power. **Mining and Metallurgy** (Vol. 20) contains the following chapters: 11. Post-war Mining and Metallurgy; and 12. Open Economy and Japanese Mining and Metallurgy. In **Chemical Engineering** (Vol. 21) the chapters are: 8. Reorganization of Chemical Techniques, beginning with Fertillizers (1946–1954); 9. The Conversion of Raw Materials and Petroleum Chemistry (1955–1960); and 10. Prospects—of Safety and Autonomy (after 1960).

As is shown in the chapters of the volumes listed above, this 25 volume outline history allots most space to scientific and technological developments after World War II. The chapters assigned to this period in **Philosophy** (Vol. 6) are: 9 Defeat, Reconstruction, Science and Technology; and 10. The Age of Science and Technology. The chapters of **International** (Vol. 7) are entitled: 12. The Atomic-Hydrogen Bomb and Scientists (1948–1955); 13. Science and Technology under 'Peaceful Coexistence' (1956–1965); and 14. Science and Technology in Under-developing Countries (1945–1965).

Appendix

No.: Number of source materials

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10	June	1966	207	23	August	1970	149
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