I am truly grateful to have the great honor of the Kyoto Prize conferred upon me, and also very thankful for this opportunity to speak to you all today. I am a born optimist. People have said this about me my whole life, and I believe they are right. I suppose that this characteristic is one reason I have always been able to enjoy my research over the years. President of the Inamori Foundation, Kazuo Inamori once said, “Conceive optimistically, plan pessimistically, and execute optimistically.” As I have spent most of my brainpower considering how to form research plans, my optimistic nature may have suited me to this career.

During my many years as a researcher, I have often been asked the same questions. “Why did you become a researcher?” “What should I do to become a researcher?” “What made you first decide to become a researcher?” The list of questions goes on. When I ask other researchers these questions, they generally give clear answers. They say, “I’ve been attracted to living things since my childhood,” or “I was impressed by the wonders of the stars and outer space,” or “I was influenced by a schoolteacher,” or “I wanted to help the sick people I saw around me.” When I ask myself what specifically prompted me to seek a lifetime career as a researcher, however, I find that I do not have any kind of “straight answer” such as these. If I had to explain, I would say that I was fortunate enough to stumble across a career opportunity as a researcher, and that before I realized it I had become enchanted by the profession. The answer ends up being very ambiguous. I therefore decided to take a slightly different approach today. I will first talk about the circumstances under which I was brought up and the education that I received. I will then describe what prompted me to pursue my career as a researcher. I will also touch upon numerous events that took place throughout my career and memories of the many people of whom I have had the pleasure of meeting thus far, and discuss how these experiences helped shape my mindset.

1. Childhood to first steps as a researcher

I was born on February 26, 1936 in Fukuoka Prefecture’s Kurume City on the island of Kyushu, Japan. My date of birth happened to occur on the same day as a major turning point in the history of Japan. In the early days of the Showa era, the country was deeply mired in recession. Blaming party politics for the economic impasse, a group of young Imperial
Japanese Army officers staged a coup and laid siege to the Imperial Palace on this day, but ultimately failed in their attempt (Fig. 1). My parents were running a grocery store at the time. As I was born when they were older, they seemingly lavished me with particular love and attention. I was not particularly familiar with science or scholarship in general as a child. On the contrary, no one in my circle of acquaintances was academically oriented. World War II came to an end in the summer of my fourth year in elementary school. My hometown of Kurume was one of the cities bombed by the U.S. military, and its city center was razed to the ground. Fortunately, I did not directly experience the destruction because I had been evacuated to the countryside. Even after the war ended, however, women and children were told to take shelter in villages deep in the mountains, under the belief that the occupying U.S. soldiers would resort to acts of violence against civilians, and I ended up staying in a rural village for a while. I managed to enjoy myself there, helping with farm work, making rafts and floating them down the river, and playing all sorts of games (Fig. 2). My father had never received higher education, and it seems that he had had a tough life since childhood. I do not know if this was the reason, but both of my parents were intent on giving me a good education. After I reached the higher grades in elementary school, my parents would force me to help out in their store if they caught me going out to play, but if they saw I was working at my desk they would always leave me alone. I remember forcing myself to sit at my desk just to avoid getting called to help. I was very envious of the families of company employees, as I was sure they had more free time. After elementary school, I took the entrance examination for a local junior high school attached to the Fukuoka University of Liberal Education (now University of Teacher Education Fukuoka), but failed miserably. I vividly remember one mistake I made in the Japanese examination at that time. I confused the word fumi, meaning letter or book, with its homonym meaning, “to tread,” because “to tread” wheat plants was much more familiar to me! This was the first of many setbacks that I would experience during my life.

I finished elementary school shortly after the war ended, at a time when the public junior high school system was still rather chaotic. Although a new educational system had been put into place, the proper school buildings and furnishings were not yet available. I ended up going to Nanchiku Junior High School, which was the lower division of a private integrated junior and senior high school for boys. I never asked why my father chose to send me to that school, but it may have been because it made the transition to high school easier. For better or worse, the school’s overall academic level was not very high and I was able to rank highly. This may have given me confidence in myself for the first time. It was around then that I developed my love of books. While commuting or in class, I was constantly
engrossed in adventure stories and other books aimed at teenage boys. People started to call me a bookworm. I was so impatient for my favorite monthly compilation for boys to hit the stands that, as the release date approached, I would visit the bookseller every day to check whether it had arrived yet. This love of books remained with me over the years. Although I was forced to resist the temptation while in high school because I had to study for the university entrance examinations, my passion for reading flared up again as soon as I was admitted to university. Poring over secondhand bookstores, I purchased one volume after another of a compilation of world literature, which was about 30 volumes in length and was published by Kawade Shobo, until I had read most of the entire collection. Tolstoy, Stendhal, and Balzac were but a few of the authors contained within those pages, and those great Western writers taught me the joy of reading novels and the complexity of human relationships. The opportunity to immerse myself in some of the world’s greatest literature before the age of 20 was indeed an invaluable experience.

Coming back to my story, I transferred to a nearby public junior high school toward the end of my second year, where I led a happy school life thanks to many good teachers and friends, some of with whom I developed true friendships that have lasted throughout my life. At the time, I was small for my age, and I was a late bloomer in every regard. If you were to take a look at a photo of my classmates and me, you might think that I was the only child in a group of adults. I eventually went on to Kurume University Senior High School, which had been founded the previous year. Established by a group of teachers who were not satisfied with the public education system at the time, this boys’ school followed a highly unique curriculum. Both English and German were required as second languages, and students were also made to recite Chinese poems. For physical education, students played rugby in winter and volleyball in summer. The school had been built rather hastily, and the school facilities had apparently been converted from former Imperial Army barracks and munitions depots (Fig. 3). As they were unable to recruit all the required teachers, some classes were put on hold for a period of time. For social studies, a professor from Kurume University taught economics, while a white-coated professor taught chemistry for the science class. I found this chaotic situation and sense of freedom rather stimulating. I enjoyed the Japanese literature class so much that at one time I was thinking of studying Japanese literature at university. I was also intrigued by economics, and wanted to perhaps pursue medicine or chemistry. It was like being in a dream with no concrete image of what the future would hold for me.

In my senior year, I finally needed to give serious thought to my university applications. My father urged me to become a pharmacist, possibly inspired by a drugstore that was
nearby. However, I did not think that spending my whole life selling drugs at a pharmacy would be very interesting, and so I decided to apply to Kyushu University’s Faculty of Engineering under the pretext that applied chemistry was the closest thing to pharmaceutical sciences. Applying to the Faculty of Engineering meant that I had to choose physics and chemistry as sciences. Until that point, I had never paid too much attention to my future and had chosen chemistry and biology to avoid mathematics and physics, which I was not very good at. To change my course to the Faculty of Engineering, I took a mock physics examination instead of biology, and ended up getting only five points out of a possible 100. This gave me the shock I needed to pull myself together to study physics, and I managed to gain admission to the Faculty of Engineering in March of 1954. I guess my high scores in Japanese and English were what saved me. In high school, my scores in preparation for the entrance exams were consistently among the top ten in my grade, and seven or eight of my classmates were good enough to get into the prestigious University of Tokyo. As such, I was inclined to aim for a university in the Kanto area, where Tokyo is located. At the end of the day, however, at the request of my parents I matriculated into Kyushu University, which was within walking distance of where I was living at the time. (A branch school of their College of General Education was located in Kurume City.) This actually proved very fortunate for me. My father passed away from an illness in November of the year I entered the university. The family grocery store lost its greatest pillar. I was considering whether or not I should quit university and take over the family business to support my mother and two younger brothers, but we were ultimately able to continue the business with my mother as its head, as our neighbor in the same trade offered help with purchasing and other work, and I was able to commute to university without leaving my hometown. Given the situation, I was so busy helping my family that I did not have any time to spend on sports or other hobbies during my university years. I managed to pay my tuition with funds from the Japan Scholarship Foundation and money that I earned from part-time jobs, and thus I was not financially dependent on my family. I felt extremely fortunate just to be able to continue my studies at university. Despite the lack of free time, I was able to make friends from the same district and spent an enjoyable time as a student with my companions at the Faculty of Engineering. I was also admitted to the Department of Applied Chemistry as I had hoped.

2. First steps toward becoming a researcher

In my faculty, there was a limit to the number of fourth-year students that could be
accepted by each laboratory for their graduation studies. The choice was made by “rock-paper-scissors,” but unfortunately I lost, so I ended up joining a ceramics laboratory instead of the polymer chemistry one that I had hoped to get into. Even so, I simply could not put my interest in polymer chemistry on the backburner, and I was eventually allowed to switch to the polymer chemistry seminar taught by Professors Saburo Akiyoshi and Associate Professor Chuji Aso, on the condition that I would continue my studies at the graduate school. I accepted this condition as due to my circumstances I would have had to stay near my home anyway. For the topic of my graduate studies, I chose “polycondensation of polyester,” which was related to the “hot topic” at the time of new polymer development. Under the guidance of Associate Professor Aso, I carefully investigated the ester polycondensation process (Fig. 4). It did not take long for me to start thinking, “If I could put food on the table with a job as interesting as this, I wouldn’t mind doing it my whole life.” It was then that Professor Akiyoshi suggested that I should apply for the Kumura scholarship, which had been established several years prior in honor of Seita Kumura, the founder of Teikoku Rayon Co., Ltd. (now Teijin Limited.). It was a very generous program with few parallels in those days. I happily applied, albeit with something of an ulterior motive—combined with my funds from the Japan Scholarship Foundation, the money would allow me to stay close to my two brothers and send them to university as well. Of course, I would have been more than happy to continue with my work at graduate school, but at this point I was still intending to find a job with a company as soon as I finished my master’s course.

I did not think that I would make research my life’s work until Professor Akiyoshi suggested that I study at a graduate school outside of Japan. He felt that Japan’s graduate schools in those days still adhered to the old apprenticeship system and did not function properly as an educational system, and so he looked to U.S. schools to find a model for the graduate education program focusing on basic research that would soon be started at the Kyushu University Faculty of Engineering. For this purpose, he sent several of his students to graduate schools in the U.S. for training, and I was lucky enough to be among the group. I lost no time in practicing my English conversational skills, writing a letter to a professor renowned for his polymer research to inquire if I could study under him, and taking the examination for Fulbright students. I managed to get on the waiting list for students reimbursed for travel expenses, and I was able to enter a graduate school of the University of Pennsylvania. I was placed in Professor C.C. Price’s chemistry laboratory, where I started student life as a research assistant with a stipend of more than 100 U.S. dollars to cover my living expenses. This was in the spring of 1960. The research topic I chose to pursue was the development of a new synthesis technique for polyphenylene oxide, which was attracting
attention as a new polymer material. Professor Price was a brilliant scientist known for his outstanding work on the Q-e scheme for radical copolymerization and chiral polymerization. Working in his laboratory were members studying the synthesis of carcinogens and biologically active agents, and the atmosphere was one of complete freedom. I must say that there was a huge gap between Japan and the U.S. in terms of availability of research facilities, and I was fortunate to have the luxury of being in an environment so conducive to my research (Fig. 5).

At first, it was difficult to keep up with my classes at graduate school. I even received a warning after the first term, saying that I needed to improve my grades. It was a substantial curriculum which demanded a broad range of knowledge spanning the entire field of chemistry, and included cumulative exams that were required for a doctoral degree. I have particular memory of an examination in which students had to memorize important reactions in the field of organic chemistry that were named after their discoverers and explain them. At the time, I was rather surprised that graduate students were required to perform rote memorization, but this knowledge ultimately proved very handy for me. In Japan, some people claim that reading aloud without comprehending the whole meaning and memorizing multiplication tables are good for elementary school students, and I have to agree that the volume of one’s capacity to memorize things is important as it lays the foundation for one’s intellectual faculties. The education that I received at the University of Pennsylvania served as an excellent reference when later introducing new ideas to graduate education at Kyushu University. I have innumerable fond memories of my time there—mingling with other students in the laboratory, meeting a second-generation Japanese family who took very good care of me, eating steaks at the university cafeteria that were thicker than anything I had ever seen in Japan, walking the peaceful streets of Philadelphia, which is known as the city where the Declaration of Independence was signed, as well as the ghettos that stood in stark contrast to them, and becoming hooked on music and frequently dropping by the Sam Goody vinyl record store. Among the graduate students there at the time was Dr. Ei-ichi Negishi, who received the Nobel Prize in Chemistry in 2010 and is now the Herbert C. Brown Distinguished Professor at Purdue University. It is my good fortune to be currently working with Dr. Negishi in the Japan Science and Technology Agency’s Advanced Catalytic Transformation Program for Carbon Utilization (ACT-C) (Fig. 6).

About two and a half years later, I managed to put together my degree thesis and joined a research group led by Professor Carl Niemann of the California Institute of Technology, or Caltech, as a Postdoctoral Fellow. I decided to pursue this opportunity because Professor Akiyoshi often mentioned the importance of biochemistry in his dye chemistry class.
Professor Akiyoshi, who was also a researcher of terpenes (essential oils found in plants), would passionately explain to his students the intricacy of the organic compounds related to organisms and the future potentials of biochemistry. This sparked my interest in the chemistry related to living organisms. At any rate, I drove my beat-up old Ford alone from Philadelphia in the East to Pasadena over a period of nearly two weeks, armed with a tent, a camping pot, several hundred vinyl records, and a stereo player. The chemistry class at Caltech had a stellar faculty at the time. Dr. Linus Pauling, recipient of the Nobel Prize in Chemistry and the Nobel Peace Prize, was full of vitality, working on the mechanisms of anesthesia and giving general chemistry lectures to large audiences. Professor John D. Roberts, who was actively introducing nuclear magnetic resonance (NMR) and the molecular orbital method to organic chemistry, and Professor George S. Hammond, a pioneer in organic photochemistry, were also among the faculty. Dr. George M. Whitesides (a 2003 Kyoto Prize laureate), Dr. Nicholas Turro, and other celebrated scientists who would later capture the world’s attention were still in graduate school at the time. At Professor Niemann’s laboratory, we primarily applied organic chemistry approaches to elucidate the catalysis of chymotrypsin and other hydrolases, and my contribution was to provide data to deduct three-dimensional structures of enzyme activity centers from the rate of hydrolysis by synthesizing various dipeptide substrates. It was then that X-ray diffractometry revealed the three-dimensional structures of myoglobin protein molecules, finally making it possible for researchers to work on intricately structured protein molecules just as they would any other compound.

3. From the enzyme model to a bilayer membrane

After I returned to Japan, I assumed a position as Associate Professor at the Department of Synthetic Chemistry in Kyushu University's Faculty of Engineering (Fig. 7). I suddenly found myself taking on the role of promoting new graduate education in Japan, and I soon realized that what worked well in the U.S. would not necessarily work well in my own country. After a process of trial and error with other faculty members in the Department, we agreed to introduce “discussion-based studies.” I am pleased to say that departments at Kyushu University have continued to use this style since its introduction in the mid-1960s. We really did pour a lot of energy into developing our education program.

On the research front, while assisting Professor Aso in his work on cyclic polymerization of bifunctional monomers, I began studying hydrolase models as I wanted to do a project of my own. Although I had been involved in researching the working
mechanisms of enzymes at Caltech, I was now trying to figure out how I could leverage my background to tackle something new, as there would be no point in simply replicating what I did in the U.S. It was then that I looked to the concept of biomimetics, which attempts to use the structures and systems of living things in the natural world to develop new technologies or improve existing ones. I wanted to achieve this on the molecular level (Fig. 8). The human stomach contains an enzyme called trypsin, which breaks down proteins contained in food into amino acids so that they can be absorbed into the body. It was around 1960 when the detailed molecular structures of proteins became known. One key finding at the time was that the long chains of amino acids were folded precisely into specific structures. We focused on the fact that several functional units of enzymes, which are made from proteins, gather together to cause a catalysis that artificial materials could not, and so we wondered if we could reproduce enzymes’ functions by arranging several catalytic portions into one chain of polymers. This biomimetic chemistry research using simple polymers to produce enzyme models marked the starting point of my lifelong research into ways in which organisms and artificial materials could be combined.

At the outset we lacked experience in dealing with enzyme models, resulting in several painful years with no results to show for our efforts. During this time, Wang and his colleagues reported that, when iron porphyrin is embedded in hydrophobic polystyrene, oxygen molecules would form stable complexes, which are useful for the study of hemoglobin modeling. As an alternative to their model, we combined vinylpyrrolidone units, which create a hydrophobic field, with vinylimidazole units, which are capable of taking in Iron ions. However, this experimentation into making two-component polymers take in oxygen molecules did not yield any satisfactory results.

Our breakthrough came when we least expected it. Exhausted by the scant progress in our attempt to synthesize enzyme model molecules, as a last resort we experimented on hydrolase models using hemoglobin model polymers. To our great surprise, our efforts were rewarded with Michaelis-Menten reactions, which are characteristic of enzyme reactions! It had been a mistake to focus on molecular models, which were not easy to synthesize. By this time, more than three years had passed since we began working on enzyme models. We had invested a great amount of labor and funds into our work, but had thus far been unable to write any papers or present our findings at conferences—we had been driven into a corner. I was truly grateful for Professor Aso’s patient guidance as he watched over our efforts without pressuring us for results. Had it not been for his understanding and patience, I would have given up on the topic long ago, and none of the developments that followed later would have occurred.
Research into enzyme model polymers made great strides after this. We never let other frontline researchers in Europe and the U.S. take the lead in the global competition. Catalytic activity in model reactions showed a substantial increase. A typical case of this was that of bi-functional catalysts, which have two kinds of catalytic groups functioning cooperatively. However, this activity did not reflect the intricate three-dimensional structure of enzyme molecules. We also used water-soluble micelles with a spherical structure as an enzyme model, but such micelles differ from spherical protein molecules. Made up of surfactants, which have similar properties to soap, micelles are soft molecular assemblies and thus their structures are far removed from the kind of structures in which functional groups are precisely fixed, as is the case with enzyme molecules.

To take another step forward in these studies, it was clear that we needed to create assemblies with a clean-cut structural organization from artificial small molecules or polymers. To get closer to actual organisms, we needed to arrange molecules systematically and make them perform high-level functions that would normally not be conducted by individual molecules, and so we decided to use a biological membrane model instead of a linear polymer model. Just prior to this, in 1972, Singer and Nicolson proposed the “fluid mosaic model,” thus answering the ongoing discussion at the time about the structure of biological membranes. They advocated a structure in which a bilayer of lipid molecules is arranged in biological membranes, with protein molecules embedded in a fluid matrix like a mosaic. Biological membranes are only a few nanometers in thickness—the ultimate thinness of any substance, including artificial materials. A variety of cell functions take place within this thin envelope (Fig. 9): mitochondria generate energy, nuclei determine genes, ribosomes produce proteins, and lysosomes do the cleaning. Later studies showed that organelles such as the nuclei also take a specific form according to the membrane structure.

Biological membranes have a precise structure in which fatty acids and other compounds that are both hydrophilic and lipophilic (amphiphilic) are configured in a neat formation (Fig. 10). The prevailing assumption at the time was that the structure of biological membranes could be formed only by biological phospholipids with a complex molecular structure. I, on the other hand, assumed that the molecular structure of lecithin lipids, which are the main ingredients of biological membranes, was unique to the biological system, and thus it would be perfectly fine to use artificial molecules to form bilayer membranes. I wanted to use simpler materials for my chemical synthesis research, and so I dispersed dialkylammonium salt, which has a simpler structure, into water to see how molecular self-assembly occurs under an electron microscope. I was then able to observe distinctive endoplasmic reticula (Fig. 11). This was how synthetic bilayer membranes were
Now that we knew that we could make bilayer membranes without painstakingly structuring complicated lipid molecules, we then wondered if we could make even better structures if we improved the molecular design. As we tried one different material after another to make several hundred related molecules with different structures, we slowly began to see the relationship between the materials and the resultant membranes (Fig. 12). Although these artificially created membranes may not necessarily be appropriate for organisms, we are able to form a wide variety of such membranes with artificial materials. Later research also revealed that, although membranes are two-dimensional sheets, by configuring our design we were also to create rod-like three dimensional shapes (Fig. 13). Nowadays, many researchers are assembling molecules to create new materials for specific purposes in a variety of fields (Fig. 14).

As you can see, my research of synthetic bilayer membranes was the result of reaching an impasse with enzyme models. Because of this, the initial focus of my work was on how to make use of membranes’ characteristics to activate hydrolysis catalysts or coenzyme action. However, my interest gradually shifted to how molecular structures and molecular assembly are interrelated. In particular, I was increasingly inclined to discover what aggregation properties would result from characteristics of molecular structures that are grouped to make module combinations. I was also intrigued by the study of creating new molecular organizations by using the unique membrane structures thus produced. In doing so, I was essentially moving from organic polymer chemistry to physical chemistry in the study of molecular assembly. At the time, however, I had not the slightest premonition that I would be pursuing this topic for the next dozen years or so.

4. Large nanostructured films

Synthetic bilayer membranes have a structure similar to that of biological membranes, which means that they are extremely thin, or have a thickness of only several nanometers (that of two molecules), making them a very attractive research topic for chemists. Their drawback as a practical material was that their thinness made it difficult to handle the materials, and thus they were used only for a limited scope of applied research in such applications as sensors and drug carriers. In an attempt to expand the scope of application, we tried many ways of molding bilayer membranes into an easy-to-handle shape. Because bilayer membranes are assemblies of molecules, they are not sturdy enough as a material, and so we conducted a broad range of experiments by making composites between polymers.
and membranes, multiplying membrane layers to make stable films, and making layers of polymers, proteins, and inorganic materials on the molecular level to create films (layer-by-layer method). Of these attempts, I have special memories of the layer-by-layer assembly method. By simply immersing solid substrates alternately into solutions of positively and negatively charged polymers, thin films are produced on the molecular level in which two different kinds of polymers are layered alternately. Developed by Professor Gero Decher of Germany and his colleagues, the technique rapidly spread to become a frequently used method of fabricating nano-thin films thanks to its simplicity, ease-of-use, and ability to use many different polymer materials. My research team had actually discovered a phenomenon that provided the basis for this technique as part of a national project called the Exploratory Research for Advanced Technology (ERATO) research funding program, and we held discussions on this with Professor Decher. However, it was he who established a new methodology through this finding. It seems that we did not think hard enough about its possibilities.

In 2000, the Spatio-Temporal Function Materials Research Group was launched as a pioneering research program at the Institute of Physical and Chemical Research (RIKEN), and I have been leading the four teams that comprise the Group in my capacity as Group Director. The objective of our research is to take on the challenge of developing materials that incorporate temporal elements in a bid to take the next step forward in the field of material research, which has often been confined to the design of spatial elements. Needless to say, the materials constituting the living body incorporate both spatial and temporal elements. With our research objective in mind, my own team set the goal of developing new nano-thin films and dynamically applying them. Out of these endeavors came the concept of large nanostructured films (Fig. 15). It has been the dream of many researchers to develop films that are as thin as biological membranes, yet large enough to be held in our hands. We achieved our first success with ceramic nanostructured films, creating transparent and flexible silica-film that is only several dozen nanometers in thickness. We also realized that we could apply this technique to fabricate nanostructured films from a range of organic resins.

One theoretical application of the properties of such extremely thin films would be permeable membranes that separate gases or liquids. With the aim of putting nanostructured films to practical use, we started a venture business under the name, NanoMembrane Technologies, Inc. about seven years ago, and have worked on their development since. Recently, in collaboration with Kyushu University’s International Institute for Carbon-Neutral Energy Research (I²CNER), we are working to verify nanostructured film’s performance as
a gas separation membrane (Fig. 16).

5. Enhancing the creativity of individuals and groups

The first attribute one needs as a researcher is creativity, and this creativity is born from your daily efforts. This is why all researchers are keenly interested in increasing the efficiency of their research under limited capabilities and conditions. Research efficiency is determined by several things—whether you can come up with fresh and convincing ideas one after another, whether you can manage your research team in ways that prompt your members to perform at their best, and whether you can write papers adeptly. As for research ideas, it is important above all else to have a highly critical mind. It is also critical not only to have as broad a range of interests as possible, either directly or indirectly connected to your own research field, but also to constantly think about where your research theme fits in relation to these. You will never chance upon new ideas without a keen awareness of the related issues and always having your research in the back of your mind both night and day. When I was a young faculty member during the height of the period of student unrest in Japan, I was a member of a team at the Faculty of Engineering that coped with radical students, and I was constantly on the move around the clock. When something like this happens, your research can almost become an afterthought. I remember one colleague ruefully recalling those times, saying that things will fall apart unless you manage to constantly keep your research topics in the back of your mind.

One point I always bore in mind when working on my research themes was to “play catch” between abstraction (simplification, generalization) and materialization (individualization) of subjects. For example, suppose I conceive abstractly that the essence of biological membranes’ self-assembly is the assembly and ordering of molecules and the stabilization of the molecular interface. This makes it possible to search for the materials required to create such an abstract structure from a completely different perspective from those used in biological membranes, and envision a design accordingly. Also, I extended the idea of lipids’ amphiphilic properties, which are realized through a combination of hydrophilic and hydrophobic properties, to the concepts of solvophilic and solvophobic, thereby realizing the formation of bilayer membranes in organic solvents. In other words, in addition to closely studying your research subjects down to the finest detail to achieve materialization, it is important to consciously engage in abstraction so that you can bring the overall structure into perspective by deemphasizing the subjects themselves and daring to look beyond the mere details. This is one of the techniques in the TRIZ theory of inventive
problem solving, which is attracting much attention as a methodology for creating new ideas.

A university laboratory consists of a small group of people. The question of how to energize small group activities has long been a subject of attention at Japanese companies. The success of small group activities at Sony’s Atsugi Plant came into the spotlight in the 1960s. I believe that Toyota’s kaizen activities contain similar processes, and we should be able to deliberately transfer these methodologies to our research laboratories. At research universities, people are recruited based on their individual research capabilities, and thus those individuals may not necessarily be adept at steering small groups. It is true that in some research fields you only need individual talent. In experiment-based research fields, however, you cannot energize your research team unless you generate small groups who compete amongst themselves while also assisting each other. Failure to do so can result in a waste of research funding.

There were several instances in which I failed to write papers in a timely manner despite obtaining fascinating data, eventually losing interest in the topic at hand or missing the opportune time to publish research findings. Whenever I think back to these cases, I feel sorry for the members who were involved in those projects. In my case, I made excuses by saying I was too busy with something or another. In reality, however, it was not because I simply did not have time, but because I let time pass, forever hesitating in the choice of key points and structure of my papers. One time, to prevent this from happening, I made a memo to myself titled “How to start writing a paper.” In short, the key is to start writing the portions you do not have to worry about and use bullet points to describe your argument and the way to interpret the data. In order to efficiently use your limited time and capacity, it is essential that you manage small chunks of time well and adjust your mindset agilely in response to changing circumstances. I also set myself the goal of restarting writing papers that had been left open on my desk from where I left off as soon as I sat down.

Fortunately, our research group has produced many active researchers. Some people ask me what our secret is. I would say that this is because I feel that research is truly enjoyable and my favorite pastime, and because this enthusiasm rubs off on members of my team. Professor Nobuo Kimizuka of Kyushu University once compared me to an orchestra conductor. He said that I am more like Charles Munch than Herbert von Karajan, as I am good at motivating students rather than forcibly leading them. There was also one thing that I was careful about when discussing with other members of my laboratory, and this was not to begin discussions by criticizing others’ comments and ideas. I recall that I made it a rule to always start by praising their comments, saying, “That’s an interesting idea,” and then gradually guiding them over to my perspective as we talked.
6. What makes research so exciting?

I would like to conclude my lecture by explaining why I have been able to continue with a career in research for more than half a century. As I mentioned at the outset, I first regarded research as a profession when I became enchanted by its appeals during my graduation research in my fourth year at university. At the time, I was simply intrigued by the joy of solving puzzles, but, as I see it now, I realize that the keen sense of achievement that you feel when you have climbed to the top is equally important. There are many things that you can achieve when you start climbing, such as arriving at the summit of a mountain that no one has ever reached before, or going off the beaten path to reach the top, to name but a few. Likewise, researchers feel a real thrill when they have succeeded in something that no one has ever achieved before, when they look down upon the earth from high up on the summit, filled with a sense of achievement, or when they win the admiration of the people around them. This sense of achievement is even greater if this feat that no one has accomplished before happens to lead to development of technology needed by humanity or influences people to change the way they appreciate nature. The evolution of science and technology is unending. Such is humanity’s accumulation of scientific and technological knowledge that some even claim that we do not need any more of it. Humankind’s simple curiosity to know more about nature gave birth to science, and endeavors to stave off cold and hunger resulted in technology. Now, we are concerned about whether such curiosity and endeavors have gone too far. People are apprehensive of the fact that the current stock of nuclear weapons is more than enough to annihilate the whole of humanity. At the same time, however, humans are wasting an astronomical amount of food and energy, while a large amount of energy resources remain untapped. Nature is still full of wonders. To understand nature and offer solutions to these problems, we must advance science and technology even further. Not only that, but human wisdom is also indispensable. Someone once said, “Optimists change the world.” In the past, humanity has encountered numerous crises, yet managed to hold its ground. As an optimist myself, I will continue my endeavors, in the belief that my work will help to change this world for the better.

Thank you very much for your kind attention.
1936年（昭和11年）2月26日から2月29日にかけて、日本の陸軍皇道派の影響を受けた青年将校らが1483名の兵を率い、「昭和維新断行・尊皇討奸」を掲げて起こしたクーデター未遂事件。

昭和33年3月 九州大学工学部応用化学科卒業
ポリエスチルの重縮合
昭和35年3月 同大学院工学研究科修士課程修了
シクロヘプタンのイオン重合

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With Dr. Negishi in ACT-C, June, 2015
九州大学工学部（1964年）
Faculty of Engineering, Kyushu University (1964)

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12
膜分子構造と二分子架橋集合構造の相関

Fig. 13

T. Kunitake et al.

T. Kunitake et al.
J. Am. Chem. Soc. 101, 5231 (1979)

Fig. 14

自立性を有する巨大ナノ薄膜の開発

NHMニュース、新聞報道にて

Fig. 15

Fig. 16

九州大学 カーボンニュートラル・エネルギー国際研究所
International Institute for Carbon-Neutral Energy Research
(I²CNER)

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