The Growth of Scientific Communities in Japan*

Mitsutomo YUASA**

1. Introdution

The first university in Japan on the European system was Tokyo Imperial University, established in 1877. Twenty years later, Kyoto Imperial University was founded in 1897. Among the graduates from the latter university can be found two post World War II Nobel Prize winners in physics, namely, Hideki Yukawa (in 1949), and Shinichiro Tomonaga (in 1965). We may say that Japan attained her scientific maturity nearly a century after the arrival of Commodore Perry in 1853 for the purpose of opening her ports. Incidentally, two scientists in the U.S.A. were awarded the Nobel Prize before 1920, namely, A. A. Michelson (physics in 1907), and T. W. Richard (chemistry in 1914). On this point, Japan lagged about fifty years behind the U.S.A.

Japanese scientists began to achieve international recognition in the 1890's. This period conincides with the dates of the establishment of the Cabinet System, the promulgation of the Constitution of the Japanese Empire and the opening of the Imperial Diet, 1885, 1889, and 1890 respectively. Shibasaburo Kitazato (1852–1931), discovered the serum treatment for tetanus in 1890, Jiro Kitao (1853–1907), made public his theories on the movement of atomospheric currents and typhoons in 1887, and Hantaro Nagaoka (1865–1950), published his research on the distortion of magnetism in 1889, and his idea on the structure of the atom in 1903. These three representative scientists were all closely related to Tokyo Imperial University, as graduates and latter, as professors. But we cannot forget to mention that the main studies of Kitazato and Kitao were made, not in Japan, but in Germany, under the guidance of great scientists of that country, R. Koch and H. von Helmholtz.

2. Scientific Revolution in JAPAN

During the fifteen years of turmoil, beginning in 1853, when Commodore Perry entered Uraga Harbour, and ending in 1868, when the Meiji Restoration was accomplished, three great men of science came into existence in Japan, namely Kitazato, Kitao and Nagaoka, mentioned in the introductory section of the present

* Contributed to the Study of National Scientific Communities Conference, Nairobi, Kenya, 20–26 January, 1969. Sponsored by the International Union of History and Philosophy of Science and UNESCO.

** College of General Education, Kobe University, Tsurukabuto, Nada-ku, Kobe.

paper. This is a memorable fact for the scientists in Japan.

These three scientists were born and brought up in *samurai* families. A *samurai* (warrior) was a retainer of a *daimyo* or local lord under the Tokugawa shogunate. He was taught the Chinese classics called "*Shisho-Gokyo*" (Four History Books and Five Poetry Books), which were brought to Japan in the Nara Period (the seventh century, A.D.). For more than one thousand years, these classics had been taught to the Japanese both at home and in small-scale private schools, so that they had long become a sort of traditional training for children of *samurai*. These three great scientists, already referred to, must have begun their early education in this way.

The population of Japan towards the end of the Tokugawa period was nearly thirty million, governed by feudal lords called *daimyo* in the shogunate Regime. There were about three hundred feudal lords, under whom education was given to sons of *samurai* in *Han-kō* (Clan Schools) and to children of commercial, labour, farmer or peasant classes in *Terakoya* (small-scale private elementary schools). Hence we may say that Japan at the end of the shogunate government was far from being a savage or barbarous nation, for the inhabitants of the land were given training in the three R's and their culture was based upon a knowledge of Chinese classics. As a whole, they had enough knowledge for their daily life and at the same time they understood higher culture of the Chinese classics. Those who ignore or deny these facts and history, may, in my opinion, find it hard to understand the development of Japan in the past hundred years, especially the rapid formation and tremendous progress of Japan's national scientific communities.

At the beginning of the seventh century, Hōryūji Temple was built which is the oldest wooden building that now exists in the world. In the middle of the Eighth century, a big bronze statue of Buddha was cast in Nara; this was believed to be the largest statue cast at that period in history, because it is 16.2 m in height. The *Kojiki, Nihonshoki*, and *Mannyoshu* (histories and anthology of ancient Japanese poems), are already more than one thousand years old. The *Genji-Monogatari* (Story of Genji), well-known in the world as a long romance, was written by Murasaki-Shikibu who led a court life in the eleventh century.

The intellectual system differed from that of the West, in that it was first imported from China and then perfected under the influence of Buddhism and Confucianism, and spread first among the aristocratic class, Buddhist priests, and the warrior classes. Later, as a result of popular education in the Edo period under the shogunate government, it prevailed even more widely until finally it became part and parcel of the Japanese heritage.

In order to make clear the fact that, as regards modern science, national scientific communities were established in Japan during the century after the arrival of Commodore Perry in 1853, I want to apply to Japanese modern history the historical idea of Scientific Revolution advocated by H. Butterfield in *The Origins of Modern Science* (Cambridge, 1949). There existed in Japan national communities in the classical sciences which were nearly ten centuries old. I wish to state that the science in these communities was transformed into modern science with the impact of the capitalistic communities of the West. The transformation, as a mater of fact, was revolutionary. But the impact is rather a long story to tell. The beginning of the impact was the first fire-arms (muskets) that came to Japan in 1543 and greatly changed the battle tactics of war lords. Then, nearly four hundred years later, came Commodore Perry whose arrival resulted in the transformation of the older scientific communities.

As is well known, Japan under the Shogunate government had been virtually closed to foreign nations for about two hundred years from 1639–1853. During these years, Nagasaki was the only port where the Netherland traders (Dutchmen) alone were permitted to trade with Japanese people. Nagasaki was then the lean thread of communication to Western culture and civilization. In 1720, when Yoshimune Tokugawa was the eighth *Shogun*, the limitation on the import of foreign books on science and technology was loosened, and the slow development of modern science began in Japan at this date. How the modern science of the West was carried into Japan by way of books is outlined in Fig. 1.

The community which had played the *avant-gard* role in the scientific revolution in modern Japan was a group of Dutch scholars ("*Rangaku-sha*" in Japanese).

In preparing the present investigation, I made use of Heibonsha's *Dai-Jinmei-Jiten* ("Great Biographical Dictionary"), 1955. About 58,000 Japanese are included in this work (Vols. V–VI and IX). Accordingly, 58,000 biographical cards were prepared, from which 1,740 scientists were chosen, and were classified as follows:

1) Scientists born in the 18th century—512 2) Scientists born in the 19th century—696 3) Living scientists born in the 19th century—532

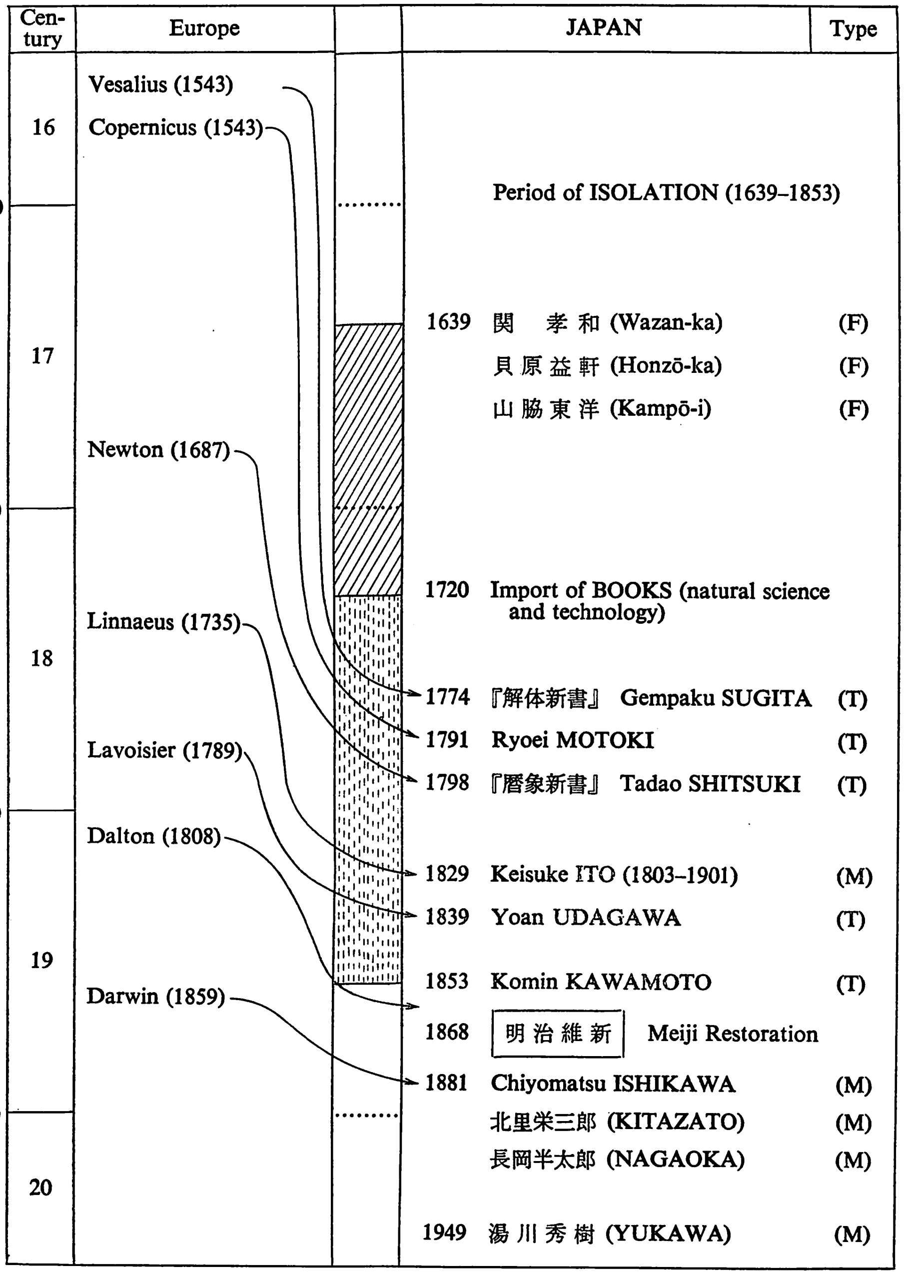
These cards were further classified as follows:

Type F (Feudalism) category includes Oriental scientists such as *Wazan-ka* (Japanese mathematicians), *Honzō-ka* (herbalists), and *Kampō-i* (physicians of the Chinese school). These had almost no connection with Western science.

Type M (Modern) category includes new Western type scientists who contributed to the scientific revolution and who were appointed to important institutional positions, from around the time of the late Tokugawa shogunate era and the beginning of the Meiji era.

Type T (Transition) category includes Dutch scholars (*Rangaku-sha*) who contributed to the scientific revolution within the frame of feudalism and who were not appointed to any institutional position in the modern social structure.

The biographical cards of the scientists born from 1701 to 1900 were divided into forty sections, each section indicating five years; names were included according to the year of birth. Each section was further divided into three groups; Type F, M, and T. The data on each type in each section were divided by the total data for the corresponding section. In this way a series of percentages was obtained.



Type of scientists: F (Feudalism), T (Transition), M (Modern)

Fig. 1. Flows into Japan of Modern Science of Europe.

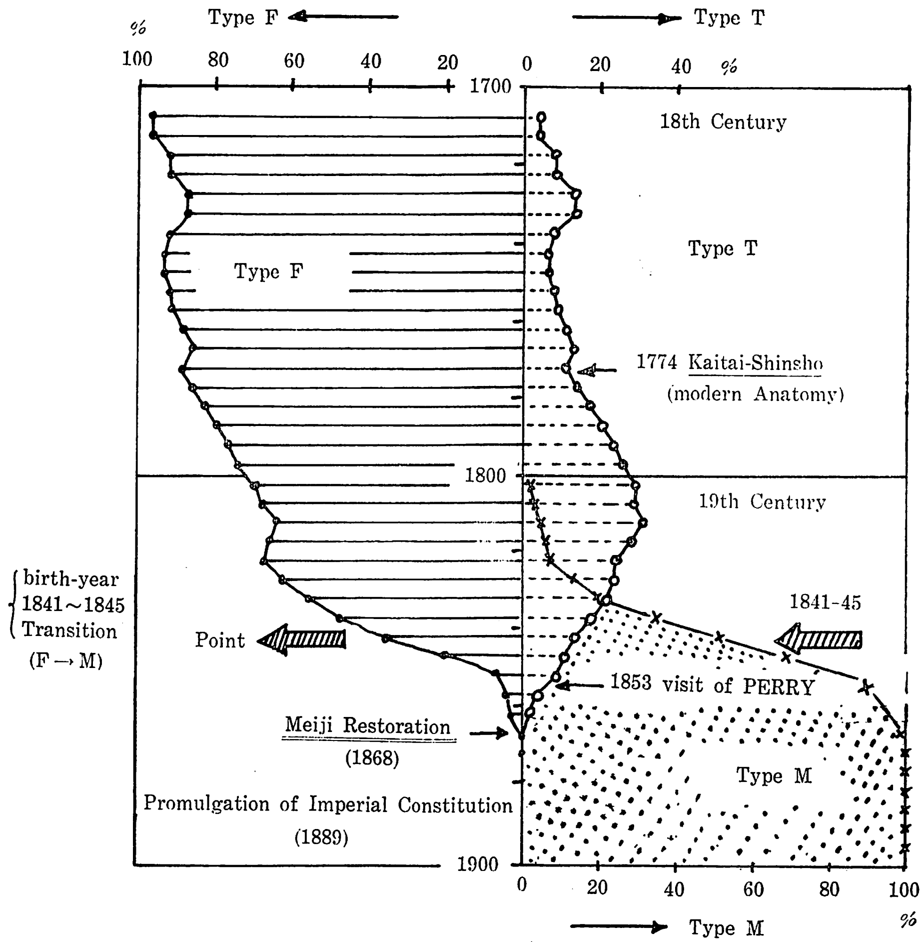


Figure 2. Changes in Type of Japanese Scientists

Type { T....Transition
F....Feudalism
M....Modern

The moving average of the Types F, M, and T from 1701 to 1900 is shown in Fig. 2. This graph shows clearly the shift in types from F (Feudalism) to M (Modern) through T (Transition). We can easily find the age of transference in Fig. 2. This transition point is in the period 1841–1845, and the curves of F and M indicate a great change. The percentages of F and M, at these points, are shown in Table 1.

Figure 2 shows the results of statistical treatments of the birth year, and we find that the time of the transition point has to be shifted.

(a) If it is assumed that a man's occupational interests are decided at the age of 15 (*Genpuku*, or attainment of manhood), we have

TABLE 1. Changes in Percentages

Birth Year	% of F.	% of M.
1826—1830	72	7
1831—1835	46	23
1836—1840	53	33
1841—1845	44	47
1846—1850	10	72
1851—1855	7	82

$(1841 \sim 45) + 15 = 1856 \sim 1860$

(b) If it is assumed that the alternation takes place at the age of 40 (the so-called "acme of manhood"), we have

$(1841 \sim 45) + 40 = 1881 \sim 1885$

The first cabinet based on the European model was organized by Hirobumi Ito in 1885. Around this year several well-known scientists, including S. Kitazato, I. Kitao, and H. Nagaoka, began to make public their achievements which resulted in international recognition.[1]

3. Scientific Communities in Edo Period

I would like to explain the beginning and the growth of scientific communities in Japan, not in a strict comparison, but using a metaphor, and state that the whole process is like the life of a butterfly that begins by being an ovum. As is well known, the butterfly is an insect that undergoes a perfect metamorphosis from an ovum, through a green catterpillar and a cocoon, and then into a mature butterfly. We wonder how a noxious worm that creeps on the earth can grow into a beautiful butterfly that dances in the air. Biologists may explain the process of metamorphosis as the effects of *corpora-allata,* a hormone secreted from the prothorax glands.

I have already introduced the idea of scientific revolution in order to explain the life cycle of scientific communities in Japan. Here I want to make use of the mechanism of metamorphosis in insects and give you the folllowing metaphoric contrasts.

(a) "Green catterpillar" period: scientific communities in Japan from the ancient days to the Tokugawa or Edo period, mainly founded upon imported classic Chinese culture together with Buddhist culture that had come over the Continent of Asia.

(b) "Chrysalis" period: scientific communities during the days when Japan was almost closed to foreign culture from 1639–1853.

(c) "Butterfly" period: scientific communities in present-day Japan since

[1] Mitsutomo Yuasa: "The Scientific Revolution and the Age of Technology", *Journal of World History,* Vol. IX, No. 2, 1965, pp. 187–207.

the year 1853.

Next, I feel the hormone that effected the above metamorphosis in science in Japan was: *Rangaku* (Dutch Learning or Netherlandish studies). This played the role of a "hormone", which could be identified with Dutch Scholars in Type T in my division made in the foregoing section. It was Type T (Transition) that had made possible the development from Type F (Feudalism) to Type M (Modern Japan).

In the *Rangaku-Kotohajime*, written by Gempaku Sugita in 1815 when he was eighty-three years old, we find the following passages:

> "They say that one drop of oil cast into a wide pond will spread out to cover the entire surface. Just like that, in the beginning there were only three of us—Ryotaku Maeno, Jun-an Nakagawa and myself—who came together to make plans for our studies. Now, when close to fifty years have elapsed, the studies have reached every corner of this country, and each year new translations seem to be brought out. This is a case of one dog barking at something, only to be echoed by ten housands dogs barking at nothing. Since I am enjoying longevity, I have the previledge of being delighted and surprised at the great developments to-day. Again and again I am especially delighted at the idea, that when the way is opened wide, doctors in a hundred years, yea, a thousand years, will master real medicine, and that will be of great profit for public welfare. When I think of this, I can not help dancing and springing for joy."[2]

Konyō Aoki (1698–1769) was the first to learn Dutch in Edo, but his studies did not go beyond collecting a few hundred Dutch words. His pupil Ryotaku Maeno went to Nagasaki, where he increased his knowledge of the Dutch languange, and Gempaku Sugita's translation of a Western work on anatomy was dependent on Maeno's knowledge of Dutch. Sugita wished to deliver western learning, hitherto monopolized by the official interpreters of the shogunate, into the hands of the scholars so that they might pursue more profound research, and the word *Rangaku* was first used by this pioneer. The *Kaitai-Shinsho* was published by this group of scholars in 1774. This translation proved to be a turning-point in the importation of Western science in the Tokugawa period. After this date Dutch Learning made rapid advances.

An account of the actual stages in the establishment of modern science in Japan can be given by dividing the period of scientific revolution in the country into three stages, analogous to those of J. D. Bernal.[3]

1st stage (1774–1853), from the publication of *Kaitai-Shinsho* (Anatomy) to Commodore Perry's arrival at Uraga.

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[2] Eikoh Ma (Shimao): "The Impact of Western Medicine on Japan, Memoirs of a Pioneer, Sugita Gempaku, 1733–1817," *Archives Internationales d'Histoire des Sciences*, 1961, pp. 65–84, pp. 253–272.

[3] J. D. Bernal: *Science in History*, London, Watts & Co., 1954, p. 257.

2nd stage (1853–1868), from Perry's arrival to the Meiji Restoration.

3rd stage (1868–1889), from the Meiji Restoration to the promulgation of the Imperial Constitution.

The above stages are to be treated merely as a working hypothesis for now. Moreover, they do not constitute three different periods that may be distinguished clearly one from the other; they are three stages in the single process of change from feudalism to capitalism.

In the 1st stage (1774–1853), the essence of the scientific revolution in Europe was translated into Japanese by way of Dutch, as follows:

A. Vesalius (1514–1564): *De Humani Corporis Fabrica* (1543). The contents of this book were introduced into Japan through *Kaitai-Shinsho* (1774) by G. Sugita and his collaborators.

N. Copernicus (1473–1543): *De Revolutionibus Orbium Caelestium* (1543). The essence of Copernicus' heliocentric theory was introduced through Ryoei Motoki's *Tenchi-Nikyu-Yōhōki* (1791).

I. Newton's dynamics, published as *Principia* (1687), was introduced through Tadao Shitsuki's *Rekishō-Shinsho* (1798).

C. von Linnaeus's theory of biological classification, published as *Systema Naturae* (1735), was introduced through Keisuke Ito's *Taisei-Honzō-Meiso* (1829).

A. L. Lavoisier (1743–1794): *Traité élémentaire de Chimie* (1789). The contents of this work were introduced through Yōan Udagawa's *Seimi-Kaisō* (1839).

J. Dalton (1766–1844): *New System of Chemical Philosophy* (1808). The theory of atoms was introduced through Kōmin Kawamoto's *Kagaku-Shinsho* (1857).

In the 2nd stage (1853–1868), there occurred two major changes. One was the turning of *Rangaku* (Dutch Learning) to military use, and as a consequence of this change, the turning of these studies into government-sponsored learning. The other major change was the shift from Dutch to English studies. After Commodore Perry's arrival, as conditions abroad became better known, a greater need for German, French, and English, rather than Dutch, came to be recognized.

The study of the English language began at Nagasaki in 1809 at the official command of the shogunate government. Six of the Dutch interpreters at Nagasaki began to study English under Dutch trade-station members there, nearly seventy years after Konyō Aoki began his study of the Dutch language in 1740 at the command of the shogunate government. The study of French and German was begun years after that of English.

Bansho-Shirabe-Sho ("Institute for the Study of Foreign Books"), was founded on September 18, 1857. This was the first school in Japan for higher education in Western science. The first students of this school numbered 191, all of whom were sons of *samurai* who were direct retainers of the shogunate government. The main languange that was taught here was Dutch, but English was taught to some extent at the same time.

The branches of training consisted of science and technology, astronomy, geography, physics, mathematics, chemistry, mechanics, and drawing. This institution later developed into Tokyo Imperial University, which was officially founded by the Meiji government and consisted of faculties of Laws, Letters, and Science. The medical faculty which was contained in the new university developed from the *Shutō-Sho* ("Institute for Vaccination"), which was founded at Otamaga-ike, Edo, in 1858 by medical researchers in the Dutch style. This institute was later called *Seiyō-Igaku-Sho* ("Institute for Western Medical Science") in 1861, and, further on, renamed *Daigaku-Tōkō* ("Eastern School of the University").

The great shift from Dutch studies to English studies was rapidly made, as we have already seen, in the second stage of scientific revolution (1853–1868). A vivid description of this shift is found in *Fukuō Jiden* (1899), an autobiography of Yukichi Fukuzawa. The passage I want to translate and quote in connection with this, tells about his visit to Yokohama on a certain day in 1859.

> "Foreigners had set up their shops there. I went to see them, but I could not make myself understood. What I said was not understood by them nor did I know what they said. I cannot read their sign-boards or even the labels on bottles. There were no words that I could understand. I never knew whether the language these foreigners spoke was English or French...I returned from Yokohama in great disappointment. I was quite at a loss. For the past several years I did my best in learning Dutch. My endeavour was all to no purpose. I could not read even the sign-boards of shops. I was greatly discouraged. But I cannot afford to remain discouraged...Their language must have been English. Our country has contracted treaties with foreign nations. From now on, the most necessary language should be English....The next day I made up my mind to learn English and to study everything English."[4]

Fukuzawa's autobiography goes on to say.

> "Dutch scholars at the time, I among the rest, all thought that, if the Dutch language which they had worked hard to master, should prove of no use, and they should study English afresh, they would have to experience hard work again. What a useless and vain endeavour they had made! They were like those who have worked hard at learning how to swim for, say, two or three years. Then, all of a sudden, they were told not to swim, but to begin to learn the art of climbing trees. All their former efforts proved vain and useless. I thought of the affair over and over again. It was hard for me to make up my mind."[5]

At the beginning of this section, I compared the period when Japan was closed to foreign nations, and the days when Japan began to learn everything from Western

[4] Yukichi Fukuzawa: "*Fukuō Jiden*", 1899, Iwanami-Bunko, (in Japanese), 1954, p. 99.
[5] *Ibid.*, p. 102.

countries and had become a highly civilized and industrialized nation, the chrysalis and the mature and beautiful butterfly respectively. Dutch Learning had been of use only in the chrysalis stage of Japan, for it had merely been a phenomenon of the transitional process. Yet it had played a part ocrresponding to a hormone or *corpora allata* for the "chrysalis" Japan.

4. Assistance from Foreigners

Modern science came to be firmly rooted in Japan in the 3rd stage of the scientific revolution in Japan, 1868–1889, as mentioned previously. Science in Japan had, so to speak, achieved a complete metamorphosis from a green caterpillar into a butterfly. In Tokyo University, which was the centre of activities, a number of foreign professors had given assistance to Japanese researchers.

Bansho-Shirabe-Sho, opened in 1857, changed its official name several times before it came to be called Tokyo University. These changes of name were aftermaths of the big and rapid changes in the system of government, administration and education before and after the Restoration of Meiji in 1868. *Yōsho-Shirabe-Sho* (1862)→*Kaisei-Sho*→*Daigaku-Nankō* (1869)→*Dai-Ichiban-Chūgaku* (1872)→ *Tokyo-Kaisei-Gakkō* (1874)→*Tokyo University* (1877). Tokyo University was founded on April 12th in 1877, after annexing *Tokyo-Kaisei-Gakkō* and *Tokyo-I-Gakkō* ("Tokyo Medical School"). *Tokyo-Kaise-Gakkō* contained, as regular courses, Law, Chemistry, and Mechanics, and, as temporary courses, Polytechnique and Mining. The Ministry of Education which controlled education throughout the land, recognized the advantages of using one foreign language in the classes to be opened in the new institute of higher education. When it opened *Kaisei-Gakkō*, it decided to use only English, and temporarily allowed those students who had learned French, German or Dutch to study polytechnique and mining. And in 1875, classes given in French were changed from politechnique to physics and class numbers were decreased, those in German, altered from mining to chemistry and decreased in number. After some time, classes in German in chemistry were discontinued because applicants for the course greatly decreased in number. The Faculty of Science in Tokyo University consisted of six courses, only one course of which, that is, French Physics was given in French and the other five courses—physics, chemistry, biology, and engineering—were taught in English. Aikitu Tanakadate, who was a physicist, entered *Tokyo-Kaisei-Gakkō* in 1876 and graduated from Tokyo University in 1882. He wrote about his old class-room life as follows:

> "Students were about 90 in number. They were divided into three groups called *Ko, Otsu,* and *Hei* Classes, ordinarily called A, B, and C Classes. The Japanese professors were merely Prof. Yamagawa and Prof. Toyama. The other teachers were mostly Americans and a few Englishmen and Germans. All the classes were given in English and recitation was the chief method of teaching."[6]

[6] Aikitu Tanakadate: *Kuzu no Ne*, (in Japanese), Nihon-no Romazi-Sya, 1938, p. 118.

After classes in French physics were discontinued in 1880, all the lessons in the Faculty of Science in Tokyo University were given in English. The Dutch language, which was the only and the first language in the *Bansho-Shirabe-Sho*, opened in 1857, had become less important as diplomatic treaties were made with foreign nations and trade was opened at Yokohama, Kobe, and several other ports after the arrival of Commodore Perry in 1853. According to the statistics in the *Report of the Ministry of Education*, No. II (1874), there were 91 foreign language schools in Japan at the time, including governmental, prefectural and private schools, 82 schools or 91% of which were English language schools.

Table 2 shows the foreign professors in mathematics, astronomy, geophysics, physics, chemistry, geology, biology, and similar sciences during the period from 1860 to 1900.

TABLE 2. Foreign Professors in Japan (1860—1900)

Sciences \ Nationality	Great Britain	U.S.A.	Germany	France	Nether-lands	Total
Mathematics	5	4	6	5	—	20
Astronomy	—	—	—	1	—	1
Physics	6	8	2	5	—	21
Geophysics	1	1	2	—	—	4
Chemistry	4	4	5	3	2	18
Geology	1	3	6	1	—	11
Biology	1	4	4	2	—	11
Total	18	24	25	17	2	86

Fig. 3 shows the number of foreign teachers in Japan (in natural sciences alone) over the years from 1860 to 1900. You will be able to understand that the number of foreign teachers was the highest in the 3rd period of the Scientific Revolution in Japan from 1868–1899, as we have mentioned before. The period from 1871–1882, which contains the date of the founding of Tokyo University, 1877, was the highest in number. In the finishing touches of this revolution in science, the Japanese seem to have owed much to the guidance and assistance of these foreign teachers. By 1889 most of these foreign professors returned to their own countries and their successors were selected from among Japanese scientists.

In regard to Modern Technology, it may also be said that the Japanese owe much to technologists from abroad in the same period, *i.e.*, in the 3rd Period of Japan's Scientific Revolution from 1868–1889. Without their assistance, Japan would not have so rapidly made modern technology her own. The *Kōbu-Shō* ("Ministry of Engineering") played the same role in the field of technology as that played by Tokyo University in the field of science. The *Kōbu-Shō* was a ministry of the Government that was organized in 1870 and was abolished in 1885 so as to develop the general organization of the government. However, this ministry

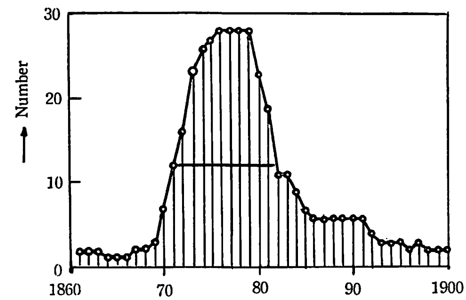

Figure 3. The number of foreign science teachers in Japan (1860–1900)

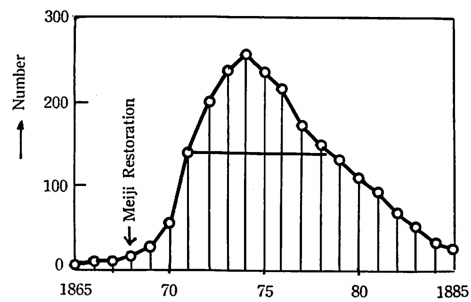

Figure 4. The number of foreign technical advisors (Ministry of Engineering, 1865–1885)

TABLE 3. Settle Accounts of Ministries (1876)

Ministry	Settle Accounts Unit: 1,000 Yen
Foreign Affairs	153
Home Affair	2977
Finance	1560
War	6904
Navy	3424
Education	1695
Engineering	4343
Jurisprudence	1383
Imperial Household	290

had built the bases for the Industrial Revolution in Japan. The first Minister of Engineering (1873–1878) was Hirobumi Ito, who later, in 1885, became the Prime Minister in the first Cabinet organized on the European model. The Ministery of Engineering, though it was a branch of the Cabinet under the charge of a minister, played an important part in the Cabinet in developing Japan into a modern nation, together with the Ministries of Foreign Affairs, Home Affairs, War, Navy, and of Education. As is shown in the Table 3, the sum expended by the Ministry of

Engineering in the settlement report for 1876, was 4,343,000 yen, which was next to the War Office with 6,904,000 yen, the highest amount in the Budget. The Ministry of Engineering, when it was organized in August, 1871, consisted of ten bureaus, *i.e.,* Engineering, Industries, Mining, Railways, Civil Engineering, Light-Houses, Ship-Building, Telegraphy, Iron Foundry, Mechanics, and one office for Survey, and affairs concerning mechanical industries were all controlled by the Ministry.

The various works that were completed by the Ministry of Engineering were, all of them, run by importing and introducing foreign technology, so that scores of foreigners were employed by this Ministry. The number of foreign technical experts who were employed during the 15 years, 1870–1885, when this ministry was in existence, was as follows: Railways (256), Mechanical Engineering (81), Mining (78), Telegraphy (59), Light-Houses (52), School in Mechanical Engineering (21), Building and Repairs (13), School in Arts (7), Primary School under the direct control of the Department of Engineering (5), Crew for the *Meiji-Maru* and for two other ships (175) and others (2). When we calculate the number of foreign technical advisors staying in Japan for each year during the period from the number of years they spent in Japan, the number is as seen in the Fig. 4.

As can be seen in Fig. 4, the number was bigger in 1870–1880, reaching the peak in 1874. This Figure is similar in character to Fig. 3 which tells us of the number of natural science foreign professors in Japan. Judging from this trend, we may say that modern technology took root in Japan, as is the case with modern science, in the 3rd stage of the Scientific Revolution.

The year 1886 saw the promulgation of the Edict Concerning Imperial Universities, and Graduate Schools were established. The Edict Concerning Academic Degrees was promulgated in 1877. The next year, 1888, a total of 25 doctorates were granted—five each in law, literature, science, medicine, and engineering. In Dr. Eri Yagi's paper "The Growth of Modern Science in Japan, 1960", the number of Doctors of Science from 1888–1956 was calculated, and the number was found to have doubled every ten years, showing normal development in the country. She has also considered and found normal the growth in the number of members of the Physico-Mathematical Society of Japan from 1888–1945. (Fig. 5),[7]

1888–1911: Membership $= 37 \exp(0.0064\, n)$

1919–1945: Membership $= 33 \exp(0.0064\, n)$

(n, being the number of years elapsed from 1877)

These figures may be regarded as proof that in regard to science, national communities have made as normal and regular development as in the countries of Western Europe.

From about the year 1877 when Tokyo University was founded, learned societies were organized, and professors and graduates made up an important part of the

[7] Eri Yagi: The Growth of Modern Science in Japan, *Abstract of Paper Presented at the New York Meeting of A.A.A.S.*, 1960.

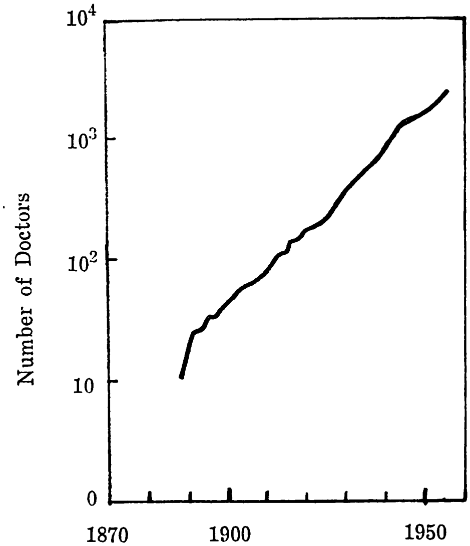

Figure 5.
The number of Doctors of Science in Japan, as function of data (1888–1956)
Number of doctors = 18 exp 0.07 n (n is the number of years elapsed from 1888) from Eri YAGI: "The Growth of Modern Science in Japan," *Abstact of Paper presented at the New York Meeting of A. A. A. S.*, 1960; *Nippon Kagaku-gizyutsusi Taikei* Vol. 7., Tokyo, 1968, p. 547.

membership. All these societies are still going on now, nearly a century after their inauguration. A list of learned societies in the chronological order of their founding runs as follows: Mathematical Society (1877); Medical Society (1877); Chemical Society (1878); Geological Society (1879); Engineering Society (1879); Seismological Society (1880); Botanical Society (1882); Physical Society (1884); Anthropological Society (1884); Mining Society (1885); Veterinary Society (1885); Architectural Society (1886); Agricultural Society (1887); Zoological Society (1888); Electricity Society (1888) etc. By this time, societies had been established in all the branches of basic sciences.

To organize and manage these learned societies, advice from resident foreign teachers and Japanese researchers trained abroad should be highly evaluated. Now I want to report on the establishment of the Seismological Society in Japan, which was the first society of this branch of science in the world. The first general meeting of the Society was held in March, 1880. In February of that year, there was a strong earthquake in Tokyo Bay and damage was done to the Yokohama district where a number of foreign professors lived. This event might have stimulated the founding of the Seismological Society, for nearly a hundfed people gathered together to organize a society for scientific research into earthquakes. The central figure of the society was an Englishman named J. Milne, who was a professor of Geology and Mining in the *Kōbu-Daigakkō* ("College of Engineering") from 1875–1895. The second meeting of the society was held on April 26, 1880, in which a report was made on an original idea for a seismograph by Prof. Ewing and Gray, who stayed in Japan from 1875 to 1882 and from 1878 to 1881 respectively. The modern scientific and mechanical seismograph was invented in Japan by these two foreign Professors. This was the beginning of seismology in Japan which is now playing an important part in this branch of science.

In concluding this section I want to make a list of foreigners who contributed much to Japanese civilization and culture in the Meiji Period, 1868–1912, classifying them by their nationality and their fields of contribution.

Englishmen and Americans are greatest in number, but, in natural science and medicine, the Germans, and, in Military affairs, the Frenchmen contributed much to Japan in the Meiji Era.

TABLE 4. List of Foreigners in the Meiji Period (1868—1912)

Field of Contribution	U.S.A.	Great Britain	German	France	Nether-lands (Dutch)	Italy	Russia	Others
Laws & Economics	16	4	5	5				1 (Belgium)
Religion	20	7		5			2	1 (Belgium)
Education	17	12	3	4	1		1	1 (Switzerland)
Literature	10	13	4	1		4	1	2 (Austria)
Natural Sience	16	10	11	3			1	2 (Sweden)
Medicine	4	1	16	1	8			
Industry	10		11	2		1		2 (Austria)
Architecture & Civil Engineering	4	6		1	5	1		1 (Canada)
Traffic	2	19		1				1 (Sweden)
Military Afairs	2	1	2	13		1		
Total	101	73	52	36	14	7	5	11

5. Economic Development of Japan

W. W. Rostow has divided the economic growth of Japan into the following stages:

1. the traditional society—the Tokugawa Shogunate Period
2. the preconditions for take-off
3. the take-off—1878～1900
4. the drive to maturity—1940
5. the age of mass-consumption—1955

"The beginning of take-off can usually be traced to a particular sharp stimulus. The stimulus may take the form of a political revolution which affects directly the balance of social power and effective values, the character of economic institutions, the distribution of income, the pattern of investment outlays and the proportion of potential innovations actually applied."[8]

In underdeveloped countries or non-initiated countries the most important stage in economic development is "Take-off." The Take-off is the interval when the old blocks and resistances to a steady growth are finally overcome. In Japan the epochal change of scientific revolution overlapped in this interval. In the Scientific Revolution (in the 3rd stage, 1868–1889), the whole edifice of the intellectual system, which had been brought from China and cultivated under Buddhism and Confucianism, was overturned and replaced by a completely new system introduced from Europe.

As we have already mentioned, Japan owed her success in introducing a completely new system to the growth of scientific communities of the so-called *Rangaku-sha* (Dutch Scholars) and to advice and assistance from foreign scientists and technicians who came to Japan. In the first half of the Meiji Period Japan started its take-off, and, by the end of the 1960's her GNP has overtaken the civilized countries of Europe and occupies third place in the world next to the U.S.A. and the U.S.S.R. Japan has made a phenonomenal economic development in about a century after the Meiji Restoration, which we might regard as a 20th century miracle. To explain the miracle, I want you to look at two points, where the Japanese have made continuous efforts, but which have not yet been noticed by the people of the world.

1) Technical terminology was put into order and unified.
2) Since Jan. 1, 1959, the metric system has been adopted as the only authorized system of measuring.

(1) Among the countries of Asia and Africa, it seems that one of the greatest difficulties in introducing modern science was the problem of technical terminology. In order to found scientific communities in a country, it is necessary that technical terminology should be established so that the people may use it in a unified way.

In the first half of the Meiji Period, one of the greatest efforts among Japanese scientists was to unify the technical terminology in each branch of science. To translate a great number of foreign scientific terms into Japanese words and to unify the translated words—this might have been the most difficult work to do. Here I want to show examples of this. The term "gas" is now called "Kitai" in Japanese. But, at the end of the Shogunate Period and in the first days of the Meiji Era, it was called "Kijotai," "Kyoshitsu," "Fukitai" or "Gasutai," all being expressed by using various Chinese characters. As for Strontium, Sr, in Yōan Udagawa's *Seimikaisō* (1837), which was the first book in Japan on modern chemistry, it was spelled in Japanese "期多論胃母". The present writer looked up a dozen chemical books published prior to 1886, and the same term was spelled "ストロンチウム," "斯篤論母", "思而", "鍶," or "鐳".

[8] W. W. Rostow: *The Stages of Economic Growth*, Cambridge, University Press, 1966, p. 36.

In the community of mathematicians, there were *Wazan-ka* of Type F, (Feudalism) and mathematicians of the Western school belonging to Type M, (Modern); to these some elements of the Chinese language using Chinese characters were mixed together. As a result, the chaotic condition of mathematical terms was regarded as a great handicap when elementary schools were opened in Japan in 1872. In 1880 a translation committee was organized in the *Tokyo Sūgaku Kaisha*, (the beginning of the present Mathematical Society of Japan), but the unification of translated mathematical terms was not easily accomplished.

Mathematicians who were not teaching in schools established by the Government organized themselves into *Sūgaku-Kyokai*, which differed from *Tokyo-Sūgaku-Kaisha*. The former group decided the translated terms by vote and made public the results in their magazine entitled "*Sūgaku-Kyokai-Zasshi*." In the second number of this publication we find the following English terms, the Japanese equivalents for which the readers were asked to decide by voting:

○ Mathematics: (1) 数 学. (2) 数理学. (3) 算 学.
○ Arithmetic: (1) 算 術. (2) 平 算. (3) 数 学. (4) 算数学.
○ Trigonometry: (1) 三角法. (2) 三角術. (3) 三角学. (4) 八線学.
○ Analytical Geometry: (1) 解析幾何学. (2) 代数幾何学. (3) 高等幾何学. (4) 軸式幾何学.

Furthermore, for "Unit", the following Japanese terms were once used: (1) 単位. (2) 定個. (3) 一個. (4) 一. (5) 数基. (6) 一位度.

How can we expect science and technology, that were developed among foreign nations and countries, to be firmly transplanted to other countries, unless the translated technical terminology is used in vernacular words uniformly in the country, from elementary schools to the highest institutions of learning? The hard work of transplanting foreign science and technology in Japanese land was first begun by the *Rangaku-sha* ("Dutch Scholars") belonging to Type T (Transition), and then, was accomplished by scholars studying the English, German and French languages. In 1870, about a century after the publication of *Kaitai-Shinsho* (1774), the work of unifying translated terms began. We have already seen that learned societies for mathematics, physics and chemistry began to be organized about 1877. The first work for these societies to do was to unify the translated technical terms. As a typical result of this work, we can refer to the following dictionaries published in Japan;

○ Philosophical Terminology (*Tetsugaku-Ji-I*), 1884.

○ Engineering Terminology (*Kōgaku-Ji-I*), 1886.

○ Japanese-English-French-German Dictionary of Physical terms (*Butsuri Gakujutsu-go Wa-Ei-Futsu-Doku Taiyaku Jisho*), 1888.

○ Collection of Translations of Chemical Terms (*Kagaku-Yakugo-shu*), 1891.

These works almost firmly established the terminology of modern science in the Japanese language. These publications were all products of pains-taking efforts. For example, *Tokyo-Kagakukai*, inaugurated in 1878, organized the committee for unifying technical terms in 1881, but it was ten years before *Kagaku-Yakugo-Shu* ("Chemical Vocabulary") was published in 1891. The preface of this vocabulary says:

"Many books on chemistry have already been translated into Japanese. However, translated terms of various tools, instruments, medicines and technical terms differ with translators, so that a great many inconveniences were felt by scholars who wanted to make use of these books or manuscripts. We have long regreted these inconveniences. Our society, therefore, has appointed several members for the task of unifying the translated terms. As the work was far from being easy, we cannot expect the result to be perfect, but a step forward has been made in the past years, so we here decided to publish the results of the committee members in book-form and title it 'Chemical Vocabulary'."

We might say that national scientific communities could never be organized unless we had a unified technical terminology thanks to the efforts of many scientists. Technical terminology in Japan began to be unified by the socalled *Rangaku-sha* before the Restoration of Meiji, and then, in 1945, after World War II, the reform of the Japanese language was again attempted in our country. New Japanese words which will go with the developing science and technology, are expected.

(2) The establishment of a modern system of measuring is necessary not only for economic activities to keep order in the commercial life of the people, but is also required for the development of science, industry and culture. A Modern measuring system is needed in expanding commercial markets through a unified system, as well as in forming modern quantative ideas about nature. The so-called *Shakukan-Hō*, which was used in erecting the famous Hōryūji Temple in the Nara Period, A.D. 607, will not be sufficient in the days of modern science and technology.

Before the Meiji Restoration, the shogunate government divided the land into hundreds of domains of feudal lords. These domains were practically independent soverein states, and the methods of measuring differed from clan to clan, for there was no standard measure that was used throughout the land. To illustrate this the *Shaku* was used as unit of measuring length, but there were several kinds of *shaku: Kyoku-shaku, Ina-shaku, Kujira-shaku, Gofuku-shaku, Kyoho-shaku, Secchu-shaku*, and others. *Shō* was once a unit of cubic mearurement, but it is recorded that there were 70 kinds of *shō* from ancient times.

The metric system, begun in 1799 in France, was adopted by the Dutch people in 1816 and was known comparatively early to the Japanese through the *Rangaku-sha*. "Japan's Transition to the Metric System" (1967), compiled by the Japan Metric System Promotion Committee, reports the history of the system:

"It was in 1891 that the regulation of weights and measures was established for the first time in the form of law. Six years earlier, Japan had already decided to sign the Treaty of the Meter, and the Treaty had been enacted in 1886. In 1890, Japan received the prototype meter and kilogram from the

International Bureau of Weights and Measures in accordance with the Treaty. In the law of 1891, which came into effect in 1893, the traditional measuring units "*Shaku*" and "*Kan*" were taken as the fundamental units in length and mass. At the same time, the use of the metric system was approved in this law, and the conversion factors between these two systems were also fixed.

"Since then, there have been several amendments in this old law, and in 1909 the units of the foot-pound system were also adopted as legal. Thus, since 1909, Japan has had three measuring systems approved as legal. The actual measurements became more and more complicated and troublesome, and a desire to unify these measuring units arose. In 1919, the Ministry of Agriculture and Commerce set up a Committee for Weights and Measures and Industrial Standards to investigate which measuring system was to be adopted in Japan and to study procedures for promoting the plan. According to the advice of the committee, the Ministry decided to revise the old law and prepared a bill in which the metric system was taken as the unique measuring system. The bill was passed in the Diet in March of 1921, and the revised law was promulgated in April of the same year. The date of enforcement of this law fixed by the Imperial Ordinance was July 1, 1924. But in this same Imperial Ordinance, the use of measuring units other than those of the metric system was also permitted as a transitional measure."

In 1959, all the transitional measures were forbidden by law, and the metric system was legally and exclusively adopted within the realm of Japan. The history of the adoption of metric system in Japan may be regarded as a remarkable case in the history of unifying various measures into the metric system.

We can see, in the short history mentioned above, that the basis for the adoption of metric system was found in the "Take off" period of the Japanese economy, 1878–1900. We may say that this period partly overlaps the 3rd stage in the history of the Scientific Revolution in Japan, 1868–1889. In 1890, in the first Session of the Imperial Diet, a committee was organized for making a Bill proposing a change in the measuring system (or the adoption of metric system). Among the committee members were Dairoku Kikuchi and Kenjiro Yamagawa, both being professors in Tokyo University and well-known scientists of the time. The committee made a Bill, which was later made an Act which unified the old *Shakukan* measuring system on the basis of the metric system.

6. Conclusion

In *The Reorganization of Science and Techonology in Japan* (Report to the National Academy of Sciences, U.S.A., 1947), published by the Scientific Advisory Group that visited Japan after World War II, Japanese science is reported on as follows:

"In the fields indigenous to Japan, such as agriculture, fisheries, and sericulture, the Japanese show outstanding skill, not only in practical methods, but in the application of recent scientific results. In some subdivisions of these fields they possibly lead the world. In the fields associated with manufacturing industries and physical sciences, they have made remarkable progress, in the past eighty years, in the introduction of western skills and methods of thought. They still lag behind the United States and England in the development of a broad base of scientific and technical understanding. Science is still regarded as the exclusive possession of a privileged few, so that its influence on the life of the country is limited. This is a condition which time and the democratization of political life will tend to cure, and which cannot be suddenly changed by any type of reorganization. The social sciences, especially as they involve international comparison in the fields of history, economies, law, literature, and government, seem to have suffered greatly before and during the war from lack of freedom, both of speech and of investigation. But evidence exists of talent and training adequate to provide a basis for recovery of lost ground and future development now that defeat has lifted bans on free expression and has prompted critical reconsideration of Japanese social and political institutions." (General Comments)

Nearly twenty years after the above statement was made, the Japanese economy, which is often said to have made miraculous progress, now, in 1969, occupies the third place in the world. Science and technology in Japan, however, in L.D. D. Corral's words, is "El Rapto de Europa", and rare are the results of Japanese originality. We have only two Nobel Prize winners in Science, namely, Yukawa and Tomonaga. J. Jewkes, D. Sawers and R. Stillerman: *The Sources of Invention* (1962), points out 50 typical inventions of the 20th century, to which the Japanese had contributed nothing at all. Japanese are still "Rapto" (enraptured) of the achievements of the Western World, and have no claim at all to being called "Homo Kreata" (creators). In typical 20th century big science, present-day Japan is definitively lagging behind. But the Japanese are not merely following the steps of the European countries of the 17th–19th centuries. According to reports made by Herman Kahn and others, Japan in 2000 will be regarded as a promising country, belonging to the economic grouping that has made high progress, worthy of being called Visibly Post-Industrial (Fig. 6).[9]

Japan has completed growth from a green caterpillar through a chrysalis into a beautiful butterfly. From now on, it will create original scientific communities in the field of social sciences as it heretofore has in the field of natural science and technology. I wonder if the butterfly will continue to fly higher and higher in the air. I hope it will.

[9] H. Kahn and A. J. Wiener: *The Year 2000. A Framework for Speculation on the Next Thirty-Three Years*, New York, MacMillan, 1967, p. 60.

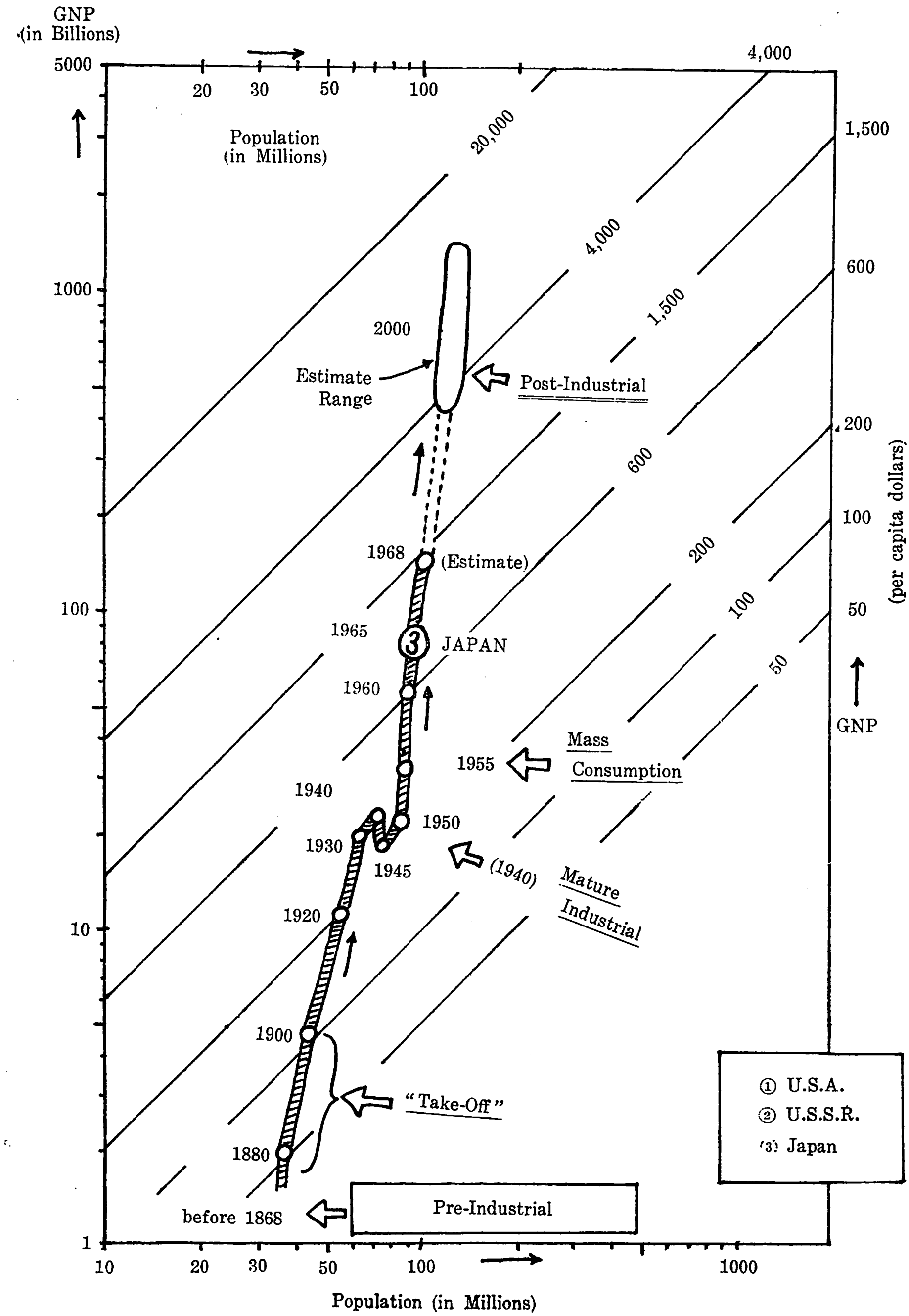

Figure 6. Growth of GNF in Japan (1880–2000)

SOURCES

Fig. 1. Mitsutomo Yuasa: *Kagakushi* (A History of Science), Tokyo, Toyokeizai-Shinpo-Sha, 1961, p. 10.

Fig. 2. *Note* (1), p. 196.

Fig. 3. Mitsutomo Yuasa: *Kagakushi*, p. 105.

Fig. 4. *Ibid.*, p. 106.

Fig. 5. *Note* (7).

Fig. 6. Mitsutomo Yuasa: "The Role of Science and Technology in the Economic Development of Modern Japan", A Figure presented at the *XIIth International Congress of the History of Science*, Paris, 1968.

Table 1. *Note* (1), p. 195.

Table 2. Mitsutomo Yuasa: *Kagakushi*, p. 104.

Table 3. Mitsutomo Yuasa: *Kagaku 50 Nen* (A Fifty Years of Science), Tokyo, Jiji-Tsushin-Sha, 1950, p. 30.

Table 4. Mitsutomo Yuasa: "Kindai Kagaku 100 Nen Shi, 3 (A Hundred Years of Modern Science), Scientific Magazine *Shizen* (in Japanese), Vol. 11, No. 7, p. 75.