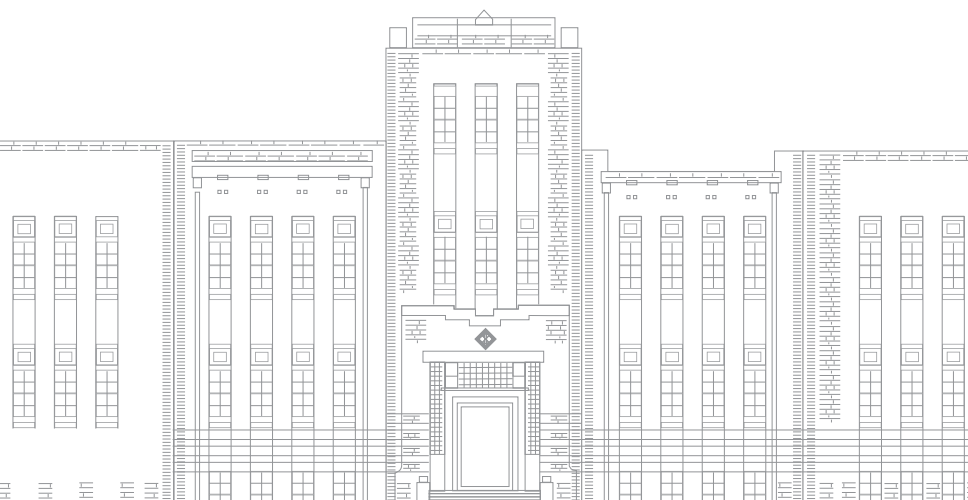


A Century of Discovery

The History of RIKEN



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A Century of Discovery: The History of RIKEN

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Foreword

This book is intended to serve as a document recording the history of RIKEN during its first hundred years, as it moved from its establishment in 1917 as a private foundation to a private company and then finally a public corporation. Today, RIKEN is a major international institute conducting research in a wide area of natural science including nuclear physics, material science, green chemistry, brain science, developmental biology, plant science, genomics, immunology, medicine, computer and computational science, artificial intelligence, and mathematics, with facilities both in Japan and overseas, and a staff of more than 3,000 people. However, there is a long history behind this development.

This book provides both a record of the people who founded and helped RIKEN prosper, as well as insights into some of the important discoveries that were made during its first century.

The bulk of the work on the English version was done in the autumn and winter of 2018, based on the monumental three-volume, 1,500-page Japanese history that was written for the Centennial in 2017. We decided in the

English to focus less on the present structure and more on some of the interesting historical events that have taken place during the institute's history, as well as on the people who crafted the early RIKEN, and have included a significant amount of material on the early years, even though the institute was much smaller at that time and hence did not have the large number of centers and research facilities that we have today. If we were to look at research results alone, the last twenty years or so would clearly provide the bulk of the history.

As an additional note, this book is not an academic work but an organizational history, intended to be a legacy and to provide insights into the RIKEN spirit for our collaborators around the world, and as such it contains at least a portion of hearsay that could be organizational legend but that is nevertheless an important part of our story. However, we should reassure our readers that although this work is not referenced or peer reviewed, we have made efforts when possible to verify the facts that appear.

There are too many people to thank for the production of this work, as many people, both currently and formerly associated with RIKEN, have contributed to the work either through articles written for the Japanese language version or through other work or donations for the centennial celebration. We are grateful for all the contributions that we received in doing this work.

It is perhaps an interesting tidbit that RIKEN has been compared to two creatures, a phoenix and an amoeba. We hope this book will give you insights into why!

—English Language History Editorial Group,
RIKEN Centennial Planning Office

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Part I

The private foundation years

A turning point for Japanese science

The Meiji Restoration of 1868 was a pivotal moment in Japan's history. Following a short civil conflict, known as the Boshin War, the Shogunate that had ruled Japan since the seventeenth century was overthrown and Japan embarked on its journey to become a modern nation-state. Domestically, the domain (*han*) system was abolished and people gained the right to travel freely throughout the country. Industrialization began, and for example, the first railroad began operating in 1872. In terms of foreign relations, along with its efforts to eliminate the unequal treaties that had been imposed by the West at the time of Japan's opening in the 1850s, the new Meiji government recognized the need to adopt modern technologies, and began importing knowledge and science from outside.

Simultaneously, as the 20th century began, the world of science began to undergo a deep transformation as well, moving toward scientific and in particular chemical industry. In line with this change, scientific institutes were being set up around the world, including the

Pasteur Institute in France, which had been established in 1887, the Rockefeller Institute (1901) and the Carnegie Institute (1902) in the United States, and notably for RIKEN's development, the Kaiser Wilhelm Society, which would later become the Max Planck Society, in Germany in 1911. Some of these were very large institutes—the Carnegie Institute, for example, set up by the steel magnate Andrew Carnegie, was founded with a grant of \$10 million US dollars, twenty times the annual budget of the University of Tokyo at the time.



Jokichi Takamine

One Japanese who noted the importance of this change in the world of science was Jokichi Takamine, a chemist who had emigrated to the United States. Takamine, who was also an industrialist, was well known for having isolated the enzyme takadiastase and the hormone adrenalin. In the United States, Takamine is still remembered as the man who financed the gift of the sakura (cherry blossom) trees, which are still growing in Washington, DC, from Japan.

During a trip back to Japan in 1913, Takamine met with Eiichi Shibusawa, a prominent businessman and industrialist who is known as the father of capitalism in Japan, and expressed his concern that Japan was lagging. He proposed that, following the example of other countries in Europe and North America, Japan establish a national research institute for the study of pure science. He felt this was important for allowing Japan to reduce its dependence on foreign technology. Initially, the focus was to be on chemistry.

Shibusawa agreed with the idea, and in the evening of June 23, just a year before the outbreak of World War I, he gathered 120 leading figures from Japan's business world, along with the minister for agriculture and commerce and other government officials, at Sei-yoken, a Western-style restaurant in the Tsukiji district of Tokyo. At the event, Takamine gave a lecture presenting his argument for the establishment of an institute to conduct research in chemistry, which would eventually become RIKEN.



Eiichi Shibusawa

The Birth of RIKEN

The meeting at Seiyoken provided the impetus for the eventual establishment of RIKEN. Despite the initial positive reception to the idea, however, the path to RIKEN's establishment was rocky. In 1914 World War I broke out, leading to a period of economic stagnation for Japanese industry as it lost access to the resources of the West, which were badly needed by the combatants.

Ironically, though this event put a brake on the establishment of RIKEN, it eventually proved to be an impetus for its foundation, because Japan found itself cut off from foreign imports due to the wartime needs of the Western powers, and its elites realized that they needed to gain independence in the area of science and technology.

In March of that year, Shibusawa, the eminent chemist Joji Sakurai and other leaders from various fields petitioned the government for the establishment of an "Institute for Chemical Research." There was initial



Prince Sadanaru

agreement, but the plan was scrapped when the Diet was dissolved. Eventually the founders raised 2 million yen (equivalent to about 1.4 billion yen in 2018) from the private sector, and added a proposal to include physics to the institute's research mission. The proposed name became Rikagaku Kenkyusho, translated literally as the Institute for Physical and Chemical Research.



Dairoku Kikuchi

Three years later, the plan was formally authorized by the minister of agriculture and industry, and RIKEN was founded on March 20, 1917, with headquarters in the Komagome district of Tokyo. In addition to the donations from the private sector, RIKEN also received 100,000 yen each year for ten years from the Imperial Household, and 250,000 yen each year for ten years as a government subsidy.

As mentioned earlier, the Kaiser Wilhelm Society in Germany was a particularly important model for the new institute. Like it, RIKEN was set up with an imperial prince, Prince Sadanaru, as President, and the mathematician Dairoku Kikuchi was appointed to be its first Director. It was set up with two departments, the Department of Physics headed by Hantaro Nagaoka, who will feature heavily in future stories, and a Department of Chemistry headed by Kikunae Ikeda. Interestingly, the constant bickering between these two departments over the control of the institute would become the trigger for the development of a unique structure that would put RIKEN apart from other Japanese research institutions.

RIKEN'S first home

For the first four years of its existence, RIKEN was essentially an institute without a home, as construction of facilities was proceeding slowly due to a lack of funds, and many of its researchers performed their work at laboratories set up within universities where they had joint positions. Initially, the institute lacked sufficient funds to establish facilities for full-fledged research activities. It did manage to acquire land in the Komagome area, with help later on from a donation of land of which 19 percent came from the Iwasaki family, the founders and owners of the Mitsubishi conglomerate, but it still lacked permanent research facilities.

Compounding the fledgling institute's difficulties, the first director Kikuchi died just five months after its establishment, to be replaced by Koi Furuichi, a civil engineer who, in 1875, had become the first overseas student sent by the Ministry of Education, and who is remembered as a bureaucrat who helped improve the state of Japan's ports and harbors.



Komagome

Things took time, but eventually the efforts paid off. The managers of the institute continued their efforts to raise funds, and in 1921, four years behind schedule, the long-awaited No. 1 Building was completed, with two stories plus a basement, and with beautiful red brick walls. The aim of the construction of this building was to create a “temple of modern science,” meaning perhaps more a paradise for scientists, or more particularly chemists, as the first building was to be dedicated to chemistry.

A major role in the construction of the No. 1 Building was played by Setsuro Tamaru, who had returned to Japan from a post in Germany as an assistant to the chemist Fritz Haber and was later to become a chief scientist at RIKEN. The building was modeled on the Institute for Physical and Electrochemistry in Berlin (now the Fritz Haber Institute of the Max Planck Society). The laboratories were state of the art, fitted with vacuum plumbing and high-pressure pipes. Incidentally, the building was built sturdy and withstood the Great Kanto Earthquake of 1923. It stood until 1985, when it was demolished.

This cutting-edge chemistry research building with its German ancestry was full of interesting features. There were marble plates (with a dimension of 60cm×90cm×5cm) fixed horizontally into the walls, some of which survive today to play other roles. There was a library on a mezzanine, a brick draft chamber built into the wall, and at

the top of a spiral staircase a small meeting room with windows on three sides.

Due to the continued financial difficulties, however, work on the critical No. 2 Building, which was to be used for physics, ground to a halt. The initial difficulty in setting up facilities may have played a part in the adoption of one of RIKEN's traditional mottoes, "Research is people." In fact, Hantaro Nagaoka, the first director of its physics division, was fond of saying, "First comes researchers, second comes researchers, third comes researchers, and fourth comes equipment."

Research in physics at RIKEN only began in earnest in 1925 when the new building, with approximately 3,800m² of floor space, was completed. This was eight years after RIKEN had begun, and four years after the No. 1 Building.

Marble plates at Wako

Incidentally, when the No. 1 Building was demolished, the company that owned it at the time donated several marble plates to RIKEN. It was later determined that these plates had been used as bases for chemical balances. One of these plates now stands in front of the RIKEN Headquarter Building, inscribed with a chronology of RIKEN. Two others were inscribed with commemorations of the discovery of the element nihonium, and have been placed in front of RIKEN's headquarters and at the entrance of Wakoshi Station, the nearest railway station to the main campus.

Women pioneers

In addition to its importance for science, the early 20th century was an important period for women in Japan. Japan's traditional feudal society was being transformed into a modern one. However, even at the time of the establishment of RIKEN in 1917, it was very difficult for women to go to university. There was no law prohibiting it, but the imperial universities that had been set up by the government to create elites only allowed men to sit for their exams.

As a result, there was no easy road to a scientific career for women. However, in 1913, one of the imperial universities, Tohoku Imperial University, bucked this trend, allowing women to sit for exams, though it appears that it was due to a lack of students rather than a strong desire to promote women. The minister of education sent the university a letter demanding an explanation, but Tohoku University went ahead with the plan anyway. That year, three women—Chika Kuroda, Raku Makita, and Ume Tange—underwent the exams and all passed. They became Japan's first female university graduates. What is interesting for RIKEN's history is that two of the

three—Kuroda and Tange—ended up working at RIKEN. It seems that hiring these first women scientists was part of the mission of building a new ideal research institute.

Sechi Kato

Sechi Kato, who was not a university graduate at the time she was hired, was the first woman to be employed by RIKEN. She was recruited in 1922 as a trainee. Kato actually began her career as a teacher, a profession that was open to women at the time. She was keen to study, however, and in 1914—at the age of 21—entered Tokyo Women’s Higher Normal School. After graduating, she



Sechi Kato

tried to get a place as a student at Hokkaido Imperial University, but was told that, as a woman, she could only be an auditing student. She did study there, and after completing her studies in 1922, was hired by RIKEN as a trainee. She had two children soon after entering RIKEN, but with the help of her mother-in-law managed, as many women continue to do today, to juggle work and family responsibilities. She was a chemist, and did important work in the field of absorption spectroscopy, trying to understand the makeup of atoms and molecules.

In 1931 she received a doctorate of science from Kyoto Imperial University, becoming the third woman to receive this degree. In 1942, at the height of the war, she was appointed to be a full-fledged research scientist, performing work on airplane fuels. In 1951 she became RIKEN’s first female chief scientist, a position she held until her retirement in 1954.

Michiyo Tsujimura



Michiyo Tsujimura

The second woman to enter RIKEN, Michiyo Tsujimura, was an organic chemist who worked with Umetaro Suzuki, who will be featured later as the pioneer of life science research at RIKEN. She explored chemical compounds such as catechins and tannins in green tea. There was no smooth road to academia for women in those days so, like Kato, she studied at a teaching school and then worked as a teacher for seven years before attending university as an auditing student. After completing her studies she began working in a medical chemistry laboratory at Tokyo Imperial University, but her laboratory was destroyed by the Great Kanto Earthquake of 1923, and she moved to Umetaro Suzuki's laboratory at RIKEN. Suzuki nurtured her as a scientist rather than simply as a technician, and Tsujimura went on later to become the first Japanese woman to earn a doctorate in agricultural science. She was appointed to a research position at RIKEN and later went on to become a professor at the newly established Ochanomizu University, a national university for women.

Chika Kuroda

Chika Kuroda is one of the best known of RIKEN's early women scientists. In 1916, as mentioned earlier, she graduated from the Department of Chemistry in the Faculty of Science at Tohoku Imperial University, becom-

ing one of Japan's three first female bachelors of science.

She was already 29 years old at the time. Before graduating she had, like Kato and Tsujimura before her, studied at a teaching school, and she had worked as an assistant professor at her alma mater in Tokyo, Tokyo Women's Higher Normal School. However, like what happened to Tsujimura, her school's building was destroyed by the Great Kanto



Chika Kuroda

Earthquake, and in 1924 she joined chemist Riko Majima's laboratory at RIKEN. Here she continued her research on natural pigments, determining the molecular structure of shikonin, a purple coloring factor in the root of puccoon (*Lithospermum erythrorhizon*). Later she determined the molecular structure of carthamin, the coloring ingredient in safflower, and for this work received a doctorate of science from Tohoku Imperial University.

During the war she worked to elucidate the constituents of onion skin in the hope of dealing with the food shortages that were plaguing the country, and later concluded that quercetin, a flavonoid found in onions and other plants, had a blood pressure lowering effect. Based on her work, a blood pressure treatment called Quercetin C was put on the market in Japan, in one example of RIKEN's discoveries being put to the service of society.

Ume Tange

The career of Ume Tange, the fourth woman to be hired by RIKEN, and like Kuroda a science college graduate, was similar to her three predecessors. She worked as



Ume Tange

a primary school teacher, and entered Japan Women's College to study chemistry. She worked as a technician in a chemistry laboratory, but decided to apply for entrance at Tohoku Imperial University in 1913 along with Kuroda. She graduated from university at the age of 45, and went on to earn a doctorate in dietetic chemistry from Johns

Hopkins University in the United States. Upon her return to Japan, she continued teaching at her alma mater, and in 1930 entered RIKEN to perform studies on vitamin B2. For this work she earned a doctorate in agriculture from Tokyo Imperial University, giving her a second doctorate.

Of course, even today, women continue to play important roles at RIKEN. In 2016, Masayo Takahashi, a developmental biologist, performed the world's first clinical study using induced pluripotent stem cells, commonly known as iPS cells, in actual patients, in this case a patient with a common type of vision loss called age-related macular degeneration, and Maki Kawai, who served as one of RIKEN's executive directors, is known for the development of spatially selective single-molecule spectroscopy.

At present, approximately 30 percent of RIKEN's scientists are women, and about 11 percent of laboratory leaders are women. An Office for the Promotion of Diversity, which was set up in 2018, is working to develop policies to further widen the road for women in RIKEN.



Surgery using iPS cells

A revolution in physics

RIKEN was established at an opportune time, where a revolution was taking place in the world of physics, and although the work of the early RIKEN was in both chemistry and physics, it is perhaps the physics that is best remembered today. Yoshio Nishina, who later came to play a major role in the institute, serving as its fourth director, was a pioneer of modern physics in Ja-



Yoshio Nishina

pan. After graduating from Tokyo Imperial University with a degree in electrical engineering, he entered RIKEN. In October 1921, he was given a scholarship to travel to the Cavendish Laboratory at Cambridge University, in pursuit of new fields of physics. At Cambridge he studied under Ernest Rutherford. At this time Europe and America were in the calm before the storm brought by Werner Heisenberg's theory of quantum mechanics in 1925.

In March 1922, Nishina, who was 31, met Niels Bohr, who at the age of 36 had also studied under Rutherford and was an up-and-coming physicist at Copenhagen

University. Bohr is known today as the key developer of the model of atomic structure under quantum mechanics. For Nishina, the young genius Bohr was a huge inspiration. This chance meeting between the two determined the course of Nishina's own career and had an enormous impact on Japanese science.

By November, less than six months remained of Nishina's planned sojourn in Europe, but he hoped to stay on longer. With a mixture of optimism and anxiety, Nishina pinned his hopes on a single letter to Bohr, and followed his dreams to Copenhagen.

Nishina's letter read:

— “You may remember that I was working in the Cavendish Laboratory when you came to Cambridge about a year ago ... I left Cambridge last September and came here for the purpose of learning the German language ... As my Institute in Tokio does not allow me to stay in Europe longer than two more terms, I do not know whether it is wise to set up new work. My chief wish is to study your theory of spectra and atomic constitution in details. But if anyone wants assistance in the experiment or the calculation, I should do it with pleasure.”



Bohr in Japan

Upon receiving this letter, Bohr made every effort to secure funding for Nishina's stay in Europe. Fortunately he was able to acquire a scholarship from the Rask-Ørsted Foundation. So Nishina was able to go to Copenhagen and study quantum physics under Bohr for the next five years. It was an exciting place to be, as Bohr had gathered top young physicists from all over the world to

work with him in Copenhagen, including well-known names such as Heisenberg, de Hevesy, Kramers, Pauli, Jordan, Dirac, Klein, Rabi, and Gamow. Bohr's labs did not just debate theoretical physics; they also conducted physical and chemical experiments. Most of these physicists were then in their 20s.

While in Copenhagen, Nishina published a paper together with Oskar Klein describing the emission of photons by electrons under quantum mechanics, and the Klein–Nishina Formula is still important in the world of physics.

In addition to his research work, Nishina absorbed the Copenhagen Spirit—a spirit of cooperation, free debate without ceremony, and commitment with humor—which later had a huge effect on the spirit of science at RIKEN.

Nishina has become known as the father of nuclear physics in Japan, and as part of his work to promote an understanding of the emerging world of quantum mechanics, he was a mentor for two Japanese physicists—Hideki Yukawa and Shinichiro Tomonaga (his first name is often spelled Sin-itiro)—who went on to win Nobel Prizes.



Hideki Yukawa



*Shinichiro
Tomonaga*

Cosmic rays

Upon his return to Japan following his stay in Copenhagen, Nishina dedicated himself to creating an environment in Japan that would be conducive to the study of quantum mechanics. In addition to that focus, his laboratory at

RIKEN was dedicated to the study of cosmic rays and the development of accelerators, which artificially produce high-energy particles like cosmic rays. It is in these fields that his work came to be remembered.

Cosmic rays have an interesting history. In 1912, physicist Victor Hess had brought instruments to a high altitude in a balloon to see if the level of radioactivity would—as was conventionally predicted—fall to lower levels as the balloon rose above the earth, since it would be further away from uranium and other radioactive substances on earth. However, just the opposite happened—the levels rose—and Hess concluded that the radioactivity was due to particles entering the atmosphere from outer space—cosmic rays.

When Nishina established his chief scientist laboratory in 1931, cosmic rays were one of the research topics he adopted. Accelerators were yet to be developed, so cosmic rays, coming from natural accelerators, played an important role in physics, being instrumental in the discovery of important particles such as the proton, pi meson, and muon.

A near victory

In fact, the discovery of the muon is one of the events that gave RIKEN an “almost victory” in an important scientific finding. Nishina’s laboratory discovered the muon independently of the Caltech group led by Carl D. Anderson, who is usually credited with the discovery. In fact, Nishina’s group found it earlier, but the publication by the other group came out first, and in the world of natural science, publication provides priority.

Nishina's group continued to study cosmic rays, in places such as tunnels underground and in Antarctica. In fact, the studies after the war in Antarctica led to a tragic incident in RIKEN's history.

Tragedy in Antarctica

Most scientists at RIKEN have engaged in fairly safe scientific endeavors, analyzing materials or doing experiments with laboratory animals. But Shin Fukushima, who died in Antarctica in October 1960, was an exception. He was studying cosmic rays, a long tradition in RIKEN, and after being hired by RIKEN became a member of the fourth expedition to Japan's Showa Station in Antarctica. He was sent to Antarctica to study changes over time in cosmic rays. But he was never to return. In early October, a blizzard began, disrupting life at Showa Station and other scientific stations.

On the morning of October 10, Fukushima went out with another Japanese team member to feed dogs and check equipment, but the two were separated and Fukushima failed to return. By bad luck, a Belgian team was also experiencing difficulties, and a rescue mission to find Fukushima was sent out, but in the confusion he was not found. His body was finally found on the 17th.

In the postwar period, cosmic ray research continued, mostly with space-based satellites. RIKEN participated, along with NASA, MIT, in the HETE-2 observatory, which was sent to study gamma-ray bursts using ultraviolet, x-ray, and gamma ray instruments. In addition, the MAXI x-ray observatory, which is stationed on the International Space Station and was designed by a group including JAXA

and RIKEN, has been instrumental in discovering new x-ray objects such as black holes. Presently, a group in RIKEN is developing a new instrument, JEM-EUSO, which also from a base on the ISS will use the earth's atmosphere as a giant observatory to detect high-energy cosmic rays entering the earth's atmosphere.

Accelerator science

Another key research project of the Nishina laboratory was the development of accelerators. Accelerators were first developed in the early 20th century to conduct experiments by accelerating atomic particles to extremely high speed and energy, the first one being a device that used a 200,000-volt transformer to accelerate particles with a static electric field. Television cathode ray tubes, which today are largely out of date, are a type of electrostatic accelerator. This work is actually an addition to the study of cosmic rays, which are the products of natural accelerators.

Electrostatic accelerators, while able to emit high-energy particles, do have inherent limitations. At around the same time the earliest accelerators were being developed, another type of accelerator with higher potential, called a cyclotron, was being developed in the United States by Ernest Lawrence, who received the Nobel Prize in Physics in 1939. This type of accelerator accelerates positively charged atomic nuclei as they travel on a circular path guided by an oscillating magnetic field.

Lawrence built the first device in 1932. And in Japan, Nishina soon realized the potential of the device, as it could produce highly energetic particles similar to cosmic rays. He began his own work to develop a device, and in

1937 built a 26-inch cyclotron, the first such machine constructed outside of the United States.

Nishina was not satisfied with the small model. Eventually, he built a second, larger cyclotron, though regrettably, as will be described later, his two early cyclotrons were dismantled and thrown into the sea after the end of World War II.



*Nishina's second
cyclotron*

By 1966, however, a near-recovery had been achieved for RIKEN from the destruction of the war, and from the 1970s accelerator science at RIKEN had begun again to move forwards in leaps and bounds, and emerged on to the world's front lines.

In 1986, the ring cyclotron (RIKEN's fifth device) was completed, under Hiromichi Kamitsubo, one of RIKEN's chief scientists. However, Kamitsubo then entrusted the homestead to Yasushige Yano and turned his energies to the planning of the world's most powerful radiation source, SPring-8. This was treated as a national project, and it involved the Japan Atomic Energy Research Institute as well as RIKEN. SPring-8's completion in 1997 was a spectacular and unparalleled achievement. SPring-8 is a type of accelerator known as a synchrotron, which works by a different principle from a cyclotron. In a synchrotron, electrons are accelerated to high energies in a large ring, and forced to change course by powerful magnets located around the ring. When relativistic electrons change course, they emit powerful x-ray photons that can be used to study protein structure, for example.

SPring-8 is the most powerful radiation source in the world, with an output of 8 GeV (8 billion electron volts).

The facility is literally built around a mountain, a location that gives it stability even in earthquake-prone Japan.

Before the development of SPring-8, however, back in 1981, RIKEN had already built another type of device, a heavy-ion linear accelerator called RILAC. A linear accelerator is an instrument that drives charged particles down a straight beam, and the particles can then be collided into targets to produce nuclear reactions.

Built by Chief Scientist Masatoshi Odera, RILAC was the world's first variable-frequency heavy ion linear accelerator. The 1973 oil shock caused prices to jump, and it was judged impossible to complete RILAC within the total budget of 1.2 billion yen (US\$4m) that had been decided in 1974. The next year the budget was therefore increased to 2.3 billion yen (US\$8m). In 1990, funding from a supplementary budget was used to add an ECR (electron cyclotron resonance) ion source and thus dramatically increase the beam intensity. This ultimately enabled the discovery of element 113, a story that will be described later.

The RILAC was later used as an injector for a ring cyclotron, and in 2006 it became the first stage of a multi-stage facility, the RI Beam Factory. At the heart of this facility lies the superconducting ring cyclotron, the world's largest cyclotron at 18 meters in diameter and weighing around 8,300 tons — nearly as much as the Eiffel Tower.



SPring-8

A machine shop for a scientific powerhouse

Hantaro Nagaoka was another important pioneering scientist at RIKEN. He is known as the developer of the idea that the atom consists of a nucleus surrounded by a cloud of orbiting electrons, a prediction that was confirmed by Ernest Rutherford in 1911. Nagaoka served as the first director of the physics department at RIKEN, and later came to head a chief scientist laboratory after his retirement from Tokyo Imperial University in 1925. His laboratory carried out work in a number of fields in physics, but he was also instrumental in the creation of a special organization that is characteristic of RIKEN.



Hantaro Nagaoka

This organization was a “machine shop” where scientists and technicians worked to develop new scientific instruments. The shop had its roots in an interesting story involving a young Japanese researcher and a Nobel laureate.

In the latter half of 1920, Nagaoka had gone on his fourth overseas inspection tour. He took with him Nao Ayabe and Chugoro Ono, two technicians who went on to study industrial technology at Harvard and Chicago Universities. Within three years Ono, who had gone to Chicago, was designing and building machinery and apparatus, and he had become an assistant to Albert A. Michelson, who in 1907 had become the first American to win the Nobel Prize in physics.

Michelson was conducting expensive research for a diffraction grating that he planned to use for an experimental verification of Einstein’s theory of relativity. He noticed Ono’s talents and asked him to build several pieces of apparatus for this experiment. Michelson was delighted with Ono’s original apparatus, and when it was set up at the Mount Wilson Observatory in California it produced a large amount of invaluable data. In later years Ono looked back on this time and said, “Our job is to build the machines that scientists need. The success of their research depends on the quality of the machines. So as technicians it is our privilege to work with physicists and contribute to new scientific achievements.”

Nagaoka continued to send young technicians from RIKEN to study in Germany, and before long he had set the course for the machine shop, which he had established, to grow into RIKEN’s scientific instruments production department, which at one point employed 1,000 people. Technology at RIKEN grew up around the famous duo of Ayabe and Ono, and people from many different countries

came to receive training. RIKEN went on to become a “paradise for scientists” with an excellent and pioneering research support system.

Later, the machine shop became a part of Rikagaku Kogyo—which will be described in more detail later—a subsidiary company which held the exclusive license to RIKEN’s patents and other rights and was the core of the RIKEN conglomerate set up in the late 1920s. The machine shop developed a large range of products that were used by scientists all over Japan, and poured its efforts into increasing sales.

However, its facilities were destroyed in the air raids on Tokyo in April 1945, and at the end of the war it was disbanded. After the war the machine shop was reborn, and it continues to produce instruments to support researchers.

Nagaoka’s alchemy

As an interesting aside regarding the early history of physics research at RIKEN, Nagaoka and colleagues published an article in *Nature* in 1924, where they claimed to have transmuted mercury into gold and bismuth using a high-power electrical arc discharge. The work was never confirmed, but interestingly, thanks to accelerators it later became possible to transmute elements, fulfilling the dream of the alchemists. Using an accelerator, Nishina himself may have discovered neptunium, and in 2004, RIKEN scientists used accelerators to discover a new element, nihonium, in a story that will be told later in this book.

Engineering

Thanks to the early work by Nagaoka and the machine shop, RIKEN was able to take a strong position in the field of engineering. The high standard of RIKEN's research was said to be in large part thanks to the excellent work of the technicians behind the scenes.

For instance, in 1926, Keiichi Ebihara developed a new method for manufacturing uniform piston rings. Later, the development of ELID (electrolytic in-process dressing) grinding technology improved the technique for making smooth engine cylinders. In the 1960s, scientists at RIKEN began working on the processing of thin metal sheets, a development that helped promote the development of the Japanese automobile industry. Car bodies seem quite simple to construct, but in fact there were many hurdles to overcome to ensure, for example, that the metal would not crack while being shaped in the press. Thanks to the new techniques, however, car companies gained the ability to put smoother curves onto cars.

Kotaro Honda and KS Steel

Magnetic steel was an important area of early engineering research at RIKEN. Kotaro Honda was one of RIKEN's early scientists, holding laboratories at both RIKEN and Tohoku Imperial University, and he is known today as one of RIKEN's "three taros," along with Umetaro Suzuki and Hantaro Nagaoka. His research focused on metallurgy and magnetism, and he earned great distinction early in his career by inventing a type of magnetic steel known as KS magnetic steel.

Important inventions often arise in response to the sudden need for novel solutions to new problems. In the years after the outbreak of World War I, Japan faced one such problem in coping with painful restrictions on imports of materials from foreign countries such as Germany. The ensuing resource shortages forced Japan to attempt to develop high quality



Kotaro Honda

steel and other metal materials on its own. Honda, who had opened his laboratory at Tohoku Imperial University in 1922, was motivated in his metallurgic study of alloys by this need for new directions in domestic steel production.

Honda's research resulted in his invention in 1917 of KS Steel, a permanent magnetic steel with three times the magnetic resistance of tungsten steel. Japan's position at the forefront of world research on magnets may largely be attributed to the early work of Honda's research team. His subsequent invention in 1933 while serving as a chief scientist at RIKEN of NKS steel, an alloy of iron, aluminum, nickel, cobalt, copper and titanium whose magnetic resistance is several times higher than that of the initial KS steel, brought him further prestige within Japan.

This work, performed by one of RIKEN's three Taros, gave Japanese metallurgy international prestige as being supported by highly advanced academic research and cutting-edge technology allowing the manufacturing of materials of outstanding quality.

It is interesting to note that just recently, engineering has come to the forefront again, with the establishment in 2017 of an Engineering Network within RIKEN to create synergies among laboratories working in this area.

Savior and innovator

Returning to the main story of RIKEN, though scientists continued to do impressive work, as outlined in previous chapters, the financial difficulties of the institute continued. Contributions to RIKEN from the private sector had dried up, and the institute's finances remained in dire straits. The development of its research facilities and administration had faltered. RIKEN was blessed by an environment that would later be described as a "paradise for scientists," but it still lacked a strong financial foundation.

Following the death of the mathematician Dairoku Kikuchi, RIKEN's first director, the directorship had been taken over by the civil engineer Koi Furuichi, but he in turn retired in 1921 due to illness, leaving the organization in a difficult position, including as mentioned earlier the constant disputes between the physics and chemistry departments.

RIKEN remained consistently on the brink of disaster, until in September 1921, Viscount Masatoshi Okochi, then aged 42, was appointed the third director of the institute. Before becoming director of RIKEN, Okochi had been a

researcher at RIKEN and a professor at Tokyo Imperial University, specializing in physics and, more specifically, military engineering. He was also a viscount and a member of the House of Peers. Okochi was a towering figure in Japanese science and technology, such as was said to appear only once in a hundred years. He was an exceptionally cultured man who was well versed in ceramics as well as painting, the tea ceremony, cookery, hunting, and fishing.



Masatoshi Okochi

Why at the tender age of 42 did Okochi agree to become the director of RIKEN as it stood on the brink of doom? Why did he cast caution to the wind and accept, when the position had even been declined by RIKEN's top advisor, Kenjiro Yamakawa, former president of Tokyo, Kyoto, and Kyushu Imperial Universities? Okochi never spoke of his reasons. But his words at his inauguration provide a clue: "I will develop a way of combining scientific research and practice, and work to establish the foundations of industry." This idea articulated by Okochi, together with the spirit of free and creative research that he encouraged, later became known as the RIKEN Spirit, and still lives on today.

Okochi's first act as director was to abolish the warring physics and chemistry departments. In their place, he established a system of independent laboratories doing curiosity-based research. The structure become completely flat, with each chief scientist deciding on the scientific topics the laboratory would pursue. This structure, with low barriers between disciplines and organizations, is

a feature of RIKEN that makes it different from many universities. At the time, there were just 14 laboratories within the institute, doing research principally in areas of physics and chemistry.

The second reform Okochi initiated was to overcome the institute's chronic financial problems by setting up a group of companies, which became known as the "RIKEN Konzern," based on the German phrase for conglomerate, to commercialize discoveries made at RIKEN. The conglomerate symbolized a golden age of the institute, and contained at its height more than sixty companies. The ostensible motive given by its architect was to promote Japanese industry, but the truth was somewhat different. Okochi felt he had a duty to provide for RIKEN. He was unable to ask the government for more money and could not expect any more donations from the private sector. He concluded that RIKEN would have to earn money for research and personnel itself.

The transformation did not go without a hitch, however. In those days RIKEN was a private foundation, and as such it was supposed to work for the public good. For RIKEN to manufacture and sell goods itself raised legal challenges. This was the background against which Okochi persuaded the fifty-seventh meeting of the board of directors to set up a new company to commercialize some of RIKEN's inventions. In this way Okochi attempted to secure a new supply line for the institute.

The initial company established under Okochi's plan, Rikagaku Kogyo—which would become the core of the RIKEN conglomerate—started doing business in 1927. It was literally a trial and error operation. Under Okochi's pioneering management principle of "scientific industry", RIKEN increased its efforts to commercialize patented

inventions. New technologies were created, including synthetic sake, piston rings, and alumite. Through Rikagaku Kogyo, RIKEN set up a succession of new subsidiaries (what we now call “ventures”). Okochi set up many companies, mainly in heavy chemical industry, with a policy of one company per type of business, under a system where the profits of the subsidiaries were returned to RIKEN. Okochi gave himself important positions at most of these companies so that RIKEN could exert a strong influence over them. The private foundation RIKEN was in dire financial straits and had to do whatever was necessary to survive.

By 1935 there were eight companies, in 1936 fifteen, in 1937 thirty-two, and by 1939 there were sixty-three. The company statutes stated that their profits were to be returned to RIKEN as remunerations. In 1940, this revenue from the companies constituted 60% of RIKEN’s gross income and 75% of its research budget.

In addition to these two major reforms, Okochi also managed to persuade the government to increase the funding it gave to RIKEN. But even then the institute’s capital was only 4.15 million yen of the 7 million that it hoped to receive. The rest was made up by the companies under the conglomerate.

Whatever the motivation for its establishment, the “RIKEN Konzern” played a vital role in opening up a new era of science and technology. Several of the companies remain major corporations today, including Ricoh—known worldwide as a manufacturer of copying machines and cameras—and the Konzern made enormous contributions to the development of Japanese industry. It was also the prototype for the venture businesses and universities’ technology licensing organizations that have boomed in recent years. Okochi’s outstanding achievement was

his success in promoting Japanese science and technology as a private citizen in place of the government. In fact, Bowen C. Dees, a physicist who was involved in the Allies' dissolution of RIKEN, wrote in his book on the Japanese recovery that, "No similar institution in the United States attained the status that Riken achieved in Japan during the nearly thirty years previous to the end of World War II, although comparable American institutions have existed for decades" (*The Allied Occupation and Japan's Economic Miracle*).

Contributing to Society

During the years following Okochi's appointment as director in 1921, based on his reforms, the institute's facilities and systems were gradually strengthened, and research was getting on track according to plan.

Meanwhile, in other areas of science, in accordance with the 1886 Imperial University Order, Tokyo University had in 1877 been renamed Tokyo Imperial University. It was followed by Kyoto (1897) and Tohoku (1907) universities. Including Seoul and Taipei, seven Imperial Universities were established, and in 1939 this number rose to nine. But their mission was to "teach and research science and its applications as necessary for the nation". They did not provide for free scientific research.

Under these circumstances, the appearance of RIKEN, whose aim was "research in pure science and its industrial applications", had made an enormous impact on the development of science and technology in Japan. Among the large number of RIKEN chief scientists who concurrently held professorships, many had their labs at RIKEN, but several set up their labs at their universities, and put up signs saying "RIKEN Laboratory". In the prewar years this

was permitted in exceptional cases; RIKEN supplied sufficient funds for research and personnel, and established good collaborative relations with the universities. These and the other dual-post chief scientists had a motto, “Education at university, research at RIKEN,” and they pushed ahead with their vigorous and dynamic research. Thanks to this, RIKEN was able to contribute to the development of science at universities.

In addition to the research, however, it is important to note that RIKEN’s chief scientists in the years after Okochi’s reforms made a series of discoveries that contributed to advances in Japanese industry and standard of living.

Adsole

The first commercial item produced based on RIKEN’s technology was Adsole, a type of coolant. The typical Japanese home is today installed with an average of three air conditioners, keeping air inside cool and dry even through the hot, sweltering heat waves that hit large cities in the summer. A hundred years ago, however, no such air conditioners existed. The country’s first commercial air conditioner was installed in 1923, in the Hogakuza, a movie theatre that was located in central Tokyo. RIKEN played a central role in the creation of this first air conditioner with its invention of Adsole.

Adsole is a desiccant, a substance that absorbs moisture and promotes drying, made from a special type of clay that is highly porous and absorbent. Okochi became convinced this was a material that could be put to use in business, and in 1922, just a year after his appointment, he established a company named Toyo Gas Shikenjo to find commercial applications for Adsole. The first major

application of the desiccant was in the air-conditioner that RIKEN researchers installed in the Hogakuzza—an early movie theater in Tokyo. The system was carefully designed for the 1,000-person capacity of the theater. The popularity of this first air-conditioner in Japan led to further installations of Adsole-based air-conditioning systems at other locations.



Adsole in use

The development of Adsole was carried out by a research group led by Kikunae Ikeda, inventor of monosodium glutamate (MSG), and Hajime Isobe. Toyo Gas Shikenjo, the company created to find commercial applications for Adsole, was RIKEN's first spin-off business and the seed that would grow into the famous RIKEN Konzern.

Alumite

Another hit product from RIKEN during those years was alumite, an oxidized coating that was applied to aluminum to prevent it from rusting. Aluminum is a light-weight and versatile metal, but it is vulnerable to both acids and alkalis. However, a thin oxide film is sufficient to protect it from rusting.

In the 1920s, researchers at RIKEN began to investigate manufacturing an oxide coating for aluminum. In 1924, Tsunetaro Kujirai and Sakae Ueki obtained the first patent on the anodic oxidation coating of aluminum. However the coating was porous and insufficient for protecting the aluminum inside.



Alumite items

The key innovation came from a failure. Akira Miyata, another researcher at RIKEN, was asked to coat a number of aluminum rulers, but the rulers stuck to each other and the coating was not uniform. He tried, without success, to

remove the coating using electrolysis, as the coating that formed between the rulers was not porous and was nonconductive. Further experimentation allowed him to perfect a high-temperature steam treatment with a porous oxide coating, and he named the product alumite. Its shiny and tough coating attracted customers and it was commercialized as a coating.

One popular use of alumite was for *bento* boxes, as it prevented the box from being oxidized by the pickled plums (*umeboshi*) that are typically put on top of rice to prevent it from spoiling. The porous base material also allowed durable coloring by doing the coloring before treatment, making it a suitable base for Japanese lacquer. Naoji Terai, who was awarded at a National Treasure, used alumite for his lacquerware.

RIKEN vitamins

Vitamins B1 and A, which are described later as part of RIKEN's work in the life sciences, are an important part of RIKEN's early history. In fact, they sparked a vitamin boom in Japan and eventually generated enough income to support all of RIKEN's re-



RIKEN vitamin

search activities. Vitamins were in fact the key commercial items that supported RIKEN's research activities in the prewar years. B1 was discovered by Umetaro Suzuki—whose work will be described in more detail later—while doing research to prevent beriberi, a nervous system ailment caused by a deficiency in the vitamin, while Katsumi Takahashi and Suzuki succeeded in isolating and extracting vitamin A from cod liver oil.

RIKEN sake

One of Suzuki's inventions in addition to vitamins was a kind of synthetic Japanese sake—"synthetic" in the sense that it was not made naturally from rice. Instead, it was made by creating a mixture of alcohol made from other cheaper ingredients, with amino acids and flavors added to give it a proper taste. Suzuki's desire to create the synthetic blend came from a sense of crisis over the Rice Riots which took place in 1918—a type of revolt against rising rice prices. Suzuki hoped that by creating a kind of sake that didn't require rice as an ingredient, he could help the prices to remain low. As a bonus, the new blend needed no preservatives.

Piston rings and photographic paper

Two early areas of research and development at RIKEN focused on piston rings and photographic paper. At the time, piston rings, which are a key element of the internal combustion engine, tended to be irregular, making the engines inefficient. RIKEN researchers developed a new



Piston rings

technology to make the piston rings more uniform. Today, a company called Riken Corporation is still a major manufacturer of the rings. Another discovery was a process for making photographic paper. That discovery was also commercialized by the company that today is known as Ricoh, which in addition to copying machine produced cameras and other devices under the Pentax brand name.

Of course, work on technologies that led to commercial products continued after the war. Some of the key inventions of recent years include the compound used in Attack, a well-known Japanese laundry detergent, and an energy drink called VAAM, which was developed based on the amino acid mixture consumed by giant hornets. Another example is Kaligreen, an environmentally friendly pesticide that was developed at RIKEN, and which is now sold around the world.

From chemistry to life sciences

RIKEN's work in the life sciences, which led to the development of the products such as vitamins and synthetic sake, began with the research of the organic chemist Umetaro Suzuki, known as one of RIKEN's "three taros" along with Kotaro Honda and Hantaro Nagaoka. Today, Suzuki is remembered as the name of one of the two large lecture halls on the Wako campus.

Though Suzuki is not terribly famous outside of Japan, he is an important scientific figure, as he actually discovered the first vitamin, which he originally called aberic acid and later called oryzanin. He could have well been remembered as the discoverer of vitamins, but in another "near miss" like the discovery of the muon, a rival, Casimir Funk, published his finding in English and has been generally recognized as the discover of vitamins.

Suzuki was originally involved in the study of amino acids and how they made up proteins, and he succeeded in the difficult task of creating a tripeptide. He did this during a six-year stint studying under Nobel Laureate

Emil Fisher at the University of Berlin. Upon his return to Japan, he took up the study of rice bran, from which he isolated vitamin B1, which is what we call oryzanin today.

The benefits to the human body of vitamins—organic compounds organisms need in small amounts for their nutritional value—are well-known today, as demonstrated by the many dietary supplements on the market. In



Umetaro Suzuki

the early 20th century, however, the term “vitamin” had not yet even been coined, and there remained a great deal of mystery surrounding the existence of such compounds.

Suzuki was the earliest to identify a vitamin with his discovery of oryzanin. The importance of nutrients in preventing beriberi, a nervous system ailment caused by a deficiency in the vitamin, had been recognized earlier, but Suzuki was the first to isolate B1 as the key nutrient for preventing the disease. He published his finding in a Japanese journal and patented the invention. For his work, he was awarded the Culture Order and, later, the First Class Order of the Sacred Treasure by the Emperor.

Suzuki’s contribution to vitamin research, however, did not end with B1. Working at RIKEN with his pupil Katsumi Takahashi, Suzuki later succeeded in isolating and extracting vitamin A from cod liver oil.

He also invented a type of synthetic sake, RIKEN sake, mentioned earlier, which differed from traditional sake in that it was made from materials other than rice and needed no preservatives. The patenting of these and other inventions sparked a vitamin boom in Japan, and generated enough income to support all of RIKEN. This work

led to the establishment of RIKEN Vitamin, a company which still exists today.

A member of Suzuki's laboratory was also responsible for a third "almost discovery" for RIKEN, like the muon. The Suzuki laboratory was performing experiments on feeding mice with amino acids rather than proteins, but unfortunately, the mice died using the mixture that they had created, which they believed contained all the amino acids. But in 1936, Shiro Maeda discovered another amino acid, threonine, which turned out to be the last essential amino acid. Unfortunately for the lab, however, threonine was also found independently by a group led by William Cumming Rose in the United States, and although their research came later, they were able to publish first and are credited with the discovery. Today, the discovery of threonine—regardless of who found it first—has helped many patients recovering from surgery to get proper nutrition.

The Suzuki laboratory was also involved in research on agricultural chemicals using their chemical expertise. In the early 1920s when their work started, Japanese farmers were struggling with the problem of the maize weevil, an insect that feeds on rice and other crops held in storage. Scientists from the laboratory isolated a compound called pyrethrin from a type of chrysanthemum which had been used even in ancient China as an insect repellent. The compound that was isolated from the flower is still used in products around the world to drive away mosquitoes. Here again, though the discovery took place in 1923, a Swiss group that identified the compound in 1924 is usually considered to be the discoverers.

Research continued after Suzuki's death in 1941. In 1948, when RIKEN came back to life from the war as a

private company, the new president, physicist Yoshio Nishina, decided to focus on the production of penicillin as a means to keep the company alive. Using the facilities that had previously been used for the production of synthetic sake, they were able in their first year to become Japan's top producer. However, it did not prove to be very profitable, and the company shifted to the production of streptomycin.

In the 1970s, RIKEN gradually began to move into the life sciences. In 1980, work began toward sequencing the human genome. Between 2000 and 2006, RIKEN was one of the partners in the global Human Genome Sequencing Consortium, and in fact was responsible for five percent of the sequencing done as part of the project, leading to five papers in *Nature* during that period.

Following the success of human genome project, two new RIKEN-led projects were launched in Japan: Protein 3000, which aimed to elucidate the structures of 3000 proteins, and FANTOM, which sought to clarify the functions of genes.

The Protein 3000 project turned out to be groundbreaking, as it allowed scientists to determine the basic patterns that protein forms adopt, and those patterns have not been overturned by subsequent studies.

The FANTOM project took a different approach in omics, looking at the expression of RNA. Its researchers began by creating a catalogue of coding RNA—meaning RNA that is used to create proteins—in the mouse, a common experimental animal, and in the human. A surprising finding of the project is that most of our RNA is actually not used to code proteins. Subsequent work of the project, which is now in its sixth incarnation, has focused on determining the functions of various types of

RNA including promoters, which are important in forming the transcription networks that cause cells to differentiate into different types. The FANTOM project was also, as we will discuss later, an important milestone in RIKEN's internationalization.

Into the long darkness

By the late 1920s, as we have seen, things were looking up for RIKEN. The institute's finances had become stabilized, and it had launched a number of commercial items that provided needed funds. However, the world was heading toward a serious crisis. The 1930s began with a worldwide depression. In a number of countries, fascism began to rear its head, and the political situation became volatile in both the East and West. Beginning with the Manchurian Incident in 1931, Japan embarked upon a path that would ultimately lead to its entry into a worldwide war. The assassination of Prime Minister Tsuyoshi Inukai in 1932 was followed by Japan's withdrawal from the League of Nations, a failed coup d'état in 1936, and then the Marco Polo Bridge Incident, which initiated Japan's full-scale invasion of China. In Europe, World War II began with Germany's invasion of Poland in 1939. And in 1941 Japan launched its fateful attack on Pearl Harbor, triggering the beginning of the Pacific war.

Louis Pasteur famously said, "Science has no borders. But scientists have their own mother countries." Sadly under the circumstances of the time, scientists were bur-

dened with mother countries and were gradually caught up in the war. Inside and outside of Japan, the war cast its shadow on RIKEN's scientists.

After 1935 the venture companies of the "RIKEN Konzern" prospered and grew in number. There were increases in research commissioned by the military and in munitions production, and RIKEN gradually took on a wartime hue. In 1939 there were 46 companies in the conglomerate, and the income from patents provided 60% of RIKEN's total income. By that year, just two years remained before the start of World War II in the Pacific.

Catching the last ship home

In 1939, in the tense days before Britain declared war on Germany, the Japanese embassy in Berlin advised its citizens to go to Hamburg to board the last homeward-bound ship, the Yasukuni Maru. This ship managed to leave safely, and traveled to Bergen, in Norway. It then headed for Japan with 180 people on board. Among its passengers were two RIKEN scientists. One was future Nobel laureate Shinichiro Tomonaga, who was the first student on a Japan-Germany exchange program, and was in his third year working under Werner Heisenberg at the University of Leipzig. When Tomonaga got the message from the embassy, he packed his things in a single night and hurried to Hamburg.

The other was Hideki Yukawa, another future Nobel laureate, who had been the first Japanese person to be invited to talk at the Solvay conference in Brussels. Unfortunately this conference was cancelled, and so Yukawa's meson theory failed to make its appearance on the international stage. It was a coincidence that Japan's first

and second Nobel laureates should have been passengers on the same ship.

The theme of the 8th Solvay Conference was to have been “Elementary particles and their interactions,” and Yukawa’s meson theory should have been its centerpiece. He later wrote, “It was terribly unfortunate that the conference was cancelled. However, my visits to the important scientists, and the conversations I had with them, and my visits to the big research facilities, were most valuable. I got back to Japan safely, with my spirits restored and my desire to do research stronger than ever” (*Obei Ryoko*, “Trips to Europe and America”).

The Yasukuni Maru stopped off in New York. Yukawa disembarked and spent a month traveling across the United States and visiting a large number of eminent physicists, including Einstein, Oppenheimer, and Fermi. But Tomonaga stayed on board and went straight back to Japan. “I was sick of talking foreign languages, so I came home. Dr. Nishina was rather displeased that I didn’t bother to stop off in America,” he wrote in his yearly report. This was typical Tomonaga.

The year 1939 was highly eventful. The physicist Leo Szilard, who was a refugee from the Nazis, told Einstein of his fear that Germany might develop an atomic bomb. In August Einstein wrote to US President Roosevelt to urge the US government to take action. Roosevelt set up a “Uranium Committee,” and in November the US and Britain commenced the top-secret Manhattan Project to build the bomb.

The Ni-go Project

On December 8, 1941, Japan triggered the start of the Pacific war with the attack on Pearl Harbor. The whole world was now at war, with the Allies on one side and the Axis powers (Germany, Italy and Japan) on the other. The United States' Manhattan Project was moving rapidly, with uranium enrichment taking place at Oak Ridge and plutonium production at Hanford. Germany had also started an atomic bomb project, but it was lagging behind. As the fear of world domination by the Nazis began to recede, the Manhattan Project turned to target Japan instead.

In April of the same year, the Japanese army had ordered RIKEN Director Okochi to begin research to investigate the possibility of constructing an atomic bomb. Yoshio Nishina's lab, the Mecca of nuclear physics in Japan, was entrusted with the enrichment of uranium, under the top-secret Ni-go Project. The project took its name from the first syllable of Nishina's name, *ni*, which sounds like the word for "two." As result, the sound could also be interpreted as "the number two project." Nishina had been working day and night on the large cyclotron, and suddenly he was up against a difficult dilemma for a scientist.

Did Nishina make a delicate "compromise with the times", in order that the young Japanese physicists who had at last caught up with the West might not die in vain? The mobilization of nuclear physics to create the ultimate weapon? What were the conflicts and anguish in the depths of Nishina's heart, we will never know.

The investigative team in Hiroshima

By late 1942, the tide of the Pacific War had changed and Japan was in a defensive position on all fronts. By 1944, the United States was carrying out intensive bombing raids on the mainland, and with the fall of Okinawa it was clear that Japan's defeat was only a matter of time. Nazi Germany surrendered to the Allies on May 7, 1945. On July 16, the Manhattan Project successfully tested a plutonium-type atomic bomb at Alamogordo, New Mexico. In the Potsdam Declaration of July 26, the US, Britain and China demanded that Japan surrender. But, following the firm policies of the military, the Japanese government ignored them.

At 8:15 on the morning of August 6 Japanese time, "Little Boy" was dropped on the city of Hiroshima. It was the first ever uranium-type atomic bomb to be detonated. In an instant, Hiroshima was reduced to ashes. The next day, Yoshio Nishina traveled to Hiroshima with an investigative team from the army and navy. From the exposure found on X-ray films at the Red Cross hospital, Nishina concluded that it had been a nuclear explosion. But the Japanese government persisted in its silence, and at 11:02 a.m. on August 9 the plutonium-type bomb "Fat Man" was dropped on Nagasaki. Late that night, the government decided to accept the Potsdam Declaration. Thus the awful nightmare of World War II came to an end.

Part II

The private company years

Back from the abyss

On August 15, 1945, Japan surrendered to the Allies and the long darkness of World War II came to an end. The war had had some terrible effects on RIKEN as well as the rest of Japan. The air raids of April 1945 had destroyed two-thirds of RIKEN's buildings and facilities, including the apparatus used for enriching uranium for the Ni-go Project.

In September 1945, two American teams came to RIKEN to examine the suspected "weapons of mass destruction". They reported that the Ni-go Project's base had been wiped out, and added that research using the cyclotrons should be allowed to continue.

However, in November the US army suddenly decided that the two cyclotrons Nishina had spent ten years building were "facilities for the production of atomic bombs". They were destroyed and cast into the sea. The cyclotrons at Osaka and Kyoto Universities met similar fates. The *New York Times* reported the incident, and stated that many American scientists strongly criticized it and made protests to President Truman.

To avoid any more such wasteful destruction, physicist Harry C. Kelly and several other scientists were sent to Japan to join the occupation forces.

During the seven years of the Allied occupation of Japan, all remaining weapons of war were destroyed, nuclear power and aeronautical science prohibited, and based on the belief that excessive economic concentration had led to the war, the major conglomerates, known as *zaibatsu*, were dissolved. And in the midst of the unprecedented disorder and deprivation, the Japanese empire was transformed into a democracy.

The war had dealt a massive blow to RIKEN, far greater than to the universities and other research institutes. Many scientists overcame their distress and tried to return to their original research, but the operation of RIKEN had been wrecked by the war and the omens for its survival were not good. Masatoshi Okochi, who had led RIKEN through its golden years, was detained at Sugamo Prison as a suspected war criminal. In March 1948, the Allies determined that the RIKEN Konzern was a *zaibatsu*, and dissolved it. They went as far as to determine that RIKEN itself should be broken up.

With this, Okochi's paradise for scientists seemed to have crumbled to the ground. Okochi was never charged for war crimes, but still in 1946 he stood before all the RIKEN employees and announced that, "Since it has come to this, the only way for RIKEN to survive is to ask for financial support from above." With these words, after twenty-five years of efforts in the face of adversity, the elderly leader passed the baton to Yoshio Nishina, and left RIKEN after serving as its director for a quarter century. Okochi died in August 1952, aged 74, and was buried in

Heirin-ji temple, located near RIKEN's current headquarters in Wako.

Yoshio Nishina, the new Director, appealed to the Allies that "RIKEN is essential for the reconstruction of Japan." Kelly and his group agreed with Nishina, and put all their efforts into ensuring the survival of RIKEN.

A friendship that shaped RIKEN's history

During the postwar occupation of Japan, Kelly worked in the Scientific and Technical Division of the Allies' Economic and Scientific Section. Kelly and his colleagues helped set the foundations of post-war Japanese science and technology, for example by establishing the Science Council of Japan.

He was also instrumental to allowing RIKEN to survive, albeit in a new guise as a private company. In the tumultuous period when RIKEN was dissolved and re-established as KAKEN, he met and worked with Yoshio Nishina, who was RIKEN's fourth Director. Despite the discord between the bureaucratic systems of the Allies and the Japanese government, Kelly and Nishina formed a strong relationship of trust, and brought RIKEN back from the abyss into a new existence as KAKEN, a private company. Kelly's youngest staff member, Bowen C. Dees, wrote that their relationship of trust grew gradually into a close friendship that included their families.

In 1949 Kelly returned to the United States, and one year later he was appointed as the vice-president of the new US National Science Foundation. For the next ten years he served as the chairman of the US delegation to the United States-Japan Committee on Scientific Coopera-

tion, and worked for collaboration in science between the two countries. He continued to make great contributions to the revival of Japanese science.

In his speech at the foundation ceremony for the new company, Nishina praised Kelly and expressed deep gratitude for his work. "After twenty months, KAKEN has been founded. This is particularly thanks to the efforts and endeavors of Dr. Kelly. His name should long be remembered in the history of this institute."

Nishina died in 1951 at the age of 61, and Kelly in 1976, aged 67. That summer, a part of Kelly's ashes was transported from North Carolina and buried in Nishina's grave in Tokyo's Tama cemetery. An inscription was written on the gravestone by Seiji Kaya, the president of the University of Tokyo, formerly of the Honda Laboratory at RIKEN and a friend of both Kelly and Nishina. It says simply, "Harry C. Kelly sleeps here."

The private company years

As noted above, RIKEN did manage to survive the chaos of the immediate postwar period. In May 1947 a new constitution was put into effect that renounced war and gave women the vote. Japan regained its independence with the San Francisco Peace Treaty in 1951, and joined the UN in 1956.

It was soon afterwards that RIKEN was allowed to emerge again, like a phoenix, but in the guise of a private company, that was called KAKEN, or Scientific Research Institute Ltd. The new company was founded on March 1, 1948, with Nishina as its first president. Though the organization was set up as a private company, its mission was still to support the development of Japan's science and technology.

As the founding director of the company, Nishina struggled hard to achieve self-reliance through the development of new technology. KAKEN's main products were pharmaceuticals such as penicillin and streptomycin, low pressure oxygen manufacturing apparatus, and various precision measuring instruments.



Pyotr Kapitsa

Nishina knew that the United States had begun cheap steel production using large amounts of oxygen during the war, and he concluded that this technology would be useful given the dire state of Japan's energy supplies, and could also provide a financial base for the institute.

One of Nishina's subordinates, Hidehiko Tamaki, learned about Pyotr Kapitsa's liquid oxygen production method from a paper that had been published in the *Russian Journal of Physics* in 1939. Kapitsa was a world-famous physicist who won the Nobel Prize in 1978 for his work on low-temperature physics. Nishina decided that liquid oxygen should be KAKEN's next big project, to go alongside its research on penicillin production. Tamaki was competent in Russian, so he got the detailed technical documents from the Allied occupation forces and made a report to Nishina.

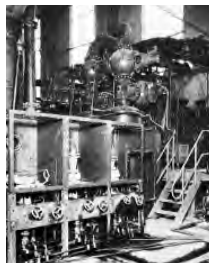
In 1947, Yoshitoshi Oyama's lab, together with the Nishina, Tsuji, Ebihara, and Kuroda labs, began their collaborative research, using funds obtained from KAKEN and a grant from the Ministry of Commerce and Industry. In June 1949 they succeeded in liquefying air, which



Yoshitoshi
Oyama

was an important step towards producing liquid oxygen. Three more labs joined the project, and a mid-term experimental division was established. They then moved on to the development of industrial production facilities, and commercialization. On June 6, 1949, an extinguished match was held in front of an open expansion valve, and

it burst back into flame. That evening, Nishina raised a toast to congratulate the researchers on their success, and the No. 9 Building (the site of the project) erupted with excitement. The institute had only just started on the road to self-reliance, but this was a major milestone along the way.



*Low-pressure
oxygen production*

Soon the world at large began to enter the age of oxygen steel-making. In Japan and overseas, large plants sprung up that produced oxygen cheaply and in large quantities using the “tonnage oxygen” technology that Nishina had been aiming for. For KAKEN and its successor, the public corporation RIKEN, the royalties received from Hitachi for this technology were one of the main three sources of income from patents. In 2003 the license was transferred from Hitachi to Nippon Sanso.

Half a century later, an unexpected opportunity arose for RIKEN to repay the favor it had received from the work of the great Kapitsa in its hour of need.

To Russia with love

At the end of March 2003, RIKEN extended an invitation to Sergei Kapitsa, Pyotr’s son, and he came to visit Japan for one week. Kapitsa was at the time director of the Institute for Physical Problems in Moscow.

In 1998, Akito Arima, then President of RIKEN, received a letter from Koji Fushimi, who was chairman of the Japan–Russia Exchange Society. Fushimi wrote to him that the Soviet Union had provided great support to RIKEN in the KAKEN years, and given the difficult state

of science in Russia after the collapse of the Soviet Union, he felt that RIKEN could do something to help.

Soon after this, Arima resigned as President to enter politics. The letter from Fushimi was passed on as Arima's "will" to the next President, Shunichi Kobayashi, and after half a century, RIKEN brought Sergei Kapitsa to Japan.

Sergei Kapitsa came to Japan under the memory of his illustrious father, but he is also an outstanding physicist in his own right. He traveled around the country visiting accelerator facilities such as SPring-8 in Harima and KEK in Tsukuba.

Part III

Public corporation

Under the government's umbrella

Despite the initial success in areas such as penicillin and oxygen production, however, things did not go smoothly for the new company. In 1951, Nishina died of liver disease, and was replaced by Kiichi Sakatani.

KAKEN struggled to escape from a vicious circle of poor business performance. It was reorganized three times, with the research division and the development division being separated, but things never got easier. In fact, by 1952 the number of personnel had fallen to half of the nearly 2,000 it had at the height of its success. Other companies started to produce the same products that KAKEN was creating, and they did not have the burden of financing a research division. After all, though KAKEN was a private company, it was still not a commercial firm, but was expected to be a research and development powerhouse. Because of a lack of funds, employees sometimes had to be paid with stocks in the company. Despite these efforts, eventually the institute's finances became too precarious, and the government decided to transform it into a semi-public

corporation. And in 1961 the development division itself was spun off into another organization, the Research Development Corporation of Japan, which today is a part of the Japan Science and Technology Agency . Perhaps the one bright sign that came from the private company years was the construction, according to Nishina's wishes, of a third cyclotron.

But the timing of KAKEN's financial crisis was perhaps fortuitous. In October 1957 the USSR had launched the first man-made satellite, Sputnik, and the "Sputnik shock" heralded the beginning of a new era of science and technology, which materialized for example in the Apollo program in the United States.

In Japan, the government set up a new Science and Technology Agency (STA) which was charged with overall management of Japan's science and technology policy. Japan was accelerating its drive to truly become a "nation based on the creativity of science and technology".

In October, the private company KAKEN was dissolved, and a law was passed to establish RIKEN, with its name restored, as a semi-public corporation. Essentially, it was bought by the government and transformed into a public research agency under the STA. As a public corporation it was given solid financial backing by the government in order to make the best use of its potential for research. At the time, *Newsweek* magazine reported that RIKEN had come back to life like a phoenix.

The public corporation's first president was Haruo Nagaoka, the oldest son of Hantaro Nagaoka, and the only RIKEN president to come from a liberal arts background. Previous to his appointment he had served as the director of a shipbuilding company called Nihon Gohansen, and when he came to RIKEN he brought four sailing boats as

a gift. He had studied German law at university and was even a member of the Goethe society in Japan. Haruo inherited his father's strong personality. In Komagome he had a small office next to the entrance hall, and on the door was a sign in German that read, "Knock, and it shall be opened onto you!"

Before the war RIKEN had been a "paradise for scientists" that led Japanese science and technology, and Nagaoka's difficult task was to find a path to rebuild it and bring it back to life in the new age. The institute's old site in Komagome had been the birthplace of modern Japanese science, but it had been destroyed by an air raid in 1945, and so Nagaoka decided to leave it and to seek a new campus that would allow the institute to grow

In May 1960 Nagaoka went on a tour to Europe and the USA, and searched for ideas for the rebuilding of RIKEN. In Göttingen he visited Otto Hahn, President of the Max Planck Society, which had been the model for RIKEN, and in Copenhagen he visited Niels Bohr at his institute, where Yoshio Nishina had studied. Both Hahn and Bohr had been close friends of Nagaoka's late father Hantaro.

Back in Japan, Nagaoka conceived a plan that would take advantage of the sympathy that many here and overseas had felt towards RIKEN since the pointless destruction of the cyclotrons in 1945. He put all his efforts into making this plan work.

Small is beautiful

In the meantime, however, while Nagaoka was working on his plan, the institute had to forge on. At the time, RIKEN was one of several research and development institutes under the control of the STA. Three other

large-scale institutes, which were working on “big projects” such as atomic energy and space, were given priority within the government’s science and technology plan. What this meant is that the government’s science policy



Torahiko Terada (front left)

put RIKEN on the sidelines, under the category of “Other basic science”. This state of affairs continued for several decades. Even thirty years later after RIKEN’s re-establishment, dark clouds still hung over its finances, and it only received a few percent of the ministry’s total budget.

But small is beautiful! RIKEN had a long and proud tradition of research full of creative thinking in areas of “small science.” For example, Torahiko Terada, one of RIKEN’s early chief scientists, had studied a variety of “small” subjects such as sparkler fireworks, candy, and ink. Terada headed a laboratory for about 12 years, beginning in 1924. He had a wide range of research interests, from astrophysics to geophysics, but he always approached research in a practical way, drawing heavily on everyday phenomena. For example, he studied combustion by performing experiments using a burning charcoal briquette and the physics of surfaces by studying ink marbling and the generation of vortices. He also studied cracks in glass and the formation of *kompeito*, a type of sugar candy. One of his achievements was to devise a research method of continuously observing crystal X-ray diffraction by rotating a crystal object. Terada was also an accomplished painter and writer, especially in the area of scientific essays.

In another example, Mizu Wada, one of RIKEN’S early women scientists, did research on safflowers. The won-

derfully creative small science projects at RIKEN before the war are too numerous to mention, but many of them gave rise to major commercial applications by the RIKEN Konzern. In the early years following World War II, when RIKEN had been reduced to a relatively small institute with a handful of chief scientist laboratories, this spirit of finding beauty in small things helped the organization carry on.

Later, of course, RIKEN underwent a major expansion and began to take on projects of national significance, so that the focus has shifted, but there are still laboratories within RIKEN working on small-scale projects like these.

The move to a spacious campus

By the time the sixties came around, the ground water under Komagome was beginning to sink—a phenomenon that was seen throughout Tokyo because of the demand by industry for water—and RIKEN clearly had no future there. The quarters were also becoming cramped as the institute recovered and slowly grew. Nagaoka continued to dream of a new site, and new buildings, to breathe new life into the institute. He enlisted the help of two people, Takeo Tanaka and Hisao Fujii, who had been his subordinates at Mitsui Real Estate and were familiar with the real estate business. His Vice-president, Kinichiro Sakaguchi, agreed with the plan and began the search for a new site for RIKEN. Fortunately Nagaoka had friends among the Allied occupation forces.

Ironically, it turned out to be a stroke of good luck that the US army had destroyed the cyclotrons in 1945. Thanks to that incident, all sides had sympathy and goodwill towards RIKEN. Sakaguchi was able to study various possible locations, and he identified an ideal site in Yamato,

now Wako City, a suburb in Saitama Prefecture toward the north of Tokyo. The site was part of the land that had been requisitioned by the US military.



The Wako campus in 1967

In 1960, two years after becoming President, Nagaoka traveled to Washington to meet Harry Kelly. He took with him an unaddressed letter of petition. The letter read, “The tide has changed. Now at present since October the year before last we have been busy in reconstructing the ‘Kaken’”. Describing the site in Wako, he wrote, “And in general, fresh air, full sunshine, solid geological foundation, underground water supply source.”

Nagaoka made the wanton destruction of the cyclotrons into the starting point for the reestablishment of RIKEN. He worked to turn this disaster into a blessing. He finally succeeded in acquiring the present campus in Wako, even though it had been the prime candidate site for the athletes’ village for the 1964 Tokyo Olympics. In 1960, the government officially decided to grant RIKEN the 23-hectare site. The construction work to prepare the site went on for the next ten years. The imposing centerpiece of the new campus was the 189-meter-long six-story Main Research Building, which still stands today. Through this magnificent drama, Nagaoka’s dream came to life. The new RIKEN was more than a “paradise for scientists”; it was a comprehensive research institute for a new era.

With the move to Wako, RIKEN was finally in a position to return to its state as a “paradise for scientists”

and to reclaim its position at the forefront of Japanese science and technology. This position was cemented in 1968, when the crown prince, who would later become Emperor Akihito, paid an official visit to the Wako campus. The relationship between RIKEN and the imperial family is actually a long one, since RIKEN was founded in 1917 partly on the basis of an imperial grant, and the first and second presidents of the institute were members of the imperial family. In the years since the move to Wako, the current crown prince visited Wako in 1989, and the current Emperor and Empress visited in 1992. The Centennial Celebration, which will be described later, was attended by both of their majesties.

Returning to 1967, when RIKEN had finally overcome the difficulties of the war period, what was needed for it to recover its status as a paradise for scientists? What was needed was a flexible organization to do distinctive top-quality research in all fields of science, and take on projects that could not be handled by universities, government institutions, or commercial research institutes. RIKEN would need to take a long-term view and devote itself wholeheartedly to the progress of science and technology.

It was against this background that Nagaoka, first President of the new RIKEN, set up an advisory committee, to include eminent persons from outside RIKEN. In 1966, after eight years and two terms of office, and after supervising the move to Wako, Nagaoka passed the baton to Shiro Akabori, who is known as the father of Japanese peptide and protein chemistry.

Toward project-based research

After RIKEN came under the government's umbrella, its structure and mission began to change. Under Okochi and into the private company KAKEN era, the core of RIKEN's research had always been the chief scientists, who carried out curiosity-based researchers in independent labs under a flat structure. When the institute was placed under the government's umbrella in 1958, however, a shift began to take place.

First, based on a proposal by the Science and Technology Council, a new program—separate from the chief scientists—was set up to study and develop agricultural chemicals as a national project. This was essentially the first project-based research center established at the institute.

Then, in October 1986, a major transformation took place. In 1967, when RIKEN had begun its relocation to the new campus in Wako, Nagaoka's advisory committee was putting all its energies into exploring and debating plans

for the future of the institute. A central role in this committee was played by the second Vice-president, Yusuke Sumiki, a specialist in plant hormones and antibiotics.

The committee proposed to keep the chief scientist system as the core of RIKEN, but noted the urgency of reviving the institute from the torpor of the KAKEN years. It also proposed that in the future RIKEN should set up new research centers, with specific fields, that would put to use the results created by labs and groups set up under a system, started in 1986, called the Frontier Research System. FRS was intended to be a flexible system for bringing together world-class scientists to work on specific projects rather than purely curiosity-driven research. What is important is that unlike the chief scientists, who were employed as permanent staff—meaning, under the Japanese employment system of the time, that they were lifetime employees—the scientists in FRS were hired as fixed-term employees, based on one-year contracts that could be renewed a number of times in line with the lifetime of a project.

Along with this, in 2002 the chief scientist laboratories in Wako were reorganized into a center known as the Discovery Research Institute, which unlike the specialized centers did not have a specific research focus. With this, RIKEN took on a dual structure, with centers focused on specific missions and chief scientists working on curiosity-driven bottom-up research. This structure, though it has evolved over the years, remains essentially in place today.

This allowed a major expansion to begin. Under the program, RIKEN began establishing large-scale facilities, and, eventually, a number of research centers set up to tackle specific national projects. The first was the Brain

Science Institute, set up in 1997 with neuroscientist Masao Ito as director. Next came the Genomic Research Center, established in 1998, and the Plant Science Center, Center for Developmental Biology and SNP Research Center (later renamed the Center for Genomic Medicine) in 2000. The Research Center for Allergy and Immunology and BioResource Center were then set up in 2001. This expansion would continue at RIKEN entered the 21st century.

Breaking new ground: new campuses

RIKEN also underwent a geographical expansion under its new status. One of the important ideas behind the establishment of the Frontier Research Program was that new research centers established under its umbrella were to be located around the country, like satellites orbiting the central Wako campus. Thus RIKEN made the decision to become a comprehensive research institute for the natural sciences.

This plan might have been natural for the prewar RIKEN, which had been modeled on the Kaiser Wilhelm Society. But for the 1960s RIKEN, which had only just managed to struggle back to life from the ashes of Komagome, the plan for satellite research institutes was still very much a dream.

In the 1960s, there were three kinds of organization that did scientific research: universities, which were free to do the research they wanted, but also had to teach students; government



The Tsukuba campus

institutions, which did testing and research and managed national standards; and the private sector, which primarily worked on improving present-day technology for commercial gain, rather than long-term problems. In the midst of the plan for satellite research institutes, a totally new model of research organization, emerged as the future of RIKEN.

The expansion started in 1980, when the Tsukuba Institute, the first of the satellite institutes, was established. At last RIKEN began to develop its own character and style. The mission of the center in Tsukuba was to study genetics as a national project, and today it continues to operate, but now as the BioResource Research Center, which is dedicated to providing biological resources, including experimental animals and plants, microbes, and cell lines, to researchers around the world.

In 1997, the Harima Institute was established, as a large-scale synchrotron radiation facility, and in 2011 the SPring-8 synchrotron was joined by a new state-of-the-art instrument, the SACLA free-electron x-ray laser. Together, these instruments are used to make high-precision studies of molecules and molecular binding. They are used by scientists around the world but also by private companies as a means to help the development of new materials.

In 1998, a center was set up in Yokohama, dedicated to genomic research. It has since developed into a number of centers, which today work in areas including genomics but also immunology, allergy studies, plant science, and nuclear magnetic resonance imaging.



The Yokohama campus

Then, in 2002, the last of the large campuses, in Kobe in

the west of Japan, was established to be home to a center studying developmental biology. A supercomputing center was later added in Kobe, as well as a facility dedicated to the use of functional positron emission tomography (PET) imaging.



The Kobe campus

In addition, research laboratories have been set up overseas at the Rutherford Appleton Laboratory in the United Kingdom, and Brookhaven National Laboratory and MIT in the United States.

A Little Prince

In April 1988, a “Little Prince” came to RIKEN. His name was Minoru Oda, and he had retired from the Institute of Space and Astronautical Science—now part of JAXA—to become the President of RIKEN,.

Oda had long been one of the world’s leading researchers in cosmic-ray physics and X-ray astronomy, and he always brimmed over with lively curiosity and youthful ambition. For these reasons his colleagues called him by the fond nickname of *Hoshi no oji-sama* (literally “a prince who came from a star”); this is the Japanese title for Antoine de St. Exupery’s novel *The Little Prince*).

Oda is known for the interesting concept, of an “*amoe-ba*,” that he developed to describe RIKEN. Normally, when a chief scientist retires, the lab they ran closes down. This system is one of RIKEN’s unique features, and for nearly a century it has continuously refreshed and reinvigorated the institute. It is only for a single generation that researchers are able to devote their whole energies



to research in the paradise of scientific freedom. When the time comes for one generation to give way to the next, a new chief scientist is appointed, from inside or outside, and the winds of change bring the new frontiers of science to RIKEN.

Thanks to this system, RIKEN has come to conduct research in all fields of science, from physics and chemistry to engineering and the life sciences, and from basic science to practical applications, and it has been able to collaborate with other research institutes around the world. In this way RIKEN resembles the amoeba, which constantly changes shape as it moves about. Oda, who had an aptitude for drawing, described the story of the birth and development of research at RIKEN in a clever cartoon that likens the institute to an amoeba.

The amoeba encounters eminent foreign visitors, politicians, the media, and scientists inside RIKEN. The first thing the cartoon shows is that RIKEN has physics and chemistry at its core. While maintaining this core, it changes shape and ventures into new areas of science, responds dynamically to the demands of the times, and sets out to explore the unknown. Paul Williams, while serving as the Director of the Rutherford Appleton Laboratory in the United Kingdom, one of RIKEN's sister institutes, praised its lively research in multifarious fields and said that RIKEN was the perfect amoebic research institute.

The RIKEN Advisory Council and governance

Ever since its days as a private foundation, RIKEN had always a wide *noren*. (*Norens* are the curtains hung in front of the entrances to shops in Japan, to show that they are open for business.) A *noren* shows the name of a shop, but it also shows the type of business and its trustworthiness, so having a wide one meant that the shop dealt with a variety of goods. The *noren* of the forefathers at RIKEN had been so magnificent that the descendants had difficulty living up to it.

When it became a public corporation, RIKEN's *noren* was set up under article 1 of the RIKEN Law: "To conduct research in all fields of science and technology, and to disseminate the results of that research." RIKEN had to achieve its mission through research in all the fields of science and technology, as written in the *noren*.

But there is a limit to the research resources (people, things, money) that can be obtained from the taxes paid by the public. Where among the huge range of possible research fields were the new directions in which RIKEN ought to move? Even thirty years after RIKEN became a public corporation, this continued to be a major question for the management of the institute.

In the early 1990s Oda decided to gather eminent “doctors” from Japan and overseas and convene an international-style advisory body, which would become known as the RIKEN Advisory Council (RAC). This decision had followed an informal talk over lunch after a meeting of the board of directors one day. Oda would lay the institute down on the examination table, submit it to a diagnosis by these famous doctors from around the world, and ask for their advice on management strategy for RIKEN as it aimed to become an international center of excellence. The RAC was the first international-style external review in Japan, and set the course for external review systems at universities and other research institutes.

Initially, the RAC consisted of three eminent people from each of Japan, America, and Europe, who covered the fields of research at RIKEN at the time. Today, it has come to be a larger group, with a chair and about twenty other members. It convenes every two to three years. At each meeting, RIKEN presents to the members a “white paper” that outlines the current state of the institute, including decision-making processes, selection of new research fields, personnel, and budget. There is also a layer structure, where the different research centers have their own advisory councils preceding the main RAC, with the feedback from their meetings fed into the overall council.

Independent Administrative Institution

In October 2003, the organization underwent another transformation. Nobel laureate Ryoji Noyori, a pioneer in the area of chiral chemistry, assumed the presidency of RIKEN as the institution was reorganized as an “Independent Administrative Institution” (IAI) under the Japanese Ministry of Education, Culture, Sports, Science and Technology. The purpose of the reform at that time was to give more autonomy to the many scientific and other public corporations that existed.

One issue that confronted RIKEN at that time, which was pointed out by the RIKEN Advisory Council meeting in 2000, was that it was a very heterogeneous organization, with the traditional chief scientists, the new Frontier Research System, and two centers, the Brain Science Institute and the Genomic Research Center. There was a need felt for more focus. As a result, the institute underwent a series of reforms as an IAI.

During its time as an IAI, the organization continued to expand, adding new centers in a variety of fields.

The RIKEN SPring-8 Center, which today operates both the SPring-8 facility and the SACLA free electron x-ray laser facility, were set up in 2005. The Nishina Center for Accelerator-Based Science, which studies the atomic nucleus using tools such as the RI Beam Factory, was established in 2006. Further, in 2010, the Advanced Center for Computer Science was set up to develop and operate the K computer, a national project to run a world-class supercomputer. And in 2011, the Quantitative Biology Center was established in Osaka with the goal to use resources such as the K computer to pioneer the growing field of computational biology.

The chief scientist system, which in the prewar period was the key pillar of RIKEN, was reshuffled a number of times. In 2002, just before the move to an IAI, they were organized into what was called the Discovery Research Institute. And in 2008, the labs under the Frontier Research System and Discovery Research Institute were moved into a new organization called in Advanced Science Institute.

In that time, RIKEN also started to restart systems to transform it into a powerhouse for industry as it had been before World War II. In 2005, the Center for Intellectual Property Strategies was established to manage RIKEN's intellectual property, and is has matured in the years since then.

Later, in 2013, the Advanced Science Institute was dissolved and spun off into two centers, the Center for Emergent Matter Science which carries out research in areas such as solid state physics, superconductivity, and quantum computing, and the Center for Advanced Photonics which does work in areas such as laser technology and terahertz radiation. The chief scientist laboratories, which had been within the Advanced Science Institute,

were put back to a position where they served directly under the president.

April 2013 also saw a number of changes in the centers, based on the idea, which continued after 2015, to promote interdisciplinary research, which after all was one of the strengths of RIKEN as an organization. In that year, two centers, the Center for Allergy and Immunology and the Center for Genomic Medicine merged to start the Center for Integrative Medical Sciences, and three centers, the Center for Molecular Imaging Science, Omics Science Center and Systems and Structural Biology Center were combined to form the Center for Life Science Technology. In addition, the Plant Science Center was combined with a number of chief scientist laboratories to form a new center, the Center for Sustainable Resource Science, which was dedicated to solutions to what eventually became the United Nations' Sustainable Development Goals.

The STAP crisis

Though developments in the IAI era were basically positive, there was a very sad episode. In 2014, RIKEN went through a crisis triggered by a researcher who claimed she had created a new kind of stem cell by bathing normal body cells in an acid bath. Other researchers were unable to replicate the findings, and ultimately it was determined that she had falsified her results and the papers announcing the research were retracted. Tragically, however, her supervisor, who was also a co-author of the papers, committed suicide in the midst of the incident, and a series of reforms were put in place to prevent future incidents.

National Research and Development Institute

The year 2015 turned out to be a turning point in a number of ways. In April, RIKEN acquired a new status, this time as a National Research and Development Institute. This was actually quite an important transformation, because under the IAI status, RIKEN was consistently expected to streamline its operations, a feat that is difficult for scientific organizations. With the new status, RIKEN and other research organizations were given the mission to maximize their research output, a goal that is much more fitting for institutes like RIKEN.

At that time, President Noyori stepped down, to be succeeded by Hiroshi Matsumoto, an astrophysicist and former president of Kyoto University. The following year, RIKEN was chosen to be one of three Designated National Research and Development Institutes, immediately before the institute celebrated its centennial in 2017.

Upon taking office, Matsumoto set up an initiative for the new RIKEN, the Initiative for Scientific Excellence, under which he set up a number of tasks for the organization, including setting up a new research system, contributing to the brain circulation of science, and acting as a hub for science and technology.

And then in 2018, following the centennial year, a number of new organizations were created to make a solid foundation for the next hundred years. They include the Cluster for Pioneering Research, a group set up to support the chief scientist laboratories and incubate new pioneering areas that will lead to new centers, as well as the Cluster for Science, Technology, and Innovation Hub, which encourages collaboration between RIKEN scientists and outside institutions including universities and private companies, based on the idea of making RIKEN a hub for collaboration. Another change in life science centers took place in 2018. The Center for Developmental Biology, Quantitative Biology Center and the divisions of Bio-Function Dynamics Imaging and Structural and Synthesis Biology of the Center for Life Science Technology were combined to form the Center for Biosystems Dynamics Research. The Division of Genomic Technologies of the Center for Life Science Technology was merged to the Center for Integrative Medical Sciences.

The discovery of nihonium

The year 2015 was a turning point for another reason as well. The morning of December 31, 2015, was probably one of the most exciting moments in RIKEN's long history. Early that morning, RIKEN scientist Kosuke Morita, the head of a group working on superheavy elements,

received word from the International Union of Pure and Applied Chemistry (IUPAC) that his group would officially be recognized as the discoverers of element 113, which has gone on to be named nihonium.

The achievement began with experiments started in 2003 to create the new element 113. In July 2004, the group had their first success, as they succeeded in creating the new element 113 using the RILAC initial-stage



*Plaque commemorating
nihonium*

accelerator. For eighty days they irradiated nuclei of bismuth, which has atomic number 83, with zinc, which has atomic number 30, and eventually they observed a single atom of element 113. The new element lasted a mere 0.0003 seconds, and in the next two and a half seconds it decayed four times,

into an atom of dubnium (element 105), a previously-discovered element. A year later, in 2005, the group saw a second event, with the nucleus of element 113 decaying by a similar route as the first.

Unfortunately, at that point IUPAC did not feel that the evidence was strong enough to officially call it discovered, as there is another decay route that should have been seen and that would cement the discovery. So the group labored on, for another seven years, before finally seeing a third event, in 2012, that did decay by the different route. And three years after that, IUPAC gave its blessing to the discovery. On that day, four new elements, including nihonium, were given a place on the periodic table.

Opening to the world

In its early years, RIKEN was an institute with an almost purely domestic focus, a natural fact considering that it had been set up to contribute to the development of Japanese industry and reduce Japan's reliance on the West for technology.

Of course, this does not mean that RIKEN was isolated from the rest of the world. Science is by its nature an international endeavor, and RIKEN scientists, particularly in the area of physics, were always in touch with collaborators through publications, visits, and international meetings such as the Solvay Conference. This was critical for remaining at the leading edge of research. In fact, RIKEN began publishing a record of its research findings in English as early as in 1922, just after Masatoshi Okochi took charge of the institute.

The domestic outlook began to change in the 1980s, as Japan became a more international nation. In particular, as RIKEN began to take on national research projects, there was a need to find outstanding personnel to take on these tasks, and the institute began to look for talented researchers from overseas. A number of programs to attract

young scientists were put into place, and every year, a large number of PhD students and postdoctoral researchers come to RIKEN under the Special Post-doctoral Researcher program and the International Program Associate program. Researchers who came to RIKEN through these programs have moved on to positions at other institutes both in Japan and abroad, contributing to the global brain circulation for scientific knowledge.

RIKEN also began looking for partners abroad in that era. In 1984, the institute signed a comprehensive research agreement with the Max Planck Association in Germany, and that relationship continues to be strong today, thirty-five years later. Today RIKEN has research agreements with more than 60 institutes around the world, including the China Academy of Science and a number of universities. RIKEN has also been an active member of many global collaborations in areas such as genomics and nuclear physics. In particular, the FANTOM consortium, which is led by a RIKEN researcher, has allowed the institute to play a major role in global collaboration in the area of RNA expression studies.

Intriguingly, there was a doctoral student who worked at RIKEN in the 1920s, and he was likely the first non-Japanese to work at the institute, though it is difficult to know for sure because we know little about him other than the fact that he studied engineering and that his name, though written in a variety of ways in Japanese *kana*, seems to have been Herbert Gregor.

Celebrating the Centennial

In 2017, RIKEN celebrated its centennial with a series of events spanning a year, along with a number of projects intended to remind future generations of RIKEN's first one hundred years.

The highlight was the Centennial Ceremony, held in Tokyo on April 26, in the presence of Their Majesties the Emperor and Empress of Japan. There were over 700 guests, and addresses were given by the Minister of Education, Sports, Culture, Science and Technology, the Minister of State for Science, and the President of the Max Planck Society, an institution with which RIKEN has had a long and productive relationship. The reception that followed the ceremony featured addresses by a number of distin-

guished guests, along with a traditional *kagami-biraki* ceremony where representatives of the hosts and guests get up on a stage together and open casks of Japanese sake with hammers. In December, celebrations were also held



Centennial Ceremony

inside RIKEN, in both Eastern and Western Japan, to raise awareness of RIKEN's history among its personnel. The days featured lectures and open laboratories so that personnel could learn what other people were working on.



Time capsules

A significant outcome of the Centennial Project, in addition to the ceremonies, was the work to create a record of the work RIKEN did during its first one hundred years. This included a series of lectures on important historical figures such as Okochi, Nishina, and Suzuki, as well as women scientists such as Chika Kuroda. The crowning achievement was the writing and editing of a monumental, 1,500-page three-volume book chronicling the history of RIKEN's first century. An abridged version was also created, as well as the English version that you are now reading. In addition, a major project was the creation of time capsules, which are now installed for viewing at the entranceway to the main research building on the Wako campus. The capsules contain items celebrating the history of the research centers as well as the Headquarters.

In addition, some of the donations raised for the Centennial celebration were put to work to ensure that RIKEN will continue to make history in the coming century. One part of the Centennial Project was a commitment of funds to the work for the discovery of elements 119 and beyond, to further solidify RIKEN's place in the history of superheavy element synthesis. Another part was given to a fund for young researchers, to ensure that RIKEN will continue to be an attractive place for the young minds that will make the coming leaps in science.

Toward a new century

At the Centennial Ceremony on April 26, 2017, President Matsumoto gave a lecture outlining his vision for the next century.

In his talk, he outlined the unique strengths of RIKEN as a research institute and then put forward proposals for making the most of these strengths.

The strengths that he listed, in particular in comparison to Japanese universities, were the capability to develop and operate large-scale facilities for the research community, relatively large laboratory with the capacity to do long-term research, a large number of technical staff and administrative staff with the ability to interface with researchers, and a strong capability for interdisciplinary research.

As an aside, Matsumoto said, soon after his arrival at RIKEN from a national university, that he was impressed by the way that administrative staff and researchers worked together in a spirit of cooperation. In fact, there has been a long tradition of such exchanges. Two examples, both mainly from the Wako campus, are the Kinsaka—a tradition of getting together for drinks

on Friday evening—and a group called the Coelacanths, which get together occasionally in a laboratory to share food and stories. The Coelacanths actually began when one chief scientist brought back a can of *surstromming*, a very smelly fish, from Sweden, and opened it (at his lab assistant’s insistence!) outside, in a place that happened to be near the headquarter building. The president at the time ran out of his office to see what was causing the stink, and the organization began. These are just examples today of how the “RIKEN Spirit” lives on.

The spirit of interdisciplinarity and low barriers remains a key part of RIKEN as well, and events such as the Interdisciplinary Exchange Evenings, which are held several times a year, Discovery Evenings, which are held for young scientists, and Joint Retreats, which are held every two years in a location between the Kanto and Kansai regions, help to promote this.

In his talk, Matsumoto also mentioned a number of reforms that need to be carried out in order to allow RIKEN to achieve its potential. One involves the personnel system. The launch of the Frontier Research System in the 1980s allowed RIKEN to achieve phenomenal growth under national research projects, but it also brought a workforce that was mostly on short-term contracts and did not have a long-term commitment to RIKEN. To redress this, he called for the adoption of a system that allowed outstanding personnel to gain permanent positions that would allow them to commit themselves to RIKEN.

The second reform involves gaining a stable source of funding. The Japanese government is in a difficult fiscal condition, and as a result it is not realistic to expect any major boost in funding. But looking back, Matsumoto reminded the audience of RIKEN’s experience in the 1930s,

when companies commercialized the institute's discoveries and returned license fees. Matsumoto proposed establishing a fully subsidiary innovation firm that would manage RIKEN's intellectual property. Fortunately, in December 2018 a bill was passed allowing public research institutes to establish such subsidiaries, and plans are in motion to establish such a firm.

Mathematics and artificial intelligence

In 2017 and 2018, RIKEN also added two new centers, both representing new areas of science for the institute. First, a new center was set up in downtown Tokyo to conduct research in the areas of artificial intelligence, a hot topic today. The center will in particular focus on areas of artificial intelligence that impact society, such as ethic. And second, in a remarkable development, a new center called the Interdisciplinary Theoretical for Mathematical Science was set up. What is interesting about this development is that although RIKEN's first president, Kikuchi, was a mathematician, the institute never had a group truly dedicated to mathematics for the first hundred years of its history. With this development, RIKEN has put itself into a position of truly exploring the similarities between the mathematics governing different natural phenomena, with the goal of making new discoveries.

The year 2018 also saw a further reorganization of the life science centers, with parts of three centers placed under a single umbrella called the Center for Biosystems Dynamics Research, as mentioned above. The goal of this consolidation is to further stimulate interdisciplinary work between different laboratories working in the life sciences.

Challenges facing humanity

Another theme of his presentation is that human civilization is facing a host of challenges, such as resource depletion, conflicts, poverty, environmental degradation, and epidemics, and that scientists need to not only make discoveries but must also consider how their research can contribute to these challenges. To this end, an Innovation Design Office was established, staffed by innovation designers who formulate blueprints for ensuring the research is used to create a better future. With these new systems and centers in place, RIKEN is ready to tackle the next century.



Dairoku Kikuchi
(1917)



Furuichi Koi
(1917-1921)



Masatoshi Okochi
(1921-1946)



Yoshio Nishina
(1946-1951)



Kiichi Sakatani
(1951-1952)



Takeshi Murayama
(1952-1956)



Masanori Sato
(1956-1958)



Haruo Nagaoka
(1958-1966)



Shiro Akahori
(1966-1970)



Toshio Hoshino
(1970-1975)



Shinji Fukui
(1975-1980)



Tatsuoki Miyajima
(1980-1988)



Minoru Oda
(1988–1993)



Akito Arima
(1993–1998)



Shunichi Kobayashi
(1998–2003)



Ryoji Noyori
(2003–2015)



Hiroshi Matsumoto
(2015–present)

