Hundred Years of Science in Japan: From a Physicist's Point of View*

Hideki Yukawa

It is a great pleasure and honor for me to talk on the occasion of the XIVth International Congress of the History of Science. The title of my talk is "Hundred Years of Science in Japan". I am well aware that it is beyond my knowledge and capacity to deal with the developments in all branches of modern science in Japan from the early years of the Meiji era up to the present. Moreover, it is almost impossible for me as a physicist to be impartial with respect to the relative merits of achievements in many branches, with which I am not well acquainted. What I can do is not more than a brief account of some of the scientific activities in these about hundred years in Japan laying emphasis on those in physics.

Japan has been under the influence of Chinese civilization since about two thousand years ago. In the early years, the influence came mostly through Korea. However, since the beginning of the seventh century, Japanese government frequently sent missions to Chinese government. This contributed a great deal to promote all sorts of cultural activities in Japan. I would like to mention only one of many such missions: in 804, a fleet four ships sailed for China. In company of the envoy, many attendants were on board. Among them were two monks, Saicho (767-822) and Kukai (774-835), who have become later each the originator of new sect of Buddhism in Japan. Kukai, who is more commonly known as Kobo Daishi, however, was not only a great religious leader, but an extremely versatile man. During his two years stay in China, he could master almost all sorts of things including Chinese and Sanskrit languages, literature, poetry, calligraphy, medicine and engineering, in addition to study and practice of Esoteric Buddhism. Thus he contributed a great deal to reduce the enormous gap between Chinese and Japanese civilization at his time almost single-handed. He did more than to transplant various parts of Chinese civilization. He was an original thinker who constructed an all-embracing system of metaphysics with Esoteric Buddhism originated in India at its summit. The essence of his thought was the unity of cosmos and man. All his mental and physical activities were to him the self-expression of cosmic vitality and wisdom. He established the first private school in Japan for common people. In many respects, he is a remarkable man worthy of further study from the viewpoint of history of science [1]. The 9th century starting from Kukai may be called an age of culturism, when the knowledge and mastery of Chinese literature and poetry were highly respected in the aristocratic society in Kyoto. This may be compared with the Humanism of the Renaissance which respected classics in Greek and Latin. The situation has begun to change since the end of 9th century, when the mission of the government to China was suspended. One important achievement which contributed a great deal to the relative independence of Japanese civilization, and which was done about the same time, was the invention of Kana letters. Already in the 8th century Kanji, i.e., Chinese ideographic letters were used as phonetic letters for expressing the pronunciation of proper names as well as poetry and songs in Japanese. It was later called Manyo Kana. However, Kanji was inconvenient for this purpose, because most of them were too complicated. Two types of Kana, i.e., Katakana and Hirakana were invented by greatly abbreviating some of the letters used as Manyo Kana. It is clear that this played a decisive role in the creation of characteristically Japanese literature including tales, novels and diaries, many of which were written by ladies of middle or lower class in the aristocracy. On the contrary, the effect of the invention of Kana on the development of science and technology was not conspicuous, because the books on calendar, mathematics, medicine and pharmacy continued to be written without using Kana. It took a long time until Kana was used for the dissemination of knowledge on science and technology.

Now, skipping many pages of the advancement or stagnation in science and technology in Japan, let us go down to the Edo period which began from around

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1600. As will be shown later, there was considerable progress in such branches as mathematics and medicine. However, the Tokugawa shogunate government has been adopting the policy of isolation from the external world, except for the intercourse with China, Korea and Netherlands through Nagasaki. It was only about two hundred years ago that the Japanese intellectuals have begun to recognize the excellence of Western science and technology. It was often stated by science historians that the translation into Japanese of a book on anatomy in Dutch in 1774 by medical doctors, who were amazed by its preciseness in comparison with the traditional Chinese and Japanese account on anatomy was the beginning of the wholehearted acceptance of Western science and technology. However, the isolation policy continued until 1858 when the government was compelled to open ports first to the United States and then to European powers. This was the time when the advancement of modern science in the Western world was at high pace. Many of the better informed intellectuals in Japan have become keenly aware of the superiority of military power of the West over Japan by this time and the Japanese people was shocked by the appearance in Bay of Tokyo of the United States fleet commanded by Commodore Perry in 1853. Thus the acceptance of modern science and technology was considered to be urgent, above all, for the purpose of defense of Japanese coast, as exemplified by the establishment of naval school in Nagasaki in 1855. However, this was not the only response. I am inclined to think that the innate curiosity of Japanese people about scientific devices as indicated by the following episode seems to have contributed even more to the rapid dissemination and advancement of modern science and technology in Japan in these hundred years. When Commodore Perry came to Japan next year for the second time he presented to the shogunate government a model of locomotive equipped with steam engine and the telegraph in order to demonstrate the most recent achievements in science and technology. Japanese officials and workers were very curious and enthusiastic about helping set-up of them. Moreover, all the Japanese audience assembled there were

H. Yukawa, a calligrapher, at his home, in 1962.

rejoiced with amazement by looking at the motion of the model locomotive. Their response was similar when the communication by telegraph was successful. It was only a little more than twenty years since the first railway had appeared in England and the telegraphy had been invented by Morse in America.

I would like to add another incident which occurred in the same period of time. Yukichi Fukuzawa, who has later become an eminent educator and one of the most influential opinion leaders in enlightening the public, was 23 or 24 years old in 1856 or 57 and the head master of a private school in Dutch in Osaka. The principal of the school was Koan Ogata, a famous medical doctor. One day Ogata brought back a book in Dutch, which he borrowed from a feudal lord. Fukuzawa looked at it and immediately noticed that it was an up-to-date book on physics. It was very much advanced in comparison with other books on physics in Dutch, which were currently used at the school. The book, however, was to be returned to the feudal lord by the end of his few days stay in Osaka. Moreover, the book was too much expensive for them to buy, even if they could find another print. So Fukuzawa decided to copy quickly the whole book with collaboration of his pupil. They were all absorbed in the novelty of the content, in particular, of the exposition of Faraday's researches on electricity and magnetism, which was quite different from that of already familiar subjects such as frictional, Galvanic and Voltaic electricity. This was again twenty years after Faraday had constructed his theory of electricity and magnetism. Although Fukuzawa has not become a physicist himself, he remembered clearly this incident for many years and seems to have kept the following conviction throughout his life: According to him, the crucial difference between the modern civilization and the traditional Chinese and Japanese culture originates in the presence and absence of physics. He defined physics as the knowledge of number, shape, properties and functions of matter based on mathematically formulated laws of nature including the utilization of such knowledge on matter. He argues that the truth in physics is universal and timeless, while ideas and logic in shapeless things are controversial and change with time and place. Thus he grasped essential character of modern science as represented by philosophy of Descartes and physics of Newton more clearly than most of Japanese scientists of his time. According to his opinion, it was fortunate for Japan that the Dutch scholars including himself lay emphasis on learning physics. He was born in 1834 as the youngest son of a low class samurai of a small feudal clan. He grew up in horrible stagnation of environment under strict clan system. It was unbearable to him that a man however capable could never be promoted to a rank higher than the rank destined by birth. He was taught in his boyhood Chinese classics as was customary among samurai families. To him, the teaching of Chinese classics seemed to be inseparably connected with the absurdity of the clan system. This was the main reason, judging from what he wrote, why he has come to believe so completely in the Western democracy as well as in the rationality of modern science. He inaugurated a private Dutch school in 1858 in Tokyo and soon afterwards he had the chance to visit the United States and Europe as one of the retainers of the mission of the shogunate government[1]. His school could survive until after Meiji restoration as Keio Gijuku, which has grown up to be the oldest of the private universities in Japan. However, he has not become a professional scholar or a scientist himself. He was typical man of the age of enlightenment in Japan. The new government established in 1868 in Tokyo after the Meiji restoration was very anxious from its beginning to transplant all sorts of things related to modern science and technology. Among other things, conspicuous number of scientists and technicians were invited from abroad in early years of Meiji. Also the government sent students to universities in Europe and the United States. University of Tokyo was established as the first national university in 1877 and various scientific societies including Imperial Academy have begun to appear in succession.

All this, however, was achieved at the cost of the decline of the branches of science which flourished during Tokugawa period. One of them was Wasan, i.e., Japanese mathematics, which was at its peak in the later years of 17th century. As a matter of fact, Chinese books on mathematics had been brought to Japan from around 6th century mostly through Korea. However, it was as late as the early years of 17th century that Japanese mathematicians began to publish books of their own. However according to experts in history of mathematics, Takakazu Seki was the real originator of Wasan. He lived through the latter half of the 17th century. He succeeded in constructing and solving simultaneous algebraic equations which previous Chinese and Japanese mathematicians never thought of. It was a pity that Wasan disappeared very soon after the time, when the government decided to exclude Wasan from the course of general education in 1872. We can think of several reasons for its rapid decline. One obvious reason is that the books written by Wasan mathematicians, solely by using Kanji was hard to understand. What written in them is, in many cases, like a cryptograph which needs decoding by experts. Another

H. Yukawa reading a book put on a lacquered bookrack presented by his former students at the occasion of his retirement from Kyoto University, in 1972.

reason, which is intimately related with it, is the absence of the general formula and general method to reach it. Wasan mathematicians concentrated their effort to solve specific numerical problems. Only the experts in the history of Wasan could find out the significance and originality of works by such a mathematician as Seki. Thus Wasan has become more and more discipline isolated from branches of sciences. This may be one of the reasons why Baien Miura, who was an original natural philosopher of 18th century, had no contact with mathematics, so that he could not reach anything comparable with natural philosophy of Descartes and Newton.

Situation was somewhat different in medicine. As mentioned already, Japanese physicians have begun to adopt Dutch medicine in addition to Kampo, i.e., traditional Chinese medicine, since 18th century. It was in 1805 that Seishu Hanaoka succeeded for the first time in the world in the operation of mammary cancer under the anesthetic which he invented. The operation was done in Dutch style, but the anesthetic was a mixture of Kampo drugs. In the last decade of Tokugawa period (1858–1867) Dutch medicine was officially recognized. When University of Tokyo was established by Meiji government as mentioned above, a heated argument as to whether the so-called Japanese-Chinese school of medicine was to be included in addition to the Western medicine in the course of University of Tokyo. The debate ended with the complete defeat of the traditional medicine. Since then, Kampo could survive only as folk remedies. It is to be noticed, however, that Kampo has been reviving noticeably since Japan entered into diplomatic relation with the People's Republic of China two years ago.

Now the period of preparation for the independent scientific researches lasted more than ten years since the establishment of University of Tokyo, until the original works have begun to appear in different branches of science from around 1890. During the period of about thirty years between 1890 and 1920, there were many achievements in various branches of sciences. I can mention only very few of them: In physics, Hantaro Nagaoka and Kotaro Honda were the two outstanding figures. As for Nagaoka, I shall come back later. Kotaro Honda is well known by his works on ferromagnetism and other properties of metals. He established Institute of Metals in Tohoku University which was the third oldest national university next to Kyoto University. Honda was an excellent organizer and brought up many scientists, with whom he produced important achievements. In Tohoku University, there was a strong group of physics at this time. Among them was a theoretical physicist, Jun Ishiwara who studied theory of relativity under the guidance of Einstein and contributed to the progress of quantum theory in its early stage. His influences to theoretical physicists of the next generation including

[1] *(The Guest Editor's footnote.) In the next year, 1859, of the opening of his Dutch school, Fukuzawa, inspecting the newly opened port of Yokohama, decided to change his Dutch school for an English school. He visited USA in 1860 and 1867, and Europre in 1862.*

Yoshio Nishina and H. Yukawa in 1950.

myself are not to be overlooked.

In chemistry, among many others, I only refer to Umetaro Suzuki who succeeded in producing vitamin B_1 in 1910. This was the first discovery of the vitamins. In medicine, the artificial production of cancer in the laboratory animal was achieved by Katsusaburo Yamagiwa in 1915 for the first time in the world. Since I am not at all sure about which of the achievements in various branches is to be mentioned, further I stop here and come back again to physics.

Hantaro Nagaoka who has later become the leading physicist in Japan, was five years senior to Honda and started experimental researches on magnetostriction in 1888, when he was a student of graduate school of physics in University of Tokyo. He obtained a number of new results and continued his work on magnetostriction during his stay in Germany for three years from 1893. He was invited to talk on magnetostriction at the first international congress on physics which was held in Paris in 1900. This encouraged his colleagues as the international recognition of his work on a current topic in physics. Nagaoka himself, however, had the keen sense that it was just the time of revolution in physics. He was impressed by meeting on this occasion many of the leading physicists in Europe. After coming back to Japan he proposed and atomic model in 1903. Since there is not enough time to go into details of the model itself and the background of his idea, I leave them to biography of Nagaoka by Itakura, Kimura and Yagi published last year [2]. I would like only to mention that the atmosphere of academic circle in Japan at that time was not favorable to him in continuing such an ambitious theoretical pursuit as his. In later years, he seems to have expected that the younger generation would go further into the direction which he had to stop midway. As a matter of fact, I had the chance to listen to his popular lecture in 1926, entitled "Physics, Past and Present", when I was 19 years old and few months after entering Kyoto University. He was 60 years old, just retired from University of Tokyo, but his youthful enthusiasm impressed me a great deal. This was just the time of advent of quantum mechanics and the world of physicists was in the state of Sturm und Drang. I made up my mind to study as many papers related to quantum mechanics as possible and as quickly as possible. These were mostly written by a host of young physicists in Europe and appeared in rapid succession. During the short period between 1928 and 1930, a number of Japanese physicists who had the chance to stay in Europe came back home and contributed to disseminate quantum mechanics. Among them, Yoshio Nishina stayed for several years in Copenhagen, when Heisenberg, Dirac and many other brilliant young physicists have been very active in creating and developing quantum mechanics under the leadership of Niels Bohr, to which Nishina also contributed. In the same period, such European physicists as Sommerfeld, Heisenberg and Dirac visited Japan and gave lectures. All this stimulated us a great deal. In Kyoto University, in particular, there were Sin-itiro Tomonaga as my class mate and Shoichi Sakata and Mitsuo Taketani who were four years younger than I. They have become later leading theoretical physicists.

The next wave came to Japan in 1932, when great discoveries and inventions appeared in Europe and United States in succession in the field of nuclear physics and cosmic rays. This time we were much better prepared than before. Accelerators of Cockcroft-Walton type and cyclotrons were built in a few years. Thus, in the later years of nineteen-thirties Japan was better equipped with the experimental apparatuses in nuclear physics than any of the Western countries except Untied States. As for theoretical investigations, important works have begun to appear in the same period. In particular, the group in Osaka University, which built only few years ago, contributed greatly to open door to the entirely new world of elementary particles.

The influences of the second world war which ended with two atomic bombs were, of course, very serious and far-reaching. Even if we confine ourselves to science and scientists in Japan, we notice the appearance of various new trends after the War. One of them was that many of Japanese physicists, in particular, we nuclear physicists have begun to take social responsibility seriously and to initiate or participate in the movements for world peace. Another trend was the democratization of community of scientists. The Science Council of Japan which sponsors this Congress was established in 1949. This was the first scientific organization in the world, whose 210 members were elected by the whole body of scientists all over Japan. Democratization went on concurrently in various branches of pure science. To take an example, the so called "Elementary Particle Theory Group" took shape around this time. I do not go into its details here, but would like to leave it to the corresponding chapter in the book "Science and Society in Modern Japan", which was published very recently and contains translation into English of relevant essays by Japanese science historians [3]. It is to be remarked, however, that the community of physicists in Japan used to be more open and less authoritative compared with most other communities since before the war. There were many chances for free discussions among theoretical physicists of different generations belonging to different institutions, thanks to the open-mindedness of the leading senior physicists. At the same time, this was the reflection of the atmosphere of the international community of physicists since the early years of the 20th century.

One of the international trends in science after the War was the change in the style of research. Rapid advancement of nuclear physics since 1932 resulted in the steep rise in both the scale and expenditure of the equipments for experiments. After the War, this tendency was accelerated. Bigger and bigger accelerators for producing particles of higher and higher energies have been constructed one after another. Only the super-power like United States and Soviet Union could afford it. Countries in Western Europe could construct such big machine only as joint enterprise. On the contrary, Japan, unlike the prewar period, was obliged to remain behind in experimental researches in high energy nuclear physics; although theoretical researches continued to be as active as before. In many other branches of science, the trend toward "big science" began to appear. The most conspicuous case was space science.

Another tendency, which is closely related with it and more general than it, is the increase in the size of the team of scientists working together on one subject. This is perhaps inevitable in many cases of experimental research. This is a kind of metamorphosis which occurred in the course of historical development of modern science since 17th century. Most of the contemporary scientists are obliged to work as if they were parts of a machine. For each of them as an individual, it has become increasing more difficult to grasp the significance of what they are doing looked from broader view point. A sense of loss of connection with other human activities deepens and often leads to resignation. He stops asking himself what science is and what it is for. However, this is an irony. Presicely because of the tendencies above mentioned, it has become all the more important scientists to ask themselves the meaning of what they are doing.

Now, let us consider more recent change which began about twenty years ago. One of them was the remarkable progress in biology. As is very well-known, the discovery of double helix structure of DNA in 1953, by Watson and Crick was the starting point of the contemporary molecular biology. This seems rather paradoxical to us physicists for the following reason: As already mentioned, the revolution in physics starting from the advent of guantum theory and relativity theory at the beginning of 20th century worked in the direction to upset more and more seriously the naive realism. Although modern physics since 17th century seems to have distructed the traditional way of understanding matter and motion as represented by Aristotelian physics, the firm belief, in the objective and permanent existence of atomic corpuscles as well as continuous mechanical ether remained until the later years of 19th century. Such a kind of naive realism became untenable in understanding subatomic particles such as electrons and also the nature of light, in particular, since the advent of quantum mechanics. Under these circumstances, it was rather surprising that many of the fundamental properties of living organism turned out to be understood mechanistically on the basis of molecular biology which is, in a sense, an extension of the line of thought connecting Democritus and Descartes. Of course, it should not be mistaken that, if we go further into details of mechanism working inside and between the molecules, we have recourse to quantum mechanics instead of classical physics.

Now, turning back again to physics proper, the new world of elementary particles was opened in the nineteen-thirties as was already mentioned. Since nineteen-forties, more and more unexpected new kinds of particles have been discovered in cosmic rays or created by accelerators. Most of them are extremely unstable, each having very short mean life. Why there are so many different kinds of such particles in Nature? No physicist can give a convincing answer to this question as yet, although there are many attempts at unifying theory of elementary particles. Under these circumstances, I have come to think, since about twenty years ago, that I might be able to take advantage of my inheritance of the way of thinking alien more or less to the West. As a matter of fact, I had been taught from my grandfather great many Chinese classics since from five years of age. This was an unusual experience for the children of my generation. When I was grown up to be 15 years old or so, I found books of Taoists such as "Laotse" and "Chuangtse". They were interesting to me, but I did not have definite intention to be a physicist or a natural philosopher at that time. It was many years later that new interest in these books arose in me. For instance, I was surprised by finding the following sentences in "Chuangtse".

"When a metal worker wanted to cast something, the metal leapt up and said "I am determined to become that finest sword ever made". The metal worker would have thought that he got hold of sinister material. In the same way, we can regard heaven and earth as a great crucible, all things including man as metals and the Creator as a metal worker. Whether man lives or dies, whatever happens, is it not enough? Surely all that matters is to sleep peacefully and refreshed." Evidently, Chuangtse sought to overcome life and death by resort to the metaphor of metal and metal worker. However, I was surprised, because I had been referring metaphorically to the notion of "invisible molds" in order to grasp intuitively the appearance and disappearance of different types of elementary particles.

This may sound to be a mere coincidence, but it is at least, stimulating to reread Laotse and Chuangtse casually [4]. More recently, I was informed that, Professor Needam pointed out the importance of the contribution of Taoists, to science and technology in China [5].

Speaking in this way, I cannot help recalling a story of Hantaro Nagaoka in his youth told by himself in later years. In 1883, when he finished his first year in College of Science of University of Tokyo, he wanted to make up his mind to become a scientist who achieves something in some branch of science. He thought he could not satisfy himself with importing and disseminating modern science. However, it was not clear to him whether the Oriental people were endowed with the ability to be a good scientist. So he decided to absent himself from school for one year in order to find the proof or disproof of the ability of the Orientals by surveying Chinese classics. He found, in several of the books written by ancient Chinese including Chuangtse, scientific discoveries and observations, which were, in some cases, even earlier than those in the West. This relieved him and he returned to school without further doubt. This story may sound very strange, but we must remind the state of scientific research in Japan at the time of his youth. As I mentioned already, original works have not yet appeared from any of the branches of modern science by this time in Japan.

I would like to end up my talk by more general considerations of science today. It is symbolical that 17th century science began with the discovery by Galilei of the law of innertia. According to it, matter is destined to run away to infinity, if it is left free to move. Thenceforth, mathematical concepts of infinitely large and infinitesimally small have been playing an important role in physics and related branches of science. However, none of the actual human undertakings can reach infinity. In recent years, the finiteness of our own earth has become more and more restrictive. It is paradoxical that the main cause for the visitation of such a situation is precisely the development of science and technology. In this respect, Japan is one of the countries, where the restrictions of space, and natural resources as well as the destruction of natural environment are most conspicuous. However, our ancestors had the experiences for more than two hundred years of Edo period to live on almost completely isolated from outside world. So I hope Japanese scientists and engineers would be able to contribute to the solution of environmental problems for ourselves and for mankind as a whole.

In conclusion, I would like to acknowledge indebtedness to 25 volume history of modern science and technology of Japan which was edited by Society of History of Science of Japan [6] in preparing my talk.

REFERENCE

[1] Yoshio S. Hakeda, *Kukai* (Columbia University Press, New York and London, 1972) is to my knowledge the book available in English, although there are great many books on Kukai in Japanese.

[2] K. Itakura, T. Kimura, and E. Yagi, *Biography of Hantaro Nagaoka* (The Asahi Shimbun Company, Tokyo, 1973), in Japanese.

[3] S. Nakayama, D. L. Swain, and E. Yagi, *Science and Society in Modern Japan* (University of Tokyo Press, Tokyo, 1974).

[4] Hideki Yukawa, *Creativity and Intuition* (Kodansha International, Tokyo, New York and San Francisco, 1973).

[5] Joseph Needam, *Science and Civilization in China*, 4 volumes (Cambridge University Press, Great Britain, 1961); Kiyoshi Yabuuchi ed., *Studies on Science and Technology in Mediaeval China* (Kadokawa Shoten, Tokyo, 1963), mostly in Japanese.

[6] Society of History of Science of Japan ed., *History of Science and Technology of Japan*, 25 volumes (Dai-ichi Hoki Publishing Company, Tokyo), in Japanese.

APPENDIX

Correspondence between Roman and Japanese Characters

Compiled by the Guest Editor

Hideki Yukawa	
Saicho	最澄
Kukai	空海
Kobo Daishi	
Manyo Kana	
Tokugawa	
Yukichi Fukuzawa	
Koan Ogata	
Keio Gijuku	
Takakazu Seki	
Wasan	和算
Baien Miura	
Kampo	
Seishu Hanaoka	
Hantaro Nagaoka	
Kotaro Honda	本多光太郎
Jun Ishiwara	
Umetaro Suzuki	
Katsusaburo Yamagiwa	
(Kiyonobu) Itakura	
(Tosaku) Kimura	
(Eri) Yagi	八木（江里）
Yoshio Nishina	仁科芳雄
Sin-itiro Tomonaga	朝永振一郎
Shoichi Sakata	坂田昌一
Mituo Taketani	武谷三男
Kiyoshi Yabuuchi	薮内清

The author wrote Sin-itiro Tomonaga and Mituo Taketani as Shin-itiro Tomonaga and Mitsuo Taketani. In those days some Japanese wrote their own names in plural ways of spelling.