Think Globally, Act Locally

An interview with Prof. Ryōji Noyori

By Ehud Keinan

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Ehud Keinan
Professor Keinan of the Technion is President of the Israel Chemical Society, Editor-in-Chief of AsiaChem and the Israel Journal of Chemistry, Council Member of the Wolf Foundation, and past Board Member of EuChemS. He was Dean of Chemistry at the Technion, Head of the Institute of Catalysis, and Adjunct Professor at The Scripps Research Institute in California. His research program includes biocatalysis, organic synthesis, molecular computing, supramolecular chemistry, and drug discovery. He received the New England Award, the Herschel-Rich Award, the Henri Taub Prize, the Schulich Prize, the Asia-Pacific Triple E Award, AAAS Fellowship, the ACS Fellowship, and the EuChemS Award of Service. Since 2022 he is IUPAC VP and President-elect.

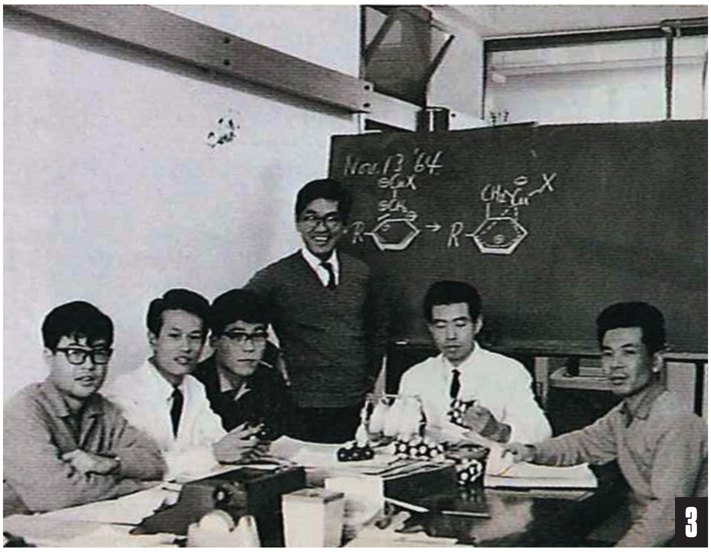
Ryōji Noyori was born on September 3, 1938, in Kobe, Japan. He obtained his B.Sc. and M.Sc. in Industrial Chemistry from Kyoto University. In 1967 he obtained a Doctor of Engineering degree from Kyoto University under Prof. Hitosi Nozaki, and in 1968 became an associate professor at Nagoya University. After postdoctoral work with Elias J. Corey at Harvard University, he returned to Nagoya, becoming a full professor in 1972. He served as president of RIKEN (2003-2015), and since 2015 he has been Director-General of CRDS (Center of Research and Development Strategy) of the Japan Science and Technology Agency. Noyori shared the 2001 Nobel Prize in Chemistry with William S. Knowles and K. Barry Sharpless. Noyori's other prominent recognitions include the 1992 Asahi Prize, the 1993 Tetrahedron Prize, the 1995 Japan Academy Prize, the 1997 Arthur C. Cope Award, the 1999 King Faisal International Prize, the 2001 Wolf Prize in Chemistry, the 2001 Roger Adams Award, and the 2009 Lomonosov Gold Medal. Our Zoom interview took place on September 27, 2021, about three weeks after his 83rd birthday. It was early morning in Israel and afternoon in Japan.

How early in your childhood has science triggered your curiosity?

Louis Pasteur once said, "Science has no borders, but scientists have their homeland." Every scientist has a different social background. My life path is much different from that of Americans, Europeans, or even other Asians in many ways. Ehud, you live in the western end of Asia, while I live at the eastern end of Asia. Although we share the same values in science, we grew up in different social and cultural environments.

My career as a scientist has been full of challenges, excitement, and joy, but at the same time, I had to overcome many obstacles. My own experience makes me think: what is behind the talent and intuition of a Japanese scientist?

My generation had a challenging time after the devastation of WWII. Yet, we survived and even contributed a bit to the progress of science. How were we able



1. Ryōji Noyori was a naughty schoolboy. In 1949 at age 11.
2. Ryōji Noyori was a black-belt "judo" expert. At a high school in Kobe, Japan in 1956.
3. Nozaki group of Kyoto University in 1964. From left, students R. Urakabe, M. Yamabe and N. Kozaki, Professor H. Nozaki, and Instructors R. Noyori and K. Kondo.

to do this? We were patient, diligent, and hardworking. Also, we enjoyed complete academic freedom without any outside pressure or restriction. That freedom was a key factor for promoting academic research. We learned much from America and Europe and later enjoyed partnerships with colleagues from all over the world, including the Asian region. I would also acknowledge industrial collaboration here, for the industry eventually transforms our basic knowledge into social benefits.

I was born in 1938 in a suburb of Kobe and grew up into the experience of World War II. At the very end of the war, in April of 1945, I was to enter elementary school. However, before the horrible atomic bombing on Hiroshima and Nagasaki in August 1945, American B29 bombers devastated Kobe, reducing the central city to ashes. My mother and her three sons (our younger sister was not born later) took refuge earlier in the nearby countryside, while my father remained working in Kobe and commuted at weekends to take care of his family. What was waiting for us there was a life of self-sufficiency. That farming village was a world with no cars, telephones, electricity, no market for daily supplies, no running water, not even cooking gas. We used to pump water from a local well, firewood for heating, and candles for lighting. Our neighbors helped us with basic food, such as rice, vegetables, eggs, and river fish. We learned how to grow our vegetables, breed hens, and collect wild nuts and plants. As a 6-year-old boy, I learned from older friends how to make traps to snare sparrows and catch fish at the pond and river. I even made straw sandals because we had no shoes for school. I constructed a study desk from wood containers, and crude lumbers using a saw and nails. Even boiling water for the bath was a non-trivial task.

These activities provided me with tacit wisdom rather than explicit knowledge taught at school and prepared me for my science career. Though very poor, the farmland, with its peaceful and beautiful natural surroundings, triggered my curiosity in science. In addition, our stay in the countryside made me physically strong. Although my mother gave me many books to read, I preferred outdoor activities and sports. My interest in indoor learning came much later.

My personal experience, learning to supply all my needs through exposure to Nature, also worked on the national scale. We learned to secure our lives and livelihood by ourselves. In a more general sense, Humanity can meet significant challenges, such as natural disasters and infectious diseases, through science and technology.

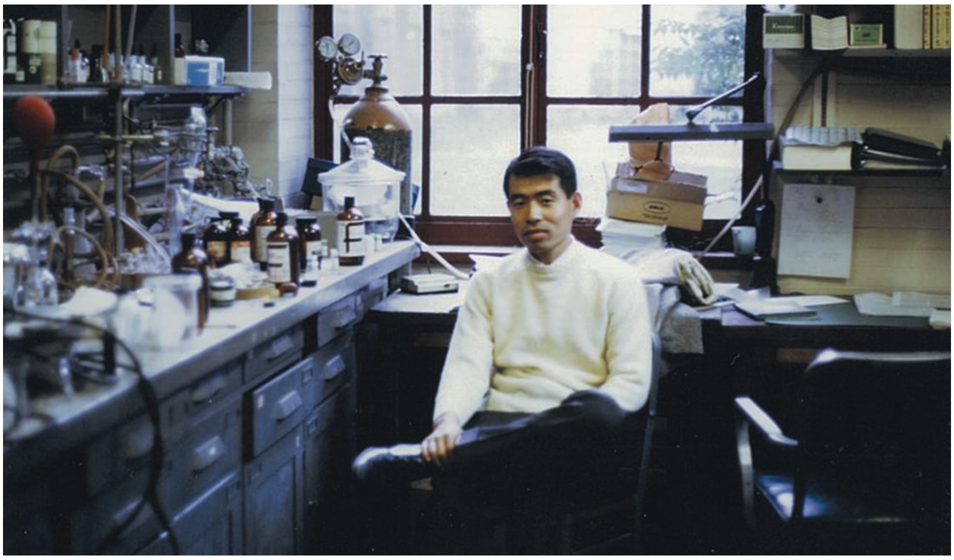
When and why did you consider becoming a scientist?

When WWII ended, we returned to Kobe, and I, a 7-year-old boy, continued my elementary school. Our country was devastated, we suffered food shortages and a lack of basic supplies, and my childhood remained difficult. My mother wisely managed to feed a family of six under these conditions. Our clothes, including underwear and socks, were all hand-made. I remember her busy repairing our clothes late at night, and we helped with cooking and gardening. My mother was clever, patient, and devoted her entire life to our family. I was happy to pay her back by taking her to Stockholm for the Centennial ceremony of the Nobel Prize in 2001. At that time, she was 87 and looked happy. My wife Hiroko learned much from her, mainly how to handle a complex person like myself.

In my view, although Japan was in ruins at the end of WWII, the Japanese scientific intellect remained unaffected. I have aspired to become a scientist ever since I was a small child, strongly influenced by my father, a gifted research director at the Kanegafuchi chemical company. In 1949 when I was 11 years old at the 5th grade, Professor Hideki Yukawa of Kyoto won the Nobel Prize in Physics. He was the first Japanese to receive a Nobel Prize, and I was especially delighted with this event because my parents knew him personally. Understandably, Yukawa has become my hero and a role model.

Another momentous event occurred in 1951 when I entered junior high school in Kobe. My father took me to a symposium on a newly discovered fiber called Nylon, and I was the only child in the audience. The lecturer, President of the Toray Company, proudly explained, "This new fiber can be synthesized from coal, water, and air, and it is thinner than a spider's thread, yet stronger than a steel wire." I was overwhelmed. Here was a new material created by chemistry from almost nothing. From that moment, I began dreaming of becoming an industrial chemist. I wanted to invent new materials to benefit society and Japan's economic recovery.

At that time, Japan's industry was still underdeveloped, far behind the Western countries. Many significant corporates worked under a technological license from American or European companies, and my father strongly disagreed with that trend. Every evening at the dinner table, he preached to our family on the significance of self-sustainability, saying, "We have to develop powerful technology by ourselves. Otherwise, Japan's stagnated economy cannot recover." My home was full of chemistry journals and books and various samples of polymer powders, beakers, and flasks. Then, my two younger brothers and I were convinced to study engineering at universities. We decided that I'd take industrial chemistry, and they would take mechanical engineering and electrical engineering. Indeed, my two brothers pursued industrial careers.



Noyori was engaged in prostaglandin synthesis in E. J. Corey's lab at Harvard in 1969–1970.

Receiving the 1995 Japan Academy Prize, Noyori was congratulated by Member Kenichi Fukui (1981 Nobel laureate).

How supportive were your family and friends about your choice?

My family was highly supportive. Perhaps, my father had expected me to become a chemical engineer in the industry rather than a university professor.

In my middle and high school days in Kobe, my favorite subjects were mathematics and sciences. Interestingly, my first chemistry teacher was Kazuo Nakamoto, dispatched from Osaka University and later became an inorganic chemistry professor in the USA, first at the Illinois Institute of Technology and later at Marquette University. My mathematics teacher, Mr. Masanori Maino, taught us math and many other things, including Chinese poetry. Several other enthusiastic teachers triggered my appetite for chemistry even more.

Another person I admired in connection with my future direction was Professor Ichiro Sakurada of Kyoto University, inventor of Vinylon, the first Japan-made synthetic fiber. He was one of the reasons I decided to study chemistry at Kyoto. The other reason was Professor Yukawa of the physics department at Kyoto University. In the mid-1950s, with the rapid development of the petrochemical industry, the chemistry departments within the engineering faculties attracted the best high school students.

Did you receive appropriate formal education to become a scientist?

If you ask about Japan's public schools or university system, you may be surprised that my answer is probably NO. We grew up mainly by self-learning rather than formal, curriculum-based, Western-style education. Although I highly appreciate my mentors' thoughtful guidance, giving me freedom, encouragement, and independence, I think that much of my background is self-education.

I believe that systematic education, as done in the USA, is essential for nurturing scientists. However, we should remember that some 30% of the American Nobel Prizes in science went to scientists born and educated in other countries, and many of them are ethnic Asians. That statistic suggests that Asian education, experience, and culture foster creativity and ambition. I believe that Israel's success in science and technology also stems from the strong emphasis on mathematical thinking in schools, regardless of the field.

A successful science career needs explicit and implicit knowledge, which is strongly affected by cultural background. English and American science, French la science, German Wissenschaft, and Japan's Kagaku are all different. "Indigenous" knowledge or wisdom is essential for unique achievements. Asian scientists exposed to diverse social environments have thus great potential. Japan was in the hinterland during my youth, but we enjoyed rich nature and freedom. In contrast, today's children who live in modern cities enjoy comfort life, but they live in a restricted, artificial space, and they like it. I feel that we are losing our blessed tradition.

I started my undergraduate studies at Kyoto University in 1957, only 12 years after WWII. Thus, we came up from Ground Zero or, more precisely, Ground Minus Ten. Since Japan's economic situation was far behind North America and Europe, the government intended to rapidly revive industrial productivity by nurturing a young workforce rather than promoting science that typically requires a much longer effort. This policy was not good, but quite understandable.

Consequently, the size of Chemistry Departments within the Faculties of Engineering, like the one I attended, became much more significant than those in the Faculties of Science. In the Japanese system, we have different chemistry departments, some belong to the faculties of Engineering, Agriculture, or Pharmacy, and others belong to the Faculty of Science. In the third year of my undergraduate course, we studied organic chemistry using Fieser's textbook, "Introduction to Organic Chemistry," which changed my interest from polymer chemistry to organic chemistry. In the following year, in 1960, I joined Professor Keiiti Sisido's laboratory at the Department of Industrial Chemistry for further experimental training. Associate Professor Hitosi Nozaki has become my guide and mentor from this starting point.

The laboratory environment at that time was very hospitable. Although Japan's economy improved, the academic research and education labs were lagging. At the organic chemistry laboratories, we determined the structures of organic compounds mainly by elemental analysis. The hand-operated Beckman UV–visible spectrometer was the sole reliable spectroscopic tool, and we had only one IR spectrometer on the entire university. As neither silica gel nor active alumina was available for column chromatography, we obtained analytically pure substances by recrystallization or by making crystalline derivatives. We purified oily compounds by large-scale distillation or steam distillation. Since only a few solvents and reagents were commercially accessible, we synthesized common chemicals and solvents, including benzophenone, triphenylphosphine, diborane, and dimethoxyethane. We conducted reactions on a relatively large scale, which required high skill.

We studied very hard in the department library. Chemical Abstracts was indispensable because access to original literature was limited. We read the literature more seriously than students of our time because photocopying machines were unavailable. We had to generate an abstract or take full notes after reading the article from beginning to end. With such inefficiency, the research progress was extremely slow. Nevertheless, students were highly motivated and enjoyed free speculations despite the limited knowledge.

The undergraduate course in all Japanese universities included practical research in the 4th year through an apprenticeship in various laboratories. In the 1960s, more than half of the B.Sc. graduates pursued industrial careers. Some students continued their graduate training under the same mentor, typically a two-year master's and three-year doctor's course. The science

Noyori group at Nagoya in 1991. Front row, left: Masato Kitamura, right: Ryōji Noyori.

From left to right: Ryōji Noyori, K. Barry Sharpless, and Robert H Grubbs (2005 Nobel laureate) watched "sumo" wrestling in the National Sports Hall in Tokyo. In September, 1996.

and engineering curriculum remained much less systematic than the US and Europe, so the Japanese graduates conducted their research in various styles. Fortunately, the research environment, and internationalization, improved in the mid-1960s thanks to coordinated efforts of the government and universities. I started speaking English only at age 30 upon my first trip to Harvard University.

Thanks for appreciating the innovative Israeli economy. I think that the situation in Israel is very similar to that of Japan. Israel does not have natural treasures and raw materials. But both Japan and Israel have outstanding human capital. In my view, the Japanese and Israeli cultures consider education and intellectual activities top priority. Do you agree with me?

I agree that both Japan and Israel are eager to nurture the young generation towards science and technology. However, the main difference is the higher level of the human network in your country. Israel, and more generally, the Jewish people, appreciate human interactions very much. Young Japanese stay in Japan, reluctant to travel and mix with other cultures. There is not much one person can do alone, so the human network is essential. I am a bit disappointed by the public attitude in Japan towards science. Unlike in Israel, many people in Japan consider scientists as slaves of the economy.

The 2001 Wolf Prize recipients. Front row: from left K. Barry Sharpless, the third Ryōji Noyori, and the fourth Henri B. Kagan. Back row: the fourth from left, Avram Hershko (2004 Nobel laureate). At the Chagall Hall of Knesset, Jerusalem in May of 2001

In December, 2001, the Nobel Foundation celebrated the centennial anniversary and invited more than 130 former laureates to Stockholm. Noyori's sharing a Chemistry Prize with W. S. Knowles and K. B. Sharpless was congratulated by his supervisor at Harvard. From left to right: Hiroko and Ryōji Noyori, Claire and E. J. Corey (1990 laureate).

Are you trying to influence the young generation to choose a career in science, and how?

Yes, I enjoy encouraging the younger generation, and I see it as one of my most important duties. The curious minds and enthusiasm of young people inspire innovative scientific discoveries.

Science is beautiful, exciting, and often beneficial for humankind. However, we should avoid pushing our yet naïve kids toward social matters too early. Children inherently love and enjoy nature simply because natural phenomena are exciting and marvelous. Our most important task is to maintain our kids' "sense of wonder" until they reach their academic studies and much later. We know that intellectual curiosity rather than duty drives the progress of science. Unfortunately, this approach is difficult in Japan because of the fallacy of our school system. Our school pupils need to sacrifice their joyful endeavors because they are too busy gaining skills to pass the entrance examination of good high schools and universities. Regretfully, the university's reputation is a major benchmark for achieving a promising career. So, parents consider that playing in wild nature or visiting science museums is a waste of time. This atmosphere misleads science teachers as well. Kids are not matric-regulated machines or robots but our living assets who will shape our future society. Education is not a tool for discrimination against children. I firmly believe healthy curiosity comes from the liberation of the spirit. Therefore, we must give our youths a well-balanced, proper STEAM (science, technology, engineering, arts, and mathematics) education. I prefer natural science - "science brut" in French, like "art brut," rather than modern computer-controlled scientific research.

We should motivate high school or university students in a bit different way. The essence of science that we should transfer to our students must always be the pursual of truth and the Socratic ability to recognize that we know nothing (knowledge of ignorance). The creation of new knowledge opens new windows to the unknown, and the accumulation of scientific discoveries keeps transforming myths into reality.

Your biography suggests that the way to attract the young generation to science is non-trivial. Your advice about education seems challenging to implement, even in your case. Your father was a successful

chemical engineer, and you have attended the best possible schools where you had excellent teachers, including primary school, the Nada Middle and High School. Yet, as a young pupil, you preferred having a good time with friends, playing baseball, practicing Judo, and going on trips rather than studying. You joined the rugby football club at Kyoto University and preferred social activities with friends and wine. You became serious about science only after joining the group of Hitosi Nozaki. So, perhaps the most effective way to attract the young generation to science is by singular events of personal experience, like the "Nylon Case" of your childhood. Such Eureka moments at a very early age can be more valuable than armies of teachers. I suspect that your father had this idea in mind, taking you to the event to create an unforgettable experience that could attract you to science. Do you agree with that approach?

I agree that accidental encounters are very influential in motivating young people. In analogy to chemistry, such singular events serve as catalysts, and they are more effective than stoichiometric formal education.

I remember another singular event when my father, on the occasion of the Nylon case, took me to a small restaurant for dinner with his colleagues. We were very poor at that time, and I was impressed by the unfamiliar, though now casual, rich menu, the group of enthusiastic industrial chemists, and the frank conversation around the dinner table. That unforgettable event impressed me so much that I aspired to be like them. Only years later, Hitosi Nozaki convinced me to switch my aspiration from industrial to an academic career.

Science has attracted me in multiple ways. One of them was the feeling that a scientist can do anything at will. Another essential factor is freedom and the sense that I can do anything by myself as a scientist. University professors should nurture their young students by pushing them to pursue an independent research career and provide them with maximal freedom. I was attracted to the academic mentality at the universities, which is quite different from the corporate or governmental institutions. Furthermore, academic research depends much on the mindset and personality of every scientist.

To encourage young science students, I often cite the statement of Isaac Newton: "If I have seen further, it is by standing on the shoulders of giants." At every age, the young students should explore new frontiers, and we must be patient as they make their way. Youth are creating new science on the assets founded by their predecessors. The young generation should be proud that their perseverant study and research lie higher than Einstein, Watson and Click, Ziegler and Natta, or R. B. Woodward, as Max Weber noticed, "Science is destined to make progress."

Many young chemists grow to become researchers, shaping future science, and we should remember that science is a single entity because it stems from the common laws of nature. Therefore, research must be interdisciplinary, trans-disciplinary, or even anti-disciplinary to create new scientific fields. As all disciplines deal with materials, chemistry links all scientific domains since all materials consist of atoms and molecules. So, I am asking our younger generation to understand that chemistry is the central science. Schroedinger asked in 1944, "What is life?" and Jim Watson, who pioneered molecular biology, responded, "Life is simply a matter of chemistry." And in this century, many Nobel Prizes in Chemistry recognized research in the interface between chemistry and physics or the life sciences.

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1. Congratulating Satoshi Omura (right) who was just announced to receive the Nobel Prize in Physiology or Medicine. October, 2015 in Tokyo.
2. Yuan-Tseh Lee (1986 Nobel laureate, left) was conferred the title of RIKEN Honorary Fellow in March, 2011. Together with Mrs. Lee and Ryōji Noyori, President of RIKEN
3. In his office of the Center for Research and Development Strategy, Japan Science and Technology Agency. In Tokyo, 2015

Therefore, I am not satisfied with the current discipline-based academic system, which I see as a global problem of our time. Our young chemists should radically change their mindset through exposure to other scientific disciplines.

In my view, the origin of creativity is highly complex, and discovery, by definition, is difficult to design. Historically, many discoveries came from serendipity and luck. As only a few researchers are outstanding geniuses, there is a need for systematic laboratory work applicable in most fields. Therefore, we must prepare a research environment or ecosystem that will encourage cooperation rather than harsh competition, thereby fostering collective knowledge. The current digital revolution is accelerating this trend. The key to promoting Asian science is to guide our youth toward enhanced collaboration. By nature, Japanese people are very collaborative, but we are affected by the competitiveness we imported from the Western culture.

Did you try to promote science in your country and the world?

Yes, I am trying to do so. Science is a universal endeavor, but scientists cannot walk alone. Individual knowledge is inseparable from the combined knowledge of all humanity. So, we must encourage multi-disciplinary collaboration to create a peaceful, pleasant world. Moreover, to promote science, we should convince the public that science is highly beneficial, particularly chemistry and its applications. We must explain what we are doing because the tax-payer money supports our endeavor. Also, we need to explain what we know and what we don't know yet so that everybody has equal expectations.

Our intellectual endeavor cannot be categorized. Science pursues the truth of Nature through exploring the unknown, leading to "discovery," whereas "invention" occurs when technology tries to overcome seemingly impossible goals. Both scientific and technological activities take place within the context of society. Today, science-based technology enriches our lives, contributes to our nation's security and peaceful sovereignty, and sustains human civilization. Consequently, we must recruit the best minds worldwide to foster scientific and technological development with diverse leadership.

Governments of many countries promote science, technology, and innovation (STI) as a source of the nations' competitiveness, public health, welfare, and the mitigation of natural and unnatural disasters. I would say that innovation is not a mere technological invention but is also the creation of economic or other societal values. Therefore, governments must consistently promote both basic and applied science. Most innovations originate from basic research and significant collaborative efforts. And meeting global and national challenges requires trusted and fruitful conjunction between the research community and other sectors.

Without ST-based innovations, we could not have realized the affluent, civilized societies we live in today. Thus, STI is strongly linked with social views and values and is affected by religion, ethics, historical and philosophical aspects, politics, economy, etc. So, to enhance STI, science cannot stand alone but must be adequately merged with national or regional cultural heritage. I would also like to acknowledge industrial collaboration, for it is the industry that eventually transforms our basic knowledge into the social benefit. In this regard, I respect Israel as a leading nation of innovation.

The benefits of modern science-based technology are evident from the enhanced food security worldwide, increased life expectancy from 45 to 80 years in just one century, external expansion of human physical abilities, improved quality of Life, and high-speed communication, to name a few. Now we are fast-forwarding to an age of networked society that we have never experienced before, entering soon into an era of super-intelligence.

We should be proud of being chemists because chemistry-based materials are everywhere in this modernized society. We have long contributed to, among others, the improvement of health care with the aid of pharmaceutical innovations based on synthetic chemical substances. The contribution of chemistry to STI has already been enormous, but our community must further develop toward creating a peaceful, pleasant world. For instance, synthetic chemists must pursue artificial photosynthesis and element strategy to overcome the resource problem. Here again, intensive interdisciplinary collaboration is needed. We must protect the environment.

I have been walking on an avenue of chemical research for over six decades. I have educated chemistry in Kyoto since 1957 and later in Nagoya since 1968. In 2003, I was appointed President of RIKEN, the flagship research institution in Japan, before assuming, six years ago, the current position, Director-General of CRDS (Center of Research and Development Strategy) of JST (Japan Science and Technology Agency). Our institution aims to navigate science and technology policy in our country.

Responding to your comments, did you try to make the world a better place?

Obviously, "Making the world a better place" is a gigantic goal. However, as a tiny individual chemist, I could have contributed a little toward this direction. And I would ask the young readers of this interview, "Where are you now? Where are you going from here? Is your destiny Utopia or Dystopia?"

Seniors like me are afraid that the combined effects of various complicated social issues since the Industrial Revolution have brought modern civilization to a severe crisis. And it is our responsibility and partly that of the younger generation. motivated by such concerns, the United Nations general assembly in 2015 passed a resolution titled, "The 2030 Agenda for Sustainable Development." The leading slogan is: "No one should be left behind." They defined 17 Sustainable Development Goals (SDGs) that rely on the advancement of science and technology. All Asian countries, together with others, must play an active role in striving for these SDGs. We cannot remain passive but must consider this an opportunity for new development and progress. If we do not change our focus now, there can be no tomorrow.

Every one of the SDGs represents a mammoth objective that is impossible for any individual researcher to attain alone. Frankly, we did not have the required foresight in our university days, and very few of us seriously considered these problems. I believe that our chemistry science goes beyond mere observation and understanding of Nature. Our science can generate very high values from almost nothing. Synthetic substances and materials determine the quality of our Life. And catalysis is fundamental because it is the only rational, general means to produce essential compounds in a cost-effective, energy-saving, and environmentally benign manner. More than 25 years ago, as a senior chemist, I took the initiative to promote Green Chemistry, which now corresponds to SDG 12 (responsible consumption and production). As an essential aspect of Green Chemistry, we sought catalysis in a safe and harmless medium.

We pioneered supercritical CO2 as a medium for catalytic reactions with the beneficial effects of both liquid and gas phases. It is a non-toxic, non-flammable, and very cheap solvent. We can remove it from the reaction mixture without leaving harmful residue.

Today, Green Chemistry is an essential component of chemical manufacturing, and it is our responsibility to reduce the amount of undesired waste. In a step-by-step synthesis of any target molecule, each step should proceed with high "atom economy" or "atom efficiency" without leaving hazardous waste. We have developed a clean oxidation reaction using aqueous H2O2 with a tungsten catalyst under organic solvent-free conditions, producing water as the only byproduct.

Regarding reduction, catalytic hydrogenation is the ultimate Green Chemistry. We have successfully replaced the most environmentally unfriendly reduction methods with clean catalytic hydrogenation with 100% atom efficiency. Asymmetric hydrogenation is essential because our Life depends on enantiomerically pure chiral molecules. Our methodology, which employs chiral BINAP/transition metal catalysts, particularly Ru, represented a breakthrough in asymmetric hydrogenation. The reaction is rapid, very general, and highly productive. These achievements, together with W. S. Knowles and K. B. Sharpless were recognized by the 2001 Nobel Prize in Chemistry. Although the Nobel Prize is the highest honor of any scientist, we need to examine the impact of my achievements on society and the economy.

In 1992, the US Food and Drug Administration set out guidelines for “racemic switches,” contributing to significant improvements in medicine. The new regulations strongly urged pharmaceutical companies to manufacture and commercialize enantiomerically pure pharmaceuticals. Our contribution to asymmetric catalysis was a crucial contributor to the policy change in the USA. Furthermore, our asymmetric hydrogenation technology with our fruitful cooperation with the industry also contributed to attaining SDG 12, SDG 3 (good health and well-being), SDG 9 (industry, innovation, and infrastructure), and SDG 17 (partnerships for the goals).

At the beginning of the 21st century, Sumitomo Chemical has established the Olyset Net technology, acknowledging the SDGs as its corporate concept. Using our asymmetric catalysis concept, Sumitomo’s researchers synthesized permethrin, a new chiral insecticide containing a cyclopropane group, and incorporated it into high-density polyethylene fiber to manufacture Olyset Nets. The new material allows for a slow release of the pyrethroid over five years.

Every year, malaria infects 300-500 million people by the Anopheles mosquito, and more than 1 million, mostly children, die of the disease. Sumitomo decided to join forces with the WHO’s “Roll Back Malaria” campaign in Tanzania and provided the Olyset Net technology to Tanzania free of charge, thus creating more than 7000 new jobs and significantly improving school facilities.

Related to this is the story on the Sakura Girls Secondary School (SGSS), which opened in 2016, with the support of ODA (Official Development Assistance) and JICA (Japan International Corporation Agency). I highly respect Professor Sumiko Iwao (1935–2018), a central figure establishing this school in Tanzania, not far from Kilimanjaro. Tanzania is still a Male-dominated country, with minimal opportunities for girls. Thus, the school’s main objective is to train women to become teachers, scientists, and technocrats. And teachers from Japan lead the efforts to encourage Tanzanian girls to develop independent careers in science and mathematics and lead their country’s future development.

I want to emphasize that I have not contributed personally to achieving the SDGs. The credit should go to the enthusiastic Sumitomo researchers and engineers and the bold decision of its CEO, Hiromasa Yonekura (1937–2018), who was a good friend of mine. He was a visionary manager of the company who also promoted Japanese governmental initiatives worldwide. The hear-warming story of the SGSS has taught me something new and significant on how chemistry may benefit society.

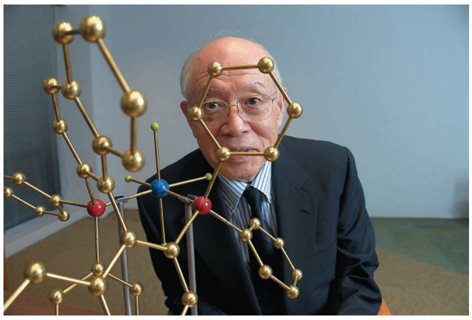
How and why did you start exploring asymmetric hydrogenation, which eventually brought you to Stockholm?

In 1966 when I was still in Kyoto, we discovered an asymmetric carbene reaction through purely curiosity-driven research. We reacted styrene and ethyl diazoacetate in the presence of chiral Schiff base-Cu catalyst. That experiment represented the birth of asymmetric catalysis using chiral organometallic catalysts, which is quite common these days. Although we achieved less than 10% ee, which is meaningless for synthesis, that experiment was probably the most exciting event in my entire academic career.

In 2001, when I received the Wolf Prize together with Henri Kagan and Barry Sharpless, I was delighted and honored that this small discovery was cited as one of the reasons for recognition by the most prestigious prize in Israel. That case teaches me that it is important to recognize the significant achievements of young researchers at their early stage, even if they seem premature or based on stupid ideas.

I was 27 years old at the time of my discovery. Immediately after that, I moved to Nagoya and then to Harvard to work under E. J. Corey, so I put aside that exciting chemistry. During my stay at Harvard, Corey asked me to selectively hydrogenate one of the two olefinic bonds in a PGF2α derivative to produce the corresponding PGF1α. That experimental work encouraged me to initiate asymmetric hydrogenation as soon as I returned to Nagoya. Eventually, my 1966 discovery of a primitive asymmetric carbene reaction, which was described in a then overlooked publication, turned out to be a starting point of a long journey from Kyoto to Stockholm.

Tadatoshi Aratani, one of the students who worked in the same laboratory in Kyoto in 1966, later joined the Sumitomo Chemical Company, where he developed an excellent chiral Cu catalyst. He established a large-scale synthesis of chrysanthemic esters and a building block of cilastatin, an in vivo stabilizer of carbapenem antibiotic produced in the USA by Merck. Such technological development in the 1980s became a logical result of our initial work. Less apparent results are the links to societal implications beyond science and technology, as reflected by SDG 1 (no poverty), SDG 4 (quality education), and SDG 5 (gender equality), in addition to the previously mentioned SDGs 3, 9, 12, and the important SDG 17 (partnerships for the goals).



Noyori has been enchanted by the molecular beauty of chiral BINAP-transition metal catalysts over four decades.

My initial discovery half a century ago in a poorly equipped laboratory in Kyoto has taught me that a tiny chemical seed could eventually lead to a significant contribution to the global welfare of all humanity. Consequently, the scientific community and industry, government, and many other sectors should always discuss the societal implications of science and technology and the mechanisms to catalyze these beneficial implications.

How would you like to conclude our conversation?

I have come to this interview to tell you my own story, and I am just one of many other Asian scientists. Although every one of us looks like a tiny dot on this planet, I can see fine red threads connecting us and all scientific knowledge. In today’s global society, and with the contributions of many countries and diverse social sectors, even small research outcomes may contribute to realizing the SDGs. Therefore, I would like to send a concise message to the young generation, “Think Globally, Act Locally.”

Modern civilization appears to face challenging times. And the science community needs to reconfirm the significance of open-science policies to avoid catastrophic consequences. Because science is a long-term, limitless endeavor, we must ensure the solidarity of researchers. Moreover, inter-sector and international collaboration will be critical in accelerating research and development to combat the difficulties we face. Earlier I said, “Science is one.” But now, I would like to say, “The world is one.”

The 20th century was an era of international competition, symbolized by war and economic rivalry. In the 21st century, however, we will have to cooperate globally to survive our species within the limits of this planet. Whatever we do, we must do our best to move in this direction.

I believe that my views represent many other senior scientists of the Asian region, and I hope you share these values with me. Thank you for inviting me to this important arena of AsiaChem. ◆