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Yoshio Nishina, the Pioneer of Modern Physics in Japan

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We are gathered here today to celebrate the centennial anniversary of Dr. Yoshio Nishina [1]. He was born one hundred years ago in 1890 in a small village called Satosho near the city of Okayama as the eighth child of a respected family. His grandfather was the local governor of that area. There still remains the old house where he spent his childhood with his parents and family. The house is now restored and is open to the public as a museum to commemorate the great man of whom the village can rightly be proud. I visited the place and was very much impressed by his notebooks, handwritings, and drawings of his schooldays. All are very beautifully done proving that he was extremely bright and was regarded as a genius.

After finishing the local elementary school and the middle school, he entered the sixth national high school at Okayama. The national high school at that time was completely different from high school of today. It was an elite school corresponding to junior college for students proceeding to imperial universities. Nishina must have enjoyed his youth there. He liked to study by himself but was also a sportsman.

After this, Nishina went to Tokyo to have his undergraduate education in the Engineering School of the Tokyo Imperial University. He elected electrical engineering

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as his major and graduated from the Electrical Engineering Department with honors receiving a silver watch from the Emperor.

But Nishina did not want to work in industry as an electrical engineer. He wanted to do something more useful than just engineering and more attractive and worth devoting his unusual talent. He considered electrical engineering as more or less a finished discipline. He thought electrochemistry was more attractive. So he accepted an invitation from Professor Kujirai, who had just started his new laboratory at RIKEN, a newly established research institute for physics and chemistry. This institute was planned taking the Kaiserliche Institut of Germany as a model. So Nishina became a research fellow at RIKEN and concurrently he registered at the graduate school of physics of the the Tokyo Imperial University to study physics under the guidance of Professor Hantaro Nagaoka, who was concurrently a chief researcher at RIKEN holding a laboratory there. Professor Nagaoka was the most influential person in the scientific community of Japan at that time. After three years of studying physics, fortune smiled on him. In the spring of 1921 he was ordered by RIKEN to go to Europe to study physics. This must have been a great encouragement for him. New physics was just being born in Europe. Europe was boiling with expectation of new ideas and new discoveries. This lucky event matched his talent and ambition. Fate made him stay in Europe for seven years, which he himself probably did not originally plan. This transformed him into a first rate physicist, which would not have been really possible if he had remained in Japan.

Nishina went first to Cambridge because Nagaoka introduced him to Rutherford. He stayed at the Cavendish Laboratory and performed some experiments on Compton scattering, which were not so successful but gave him valuable experience for his later studies. Nishina eagerly wished to work with Niels Bohr at Copenhagen and asked Bohr if this was possible. Bohr was kind enough to accept him at his Institute. So Nishina was able to move to Copenhagen in 1923. There Nishina started working on the X-ray spectroscopy of atoms under Hevesy's guidance, and soon was able to publish his first scientific paper [2] on the X-ray absorption spectra in the L-series of the elements La(57) to Hf(72) with the co-authorship of Coster and Werner. He continued the X-ray work after both Hevesy and Coster left Copenhagen and became the leader of the X-ray spectroscopy group. Indeed, Nishina made significant contributions in this field [3]. This was from 1923 to 1926, just the period when new quantum mechanics was rapidly developing. Copenhagen was the center of the revolution. Niels Bohr was the leader at revolution surrounded by its stars. There was great excitement every day. How happy Nishina was to be at the very center of this great revolution and close to the great leader and brilliant young pioneers. This excitement is vividly seen in Nishina's notes kept in the archives of the Nishina Memorial Foundation.

However, Nishina had already stayed in Copenhagen for quite a long time. The grant from RIKEN was already discontinued. His expenses were supported by his relatives at home. Also, Bohr was kind enough to arrange a grant from the Danish Government which lasted for three years. It was about time for Nishina to return home. But he wanted to do something significant in theoretical physics which he could bring back to Japan after staying so many years at the center of theoretical

physics of the world. Indeed, Nishina had been interested in theoretical physics ever since the time he turned to physics. Before coming to Copenhagen, he attended in Goettingen the lectures by Born and Hilbert. Now he wished to study theory more seriously. So he went to Hamburg in February of 1928 to study under Pauli and there he worked out a theoretical paper in collaboration with Rabi [4].

Coming back to Copenhagen he decided to take up a new problem. He thus chose the theory of Compton scattering for which he had kept a great interest for many years. The new theory is based on the Dirac theory of relativistic quantum mechanics. The method of calculation had not been so well established at that time, so the calculation was by no means easy. He started working on this problem in cooperation with Oscar Klein from the spring of 1928, and was able to finish the work [5] in the summer. The Klein-Nishina formula thus obtained is really a gem of quantum mechanics to be remembered in history. I do not dwell on this topic any further, because Professor Ekspong will talk on this subject.

So Nishina finally left Copenhagen in October, 1928, cherishing the happy memory of the time spent at Copenhagen with Niels Bohr and many physicists who were fated to carry on the further revolution of modern science. He returned home in December of that year after making visits to several places in the United States.

Having returned to Japan, he joined Nagaoka's group at RIKEN. He must have felt like Urashima Taro or like Rip Van Winkle after so many years of absence from his mother country. There tooOokouchi , science had been progressing, but the atmosphere of the society was not yet as mature as in advanced countries. He had to be patient to realize his ambitions. It took a few more years until he was promoted to a chief researcher in RIKEN and in 1931 he started to build his own laboratory.

Fig. 2.1 Nishina at Copenhagen, with his friends. 1925. From left to right : Nishina, Dennison (USA), Kuhn (Switzerland), Kronig (Holland), Ray (India)

It was very fortunate that in 1929 he was able to invite Heisenberg and Dirac who accepted the invitation to come to Japan on their way back to Europe from America. Their visit gave great excitement to Japanese physicists, particularly to the younger generation. Nishina made a great effort to arrange their visit, to help the audience to understand their lectures. All of this made Nishina's presence more impressive among his Japanese colleagues. He was invited to the universities at Kyoto and Hokkaido to lecture on the new quantum mechanics. At Kyoto he met two young physics students, who regarded Nishina as their teacher and later became to play the role of his successor and to lead modern physics in Japan. They were Hideki Yukawa and Sin-itiro Tomonaga.

In 1931, Nishina started his laboratory. As the subjects of his research program he chose

(1) quantum mechanics,
(2) nuclear physics,
(3) studies of atoms and molecules by X-ray spectroscopy,
(4) use of spectroscopy for chemical analysis and its applications.

The list was revised the following year. The items (3) and (4) were replaced by

(5) study of cosmic rays,
(6) generation of high energy proton beams.

This list shows what Nishina intended to develop in Japan, in order to bring its science from the state of an undeveloped country to that of advanced societies like Europe and America.

It was fortunate for Nishina that he was able to build up his laboratory in a relatively short time. This was only possible because RIKEN at that time was a unique institution. It was very young, less than fifteen years old, and was an entirely new system independent of the government and existing universities. Originally it was planned to raise money for research from industry, which naturally turned out to be unsuccessful. Dr. M. Ookouchi, the third president of RIKEN was an eminent administrator. He created a number of companies to use the inventions made by RIKEN researchers. Many of these companies were very successful and brought a considerable amount of research money back into RIKEN laboratories. Dr. M. Ookouchi used to tell his researchers not to worry about money but only about their work. Therefore RIKEN had an extremely active atmosphere and it was called the paradise of researchers. It is said that Nishina's spending was always much more than his budget. Universities at that time were extremely poor regarding research money. Thus we see Nishina's projects progressed unusually fast with the strong support of RIKEN. Nishina was able to recruit brilliant young researchers so that his laboratory grew up very fast. The number of researchers at its maximum exceeded one hundred. A laboratory of this size was never possible in a university or in any other institute.

Let us now survey briefly how Nishina actually proceeded to achieve his objectives. Apparently he greatly emphasized theoretical physics. Fortunately, he was

able to invite very able young researchers to his group. They were Sin-Ichiro Tomonaga, Shoichi Sakata, Minoru Kobayashi, Hidehiko Tamaki and others. Yukawa was not in this group for he joined the new science faculty of Osaka University, but he kept up good contact with Nishina's group. Nishina himself was not able to do theoretical work as much as he probably wished, because his main efforts turned soon to experimental work. But in collaboration with Tomonaga and Sakata he studied pair creation probabilities by photons [6]. As Prof. Kobayashi recollects, Nishina guided the research work in much the same way as that in Copenhagen. Namely, discussions between researchers were regarded as most important. This style of work was new among the Japanese researchers at that time. Like Bohr, Nishina was able to encourage and train younger researchers. Tomonaga writes in one of his recollections, that he often became pessimistic about whether he was talented enough to do theoretical physics and it would be better to quit. But every time, Nishina warmly encouraged him to recover confidence in his ability. Yukawa also recalls Nishina being like his loving father. When Yukawa got the idea of the meson mediating the nuclear forces [7], Nishina was one of the few who immediately recognized its importance and gave the strongest support. Although the theoretical group of Nishina's laboratory was not so big, it was the most active in Japan and was influential in developing the quantum theory in Japan.

Nishina regarded cosmic ray research as the key subject to start new experimental physics. With a few members of the laboratory he was able to improve the counters and cloud chambers and set up observatories at various places like the top of Mt. Fuji, Shimizu Tunnel and so forth. Great excitement occurred with the finding [7] of a track in 1938 a little later than that made by Anderson, and Neddermeyer which was supposed to be the evidence of a Yukawa particle but later was proved to be another kind of new particle now called a muon. Nishina's group conducted a considerable amount of work in cosmic ray physics and laid the foundation of a strong tradition of cosmic ray research in Japan [8].

However, the greatest effort of Nishina was related to starting up nuclear physics in Japan, and in particular to the construction of cyclotrons. From 1930, the frontier of physics had shifted to nuclear physics with the use of various kinds of accelerators. In 1935, RIKEN decided to start a nuclear physics program with the cooperation of Nishina and Nishikawa Laboratories. A small cyclotron with a 23 ton electromagnet was successfully constructed by the Nishina group in 1937 [9]. Using this, the researchers irradiated all kinds of elements by fast neutrons. This was important work in nuclear physics. Beside this, radio-biological studies were initiated in Nishina's group by a team of biologists in cooperation with physicists and chemists [10]. This belongs to the earliest work of radio-biology. Thus, Nishina is regarded as one of the pioneers in this field.

The small cyclotron was successful, but it did not satisfy Nishina's ambition. He wanted to build a large cyclotron, about ten times as large as the small one. Through Dr. Sagane, the son of Prof. Nagaoka, a young member of the Nishina laboratory, Nishina learned that Lawrence at Berkeley was considering a project similar to his idea. So cooperation began between Nishina and Lawrence with a deep friendship between two physicists who had never seen each other before. By this cooperation,

Nishina was able to buy a big electromagnet from an American company, which was the same make as that used by Lawrence. Unfortunately, however, the construction thereafter met great difficulties. It took much longer than Nishina expected. The difficulties were even bigger, since Japan was in the war by this time. Nishina did not give up the project. After great effort, the beam finally came out of the big cyclotron in February 1944. Although it was behind Lawrence by more than three years, this cyclotron was the second biggest in the world when it started to operate, of which Nishina had a right to be proud. When he left home for Europe in 1923, there was no nuclear physics at all in Japan, which was far behind in modern physics. But now he was happy to have put his country in second place, behind the United States. However, the story of the large cyclotron was a tragedy, to which I shall come back later.

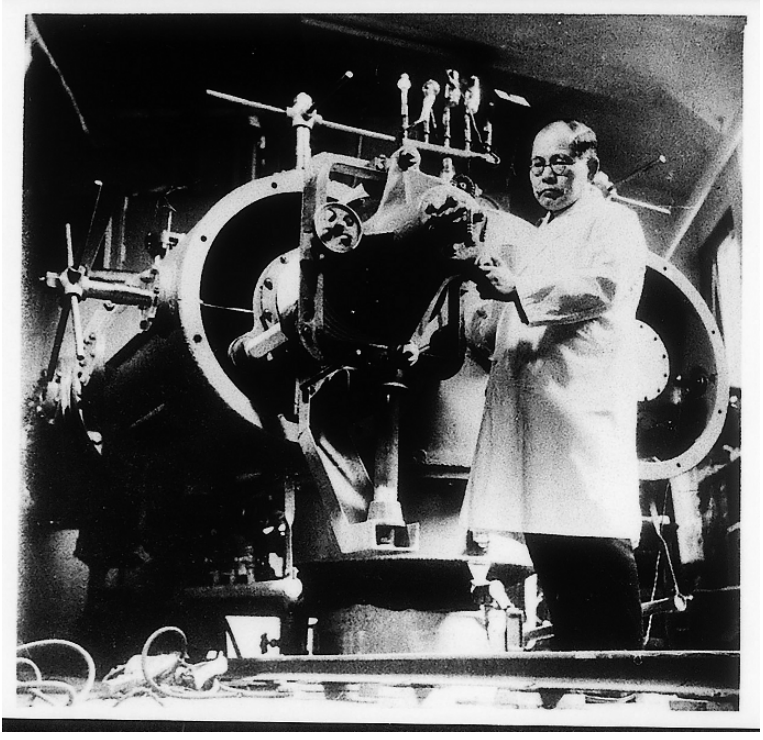

Fig. 2.2 Nishina standing in front of the ”large cyclotron”, 1943

In 1937, Niels Bohr visited Japan with his family in response to Nishina’s long-standing invitation, and gave great encouragement to Japanese scientists. It was almost the last days of the happy time, because Japan was becoming internationally isolated by her militaristic policies, finally rushing into the reckless war. During the wartime, Nishina’s group had to engage in the project to develop the nuclear bomb. The scale of the project was nothing compared to the Manhattan project and the

researchers concluded that it was impossible to produce a nuclear bomb within fifty years. Japan was already losing the war then, and finally there came the disasters of Hiroshima and Nagasaki. Nishina was sent there to investigate if the bombs were really atomic. His report must have been a decisive factor in the political leaders' final decision to surrender.

When the war came to an end, there was almost nothing left of Nishina's ten years' work. His laboratory at RIKEN was bombed and the small cyclotron was burnt. The big cyclotron fortunately escaped the damage. A few months after the surrender, the American occupation army came into Nishina's laboratory unexpectedly, broke the machine and sank it in the Tokyo Bay. Later the Secretary of War admitted that the destruction was a mistake by the War Department of the US Government. Even if it was an unfortunate accident, it still discouraged Nishina from resuming his scientific activities. However, this was just the beginning of the disaster.

Fig. 2.3 Professor N. Bohr and Mrs. Bohr, visiting Japan, 1937, at a garden party at Takamine's home

The following year, in 1946, RIKEN itself was ordered by the Occupation Force to dissolve. The RIKEN family of companies supporting RIKEN, namely the RIKEN CONCERN was considered as something similar to zaibatu, undesirable for demilitarization of the Japanese economy. So RIKEN had to seek some way of living by itself. Since Nishina was the most distinguished among the remaining senior researchers, he had to take the full responsibility for reconstructing RIKEN from its fragments. Thus he had to give up science to become an administrator to earn money for the researchers, pay their salaries, and research money. In the postwar economy in complete social disorder, the task was difficult beyond our imagination.

After a great struggle and great efforts, he managed to create a company with the name of RIKEN Co. He managed to construct a production line of penicillin within RIKEN, which was fairly successful at supporting financially the research activities at RIKEN. He became the president of the RIKEN company. Thus he saved RIKEN from collapse. If there were no Nishina, RIKEN would not have survived.

The great effort of Nishina to reconstruct RIKEN out of disaster was a part of his sacrifice to save his country . He felt very strongly his responsibility as the most influential leader in science. Building up of science and technology was the slogan of the Japanese to reconstruct the country from ashes. So he was obliged to extend his activities beyond RIKEN to the problems of the whole country. When the Science Council of Japan started in 1948, he was elected a member of the Council and then took up the responsibility of Vice-Presidency. In order to restore scientific international cooperation, he was sent by the Science Council to the General Assembly of ICSU which took place in Copenhagen in 1949. Reunion with Niels Bohr and his family was the greatest pleasure after such terrible years. The year of 1950 brought him happy news. Through the good will of American scientists, particularly Dr. Harry C. Kelly, who was a science adviser at the General Head Quarters of the Occupation Army doing his best to encourage Japanese scientists, the import of radioactive isotopes was made possible. Although the cyclotrons were lost by the war, Nishina now was able to start radio-isotope work, to encourage his fellow researchers to start working in many important fields of physics, chemistry, medicine and biology.

Unfortunately, his health was already deteriorating through overwork. It was January 10th of 1951 when he closed his 60 years' life of dedication to science and his beloved country.

Dr. Nishina died too early. In the forty years after his death, Japan has changed greatly. If not to our own satisfaction, modern science and technology have made enormous progress in Japan. Even though the number of Nobel laureates is still too small among the Japanese, the basic level of its modern science is ranked highly with the most advanced countries. And Japan's advanced technology in application to modern industries is very remarkable. What would Nishina say, if he was still alive and saw today's Japan?

Nishina lived a life in a transient era of history that was most drastic and dramatic. It was the time when quantum theory cast off the older skin of classical physics, and atomic physics shifted to nuclear physics. Older concepts were revolutionized by new concepts. When Nishina started studying physics, Japan was only a developing country in the far east, far apart from the center of western civilization and the center of science revolution.

Although Japan's physics was steadily progressing before Nishina's homecoming, as is shown by some significant achievements by Japanese physicists in the 1920's, for instance, in X-ray crystallography, atomic spectroscopy, and electron diffraction experiments, the geographic distance and still backward technological level were great barriers hindering its ability to catch up with physics in the advanced West. Nishina was the right person with the destiny to bridge the gap between the older Japan before 1920 and the modern Japan after 1930. His role could

be compared to that of Rabi and Oppenheimer in the United States. In fact, the growth of Japanese science and technology in the 1930's was remarkable. Industries were growing. National universities were created. Higher education was leveling up. Nishina was destined to lead modern science in Japan. As he might have foreseen when he chose physics after studying electrical engineering, he was successful in his pursuit of his objectives. If it had not rushed into the reckless war, Japan would have been able to attain a reasonably advanced level of modern sciences by the 1950's before Nishina's untimely death.

It is useless to talk about a historical if. But I only mentioned this to remember the great man with unusual talent who devoted his whole life to science and to his country.

Thank you very much for your attention.

Fig. 2.4 Professor Ryogo Kubo giving an opening address at the Yoshio Nishina Centennial Symposium in Tokyo (1990)

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